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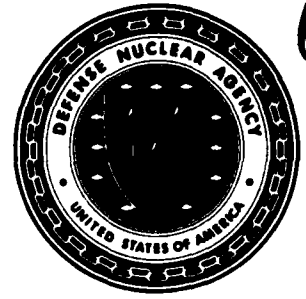
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# Guide to U.S. Atmospheric Nuclear Weapon Effects Data

Robert E. Jackson  
Kaman Sciences Corporation  
Santa Barbara Operations  
P.O. Box 1479  
Santa Barbara, CA 93102-1479

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13. ABSTRACT ( <i>Maximum 200 words</i> )  This document is a users guide to all of the atmospheric nuclear weapon effects data acquired from U.S. atmospheric explosions.  Beginning with the Trinity test in 1945 and ending with the Tigtrope event in 1962, the United States triggered over 200 atmospheric nuclear bursts, including the Hiroshima and Nagasaki weapon drops on Japan. The effects information collected in these events represents essentially all of the U.S. data from atmospheric explosions. This information resides in test reports prepared for each experiment in the various nuclear tests or test series and in survey reports covering the atomic bombings of Japan. All of these atmospheric weapon effects test or survey reports have been reviewed and briefly synopsized to describe the data collected and to identify the specific reports containing the data.				
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## AUTHOR'S FOREWORD AND ACKNOWLEDGMENTS

From 1945 to 1962, the United States detonated over 200 nuclear devices in the atmosphere and accumulated considerable nuclear effects data. Because of treaties and world opinion, there is no foreseeable opportunity to duplicate or supplement this data; thus, the Defense Nuclear Agency is taking steps to assure preservation and accessibility of the data.

As a part of the activity for preserving the U.S. atmospheric nuclear weapon effects data, this guide has been prepared to assist future users in accessing the information when today's experts are no longer available to provide assistance. Many of these experts participated in the atmospheric testing and have first-hand knowledge of the experiments performed, data quality, and circumstances surrounding the tests. This document is intended to convey some of that corporate memory and a description of the projects and data sources from the atmospheric nuclear events.

This guide does not contain the actual nuclear weapon effects data. It was purposely written at the unclassified level to make it more accessible to future users. It does contain brief synopses of essentially all of the documents in which the data are reported. Each project document was reviewed, and report title and number, project objectives and type of data acquired are presented to identify the experimental work done in any technical area and where to find the desired information.

The author wishes to express special thanks to Edwin J. Martin, Kaman Sciences Corporation—DASIAC, whose expertise, advice, and guidance were invaluable in assembling and organizing this guide. In addition, Frank H. Shelton's *Reflections of a Nuclear Weaponeer* yielded vital insight into the motivations and situations that shaped U.S. atmospheric testing 40 years ago. Connie Salus and Diane Holland were extremely helpful in providing the documents and film sources referenced in this document. Finally, my thanks to William E. Rogers for editorial assistance and to Laura Adams for interpreting my handwriting and typesetting the final product.

### EDITOR'S NOTE:

When Bob Jackson left Kaman in August 1992 he was aware that he had not quite finished all the experimental projects. He asked me to add synopses for those experiments that he knew he had missed. This I have done, as well as adding for completeness, the several appropriate experiments for the Hard Hat and Sedan events. I have also added some information on the nature of the weapon test reporting process that may be helpful to the reader and some information about the events themselves. I have also worked with Jan Hallowell on the format of the report and her contribution to this and the editing process should be acknowledged.

Edwin J. Martin  
Editor

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## **SECTION 1**

### **INTRODUCTION**

#### **PURPOSE.**

The objective of this document is to provide a guide to all the nuclear weapon effects data acquired during U.S. atmospheric nuclear explosions.

The nuclear effects data acquired from U.S. atmospheric nuclear weapon detonations during 1945 to 1962 have been maintained and used for decades. In fact, the judicious application of these data has been instrumental in the development of a strong defense posture by the United States. As the immediate need for this information decreases, the interest in preserving it could diminish. Likewise, the ability to use it will erode, especially since many of the primary data users were the data generators, and they are now at retirement age. The Defense Nuclear Agency (DNA) is taking steps to assure that the data will still be available in the future if unforeseen threats arise, once again requiring the United States to take a strong nuclear weapon stand. As an adjunct to the nuclear effects data preservation, it is appropriate to provide a guide to future users who will not have access to current experts to tell them where data can be found. This document is designed to provide such guidance and to serve, in part, as a replacement for the corporate memory that exists today.

#### **NUCLEAR WEAPON EFFECTS.**

The "Guide to Atmospheric Nuclear Weapon Effects Data" contains no nuclear weapon test data. It does identify essentially all of the atmospheric nuclear weapon effects projects that were fielded during U.S.-sponsored events from 1945 to 1962 and specifies the document where data can be found. Effects data is that information that describes how the explosion's radiant emissions and induced hydrodynamic motions and induced electromagnetic fields affect materials and objects. Nuclear weapon effects are descriptions of the bomb's destructive powers. The agents of these powers; airblast, ground shock, thermal and some of the nuclear radiation, and electromagnetic pulse (EMP) are themselves largely products of the explosion's interactions with its primary environment. Experiments that measured these destructive agents are also described in this guide as these are important in understanding the effects. Not included are the small number of x-ray effects experiments conducted in conjunction with the completely contained underground nuclear tests that took place in the last years of the atmospheric testing era.

Experiments intended to check the performance of the nuclear explosive device itself usually called weapon diagnostics or bomb physics measurements are generally not included unless they provide nuclear environment information useful for weapon effects analyses. This distinction is sometimes difficult to make and this guide errs on the side of inclusion.

#### **ATMOSPHERIC NUCLEAR TESTS.**

The U.S. nuclear detonations used as sources for atmospheric nuclear effects data in this document were not all atmospheric explosions. Some were underwater bursts and others were exoatmospheric detonations. A few were underground cratering tests. This document describes effects activities from all detonations even underground tunnels and shaft tests where the objective was to collect DoD effects data except for x-ray effects. This exclusion is noted and explained in discussing the 1958 Hardtack II series. With one exception, safety-related tests are not included since they provided no effects data. Trinity and the Hiroshima and Nagasaki bombings are

included because the bombings provided unique effects information, although the diagnostics associated with normal nuclear weapon effects tests were not available.

The majority of the U.S. atmospheric nuclear tests were for weapon development, not for effects data. However, effects information was frequently acquired on development tests on a noninterference basis.

The atmospheric nuclear testing period is generally considered to span the period from 1945, when the Trinity detonation occurred, to 1963, when the atmospheric nuclear test ban came into force. The final U.S. atmospheric nuclear test actually occurred in 1962. The vast majority of U.S. atmospheric tests occurred before the 1958 test moratorium. A relatively small number took place between April and November 1962, after the Soviets broke the first moratorium and before the atmospheric testing ended with the 1963 Treaty.

The dates listed for the nuclear explosions are local time where the events took place. Many tests in the Pacific occurred one day earlier than the date in the United States.

## **REPORT ORGANIZATION.**

In order to meet the objective of this project, it was necessary to search out, review, and synopsise every document that was used as a record for U.S. atmospheric nuclear weapon effects data. U.S. test directors were thorough in project organization and reporting from the outset of nuclear testing. Each project was assigned a project number or name and a report number. Test summary documents containing project numbers and descriptions were generated. (With this identification process and a complete library, data document review became routine if time consuming.)

Atmospheric nuclear weapon effects data sources are reported in this document in chronological order of the nuclear events or test series (see Table 1). That is, effects data sources for the Trinity tests (July 1945) are presented first, Hiroshima and Nagasaki (August 1945) second, Operation Crossroads (1946) third, Operation Sandstone (1948) fourth, etc.

U.S. test series were typically organized as "operations" with various numbers of nuclear detonations occurring at one of the test sites over a period of weeks or months. These operations were like a campaign with a commander or director, a supporting organization and limited objectives.

The form of two of the operation's name has been altered over the years since first used. In 1958 the test operations in the Pacific were called Operation Hardtack and the small operation at NTS that followed was called Operation Hardtack II. Similarly, the 1962 test operation in the Pacific were called Operation Dominic and the smaller NTS operations were called Operation Sunbeam and Operation Dominic II. In neither case was the main show in the Pacific called Hardtack I or Dominic I in the contemporaneous literature. As this report is essentially an index to this contemporaneous literature, these "I" are not used.

Within each operation, a number of effects programs might be defined, with each program identifying a technical area of interest, such as blast effects, thermal effects, aircraft structure effects, etc. Within each program, a number of projects would be performed in support of the program. Each program was assigned a number (e.g., Program 1, Blast Effects), and each project within that program contained the program number prefix (e.g., Project 1.1, Peak Pressure TableMeasurements). Generally, each technical area was assigned the same program number for all of the operations. That is, Program 1 involved blast studies in Operation Castle, Operation Redwing, etc. Thus, a researcher wishing to determine what atmospheric effects experiments were

Table 1. U.S. Atmospheric Nuclear Test Operations

Event or Operation	Year	Location
Trinity	1945	New Mexico
Hiroshima and Nagasaki	1945	Japan
Crossroads	1946	Bikini Atoll, Marshall Islands
Sandstone	1948	Enewetak Atoll, Marshall Islands
Ranger	1951	Nevada
Greenhouse	1951	Enewetak Atoll, Marshall Islands
Buster-Jangle	1951	Nevada
Tumbler-Snapper	1952	Nevada
Ivy	1952	Enewetak Atoll
Upshot-Knothole	1953	Nevada
Castle	1954	Enewetak and Bikini
Teapot	1955	Nevada
Wigwam	1955	Pacific Ocean off San Diego
Redwing	1956	Enewetak and Bikini
Plumbbob	1957	Nevada
Hardtack and Hardtack II	1958	Enewetak, Bikini, Johnston Island, and Nevada
Argus	1958	South Atlantic
Self Imposed USSR-US Nuclear Test Moratorium November 1958 – September 1961		
Hard Hat, Johnnie Boy, Sedan, Dominic, and Sunbeam	1962	Nevada, Christmas Island, Johnston Island, and Pacific Ocean off San Diego

performed in the area of blast should review the Program 1 projects in each of the operations. While this effects program format was not adhered to for all atmospheric test operations, it was followed the majority of the time.

The weapon test literature was organized in 1951 into a single numerical array that continues to be used for reporting nuclear weapon effects experiments. WT-1 (for Weapon Test report no. 1) through WT-120 were assigned to the Operation Greenhouse experiments and the WT reports in the 200 block were assigned to Ranger in the same year. Each successive test operation was assigned a block of 100 or 200 WT numbers that the projects within the formal test organization used for reporting. An exception to the blocking of reports by hundreds occurred in 1958 when Argus was given a small block within the WT-1700 block being used by the simultaneously occurring Hardtack operation. In addition, a small block of very high numbers (WT 9000) were assigned for several reports of multiple series measurements.

In later years, this blocking by centuries of report numbers broke down even further and when the United States returned to atmospheric testing in 1961 the reports began being designated as "Project Officer's Reports" or POR, although the numbering continued whether they were WT or POR. For some operations, the project reports have been published as either WT or POR, and indeed some reports have both WT and POR designations. In addition, interim reports may have been issued by the projects as ITR (for Interim Test Reports) and POIR (for Project Officer's Interim Reports). These used the same number as that assigned to the project's WT or POR, and although most of these interim reports have been superseded by final reports, some are the only report issued by the project and are considered as final.

For test series before Ranger and Greenhouse, namely Crossroads and Sandstone, an arbitrary numbering scheme was set up for the already published body of the test literature from these series. The 214 reports of Crossroads were designated XRD-1 through XRD-214 and for Sandstone the reports became SS-1 through SS-44. These were post-publication designations and do not appear printed on the covers of the documents, but because of the limited availability of these older reports this post-publication numbering scheme appears to have worked. If agencies hold these old documents, they seem to know them by these XRD and SS numbers.

Weapon effects data derived from the proof test of the implosion device at Trinity or from the attacks upon Japan are largely in the reports of the laboratory at Los Alamos (now LANL). There are also other agency reports that are, for a few experimental activities, the prime place of data publication. These sources are cited when appropriate.

An introduction to each section of this guide provides an historical background and describes the objectives of the test series, the types of nuclear weapons under development, the types of weapon effects data acquired with associated program numbers, and any other information deemed useful to atmospheric nuclear weapon effects users.

Following the introduction, each program and its associated projects are briefly described in terms of objective, instrumentation employed, and type of data reported. The title and the identification number for the report containing the data are provided. In some cases, the quality and quantity of data are indicated. Projects and reports providing no data usually have been omitted from this document.

Each test operation included various experimental, diagnostic, and support activities. These activities were assigned program numbers for organization and reporting purposes. In most cases, the Department of Defense (DoD) effects experiments were incorporated in Programs 1 through 9. Some test series included effects investigations by the Atomic Energy Commission (AEC) and by the Federal Office of Civil Defense, which were not reported within Programs 1 through 9. These projects and data sources are described in this document, usually being added to the appropriate DoD effects area or in a section entitled "Non-DoD Effects Projects."

Practically all of the data reports identified in this document were originally classified. This is to be expected, considering the state of knowledge of nuclear weapons and effects in the 1940s and 1950s. A large number of the reports have since been declassified.

Essentially all of the atmospheric nuclear weapon effects data documents and a large quantity of nuclear test film data reside at the DoD Nuclear Information and Analysis Center (DASIAC), Santa Barbara, CA, operated by Kaman Sciences Corporation for DNA. An additional number of relevant AEC environment and effects reports may exist at Department of Energy (DOE) facilities.

**SECTION 2**  
**TRINITY**  
**1945**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Trinity	July 16	Alamogordo, NM	21 KT	100-foot tower

**BACKGROUND.**

Trinity was the first test of a nuclear weapon. The fact that it functioned properly on the first attempt is remarkable.

Nuclear-effects-related activities in Trinity were understandably very limited. The overwhelming issue for the test was whether the bomb would work as predicted. Free-field pressure measurements were made, not so much to study weapon environment but to calibrate yield. A 108-ton high-explosive test had been performed in which pressure was measured at various ranges. It was believed that correlation of the overpressure vs range data from the two tests would provide an estimate of Trinity nuclear yield. This method gave a yield assessment that was low by a factor of two.

**EFFECTS MEASUREMENTS.**

Several nuclear environment and effects experiments were performed, including pressure and ground-motion measurements and a small thermal effects experiment. Descriptions of these experiments and accompanying data are contained in a series of consecutively numbered "Appendices" published as several Los Alamos reports, LA 1024, LA 1025, LA 1026, and LA 1027. These appendices are usually reprints of earlier Los Alamos Reports. While this information is part of the U.S. atmospheric nuclear weapon effects database described in this guide, it is not a significant part. Numerous measurements were made in subsequent nuclear tests employing more sophisticated instrumentation and techniques. The Trinity measurements have more historical value than technical.

LA 1024 is a compilation of eight appendices, each of which was an earlier Los Alamos report. The number of this earlier report is noted after each appendix.

**Appendix 41.** Pressure measurements were made at various distances using 52 "box" gauges. These were simple diaphragm-rupture devices; that is, different size diaphragms were designed to rupture at specific pressure levels. These gauges were used to develop pressure versus range curves for Trinity and for the large high-explosive test. (LA 354)

**Appendix 42.** Microbarograph pressure measurements were made in the range of 6 to 100 miles from GZ. Nineteen sensors were deployed, primarily "to disprove outlandish claims of damage from a nuclear detonation." Tables of pressure vs distance are presented. (LA 360)

**Appendix 43.** Mechanical impulse gauges were deployed to measure peak pressure and positive pressure duration. Twelve gauges were fielded, and one gave a correct reading. (LA 355)

**Appendix 44.** Geophone measurements of earth motion were made in Trinity and in the 108-ton high-explosive test. The two sets of data were correlated to estimate the Trinity device yield. (LA 351)

**Appendix 45.** Ground vibrations were measured using seismographs. These measurements were used for estimating the Trinity device yield and for assessing potential damage to civilian structures from the test. (LA 438)

**Appendix 46.** The dimensions of the Trinity crater were measured and reported (LA 365), and the effects on the test tower postings are examined (LA 365A).

**Appendix 47.** The incendiary effects of the nuclear detonation were given a cursory assessment. Excelsior and blocks of wood were exposed. The response of the samples is described. (LA 364)

**Appendix 48.** Various optical measurements were made. Pinhole cameras, Fastax cameras, and motion picture equipment were employed. This appendix describes the operations but contains no data. (LA 165)

LA-1025 consists of one appendix.

**Appendix 49.** Presents photographic data on fireball and early cloud. Dimensions are derived and many motion picture frames are reproduced as still photographs. (LA 531)

LA 1026 consists of five appendices.

**Appendix 50.** Discusses an unexecuted experiment to detect the cloud with radar.

**Appendix 51.** Reports unsuccessful attempt to record the motion of the radioactive particles in the fireball and cloud. (LA 430)

**Appendix 52.** Reports cloud track for several hours after burst. Reports beta and gamma radiation from cloud on surface for 6 hours after burst.

**Appendix 53.** Discusses the Wilson cloud chamber effect. Presents photographic data from a 1944 maritime explosion and from Trinity. (LA 488)

**Appendix 54.** Presents optical spectra from burst during the first few milliseconds. Tables of identified lines are given. Temperatures are derived. (LA 588)

LA 1027 contains four Trinity appendices and 15 appendices on the pre-Trinity 108-ton HE experiment.

**Appendix 55.** Measurements of total thermal radiation are reported from which a total weapon yield is inferred. (LA 353)

**Appendix 56.** Discusses how the radio-active material from the detonation is deposited as fallout and presents results from Trinity. (LAMS 277)

**Appendix 57.** Surveys the Trinity shot area for gamma radiation intensities four weeks after the explosion. (LA 359)

**Appendix 58.** Reports weather from Trinity. (LA 357)

**SECTION 3**  
**HIROSHIMA AND NAGASAKI**  
**1945**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Hiroshima	August 6	Japan	15 KT	Airdrop (HOB ~ 1,850 feet)
Nagasaki	August 9	Japan	21 KT	Airdrop (HOB ~ 1,850 feet)

**BACKGROUND.**

The bombings of Hiroshima and Nagasaki have been the only operational applications of nuclear weapons. In the aftermath, there was considerable damage survey activity. These damage surveys are a significant source of nuclear weapon effects information.

Acquisition of credible nuclear weapon effects data generally requires (a) good bomb diagnostics information so that yield can be accurately determined and (b) precise location of the burst point so that effects as a function of range can be established. Neither of these requirements was met in these bombings, and data interpretation has suffered somewhat. Analyses of observed effects performed many years after the bombings have improved the estimates of burst points and yields.

These events provided unique weapon effects information that is irreplaceable. A myriad of structures were exposed and a huge amount of biomedical data was acquired.

**WEAPON EFFECTS MEASUREMENTS.**

The most comprehensive collections of physical effects data were taken by groups called the U.S. Strategic Bombing Survey and the U.S. Navy Bureau of Yards and Docks. Detailed descriptions of damage to all sizes and types of buildings, walls, poles, towers, etc. were assembled. Numerous photographs of exposed structures were taken. cursory engineering drawings of buildings, pre-explosion and post-explosion, were made. Exact geographical locations of the structures were determined.

The Hiroshima and Nagasaki damage survey information is presented in two series of documents. The earlier series is *The Report of the Bureau of Yards and Docks Mission to Japan 1945; Volumes 1-7*. The second series consisted of *Effects of the Atomic Bomb on Hiroshima, Volumes 1-3; Effects of the Atomic Bomb on Nagasaki, Volumes 1-3; and Effects of Atomic Bombs on Hiroshima and Nagasaki* by the U.S. Strategic Bombing Survey. While numerous other documents contain Hiroshima and Nagasaki weapon effects analyses, these two series (available at DASIAC, Santa Barbara) contain the vast majority of the basic nuclear weapon effects physical data.

Another category of nuclear weapon effects data uniquely available from the Hiroshima and Nagasaki bombings is human biomedical information. Unlike the physical and structural effects, the biological database has continued to grow, since the effects on people continue to evolve over time. Even so, the initial responses and conditions for the exposed subjects are vital information.

Biomedical data was gathered by individual doctors and observers immediately after the bombings. The most comprehensive of the early reports was *Medical Effects of Atomic Bombs;*



*The Report of the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan, Volumes 1-6.* This series was published by the Atomic Energy Commission in 1951 and is available at DASIAC, Santa Barbara. Numerous less comprehensive reports of the same period contain useful information.

Later biomedical reports build on the original database and include observations on the subsequent health and mortality of the nuclear bombing survivors. Some of the documents containing data on delayed nuclear effects on people include *Analysis of Japanese Nuclear Casualty Data, Final Report*, Dikewood Corp., 1966; *Delayed Radiation Effects in Atomic Bomb Survivors*, National Institutes of Health 1969; *Biological Effects of Initial-Nuclear Radiation Based on the Japanese Data*, Dikewood Corp., 1980; and *Data on Japanese A-Bomb Survivors*, Health Physics, January 1987. These and other relevant biomedical effects data documents are available at DASIAC.

**SECTION 4**  
**CROSSROADS**  
**Bikini Atoll, Marshall Islands**  
**1946**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Able	July 1	Bikini Lagoon	21 KT	Airdrop (HOB, ~520 feet)
Baker	July 25	Bikini Lagoon	21 KT	Underwater (DOB, ~90 feet)

**BACKGROUND.**

When Operation Crossroads was conceived in 1945, there had been three nuclear explosions. Crossroads, consisting of two events, was designed primarily to provide information on atomic bomb effects on naval vessels. Nearly 100 ships and submarines were in the target fleet inside the Bikini Atoll. Types of naval vessels included battleships, aircraft carriers, destroyers, transports, submarines, dry docks, and landing craft. During the testing, several submarines were submerged and some of the landing craft were on the beach. The ships were loaded with fuel, ammunition, animals, food grains, and exposed Army combat equipment to simulate battle conditions.

The nuclear devices used for Able and Baker were similar to those of Trinity and Nagasaki. The Able device was dropped by a B-29 aircraft and detonated at about a 500-foot altitude. The bombardier apparently missed the desired GZ by approximately 2,000 feet; the actual detonation point was never precisely determined. The Baker device, suspended from a landing ship, was detonated about 90 feet below the surface of the ocean.

There was considerable interest in attempting to quantify phenomena associated with a nuclear airblast Mach stem, and a number of rather primitive blast gauges were hurriedly created and fielded. Due to the uncertainty of the Able detonation point, no useful blast measurements were collected.

In considering the types and quality of nuclear weapon effects data that are available from the Crossroads operation, two factors need to be considered:

1. Crossroads was actually the first nuclear weapon effects test series. Trinity was obscured in secrecy, and there was little chance to plan and implement weapon effects activities. The only other previous nuclear detonations were those at Hiroshima and Nagasaki, which had no instrumentation or technical observers. Hence, the experimenters approached Crossroads with no experience, resulting in relatively little data acquisition.
2. Since World War II had ended shortly before the Crossroads operations, a wealth of surplus war equipment was available for exposure to nuclear tests.

To a large extent, data from Crossroads consist of observations of physical damage to hardware. Few phenomenological experiments were performed since instrumentation development had not matured. To illustrate, one method used for estimating overpressure was to place cans on decks of ships, using the degree of deformation as a pressure indicator. A major consideration in test planning and implementation was to determine if the equipment could function or be repaired after exposure to a nuclear burst. Reporting consisted of considerable redundant data describing damage to ships' hardware.

Crossroads experiments were in two programs. The first program was under the Director of Ship Material (DSM) and included the collection of information from the exposure of ships and equipment. The DSM program was in turn divided into groups that were oriented along the organizational lines of the interests of the services (primarily the Navy) and whose experiments reflected these interests. The largest group was that of the Navy Bureau of Ships (BuShips), which reported on each exposed ship for each test, summarized results by class of material (e.g., welding, yardarms, etc.) in a series of special reports, as well as summarizing results overall. BuShips Instrumentation [sub]Group reports attempt to measure airblast and other weapon phenomena.

The second experimental program was under the Technical Director. In this program, measurements of pertinence to weapon physics were made along with measurements pertinent to weapon effects.

## **DIRECTOR OF SHIP MATERIAL (DSM) PROGRAM AND REPORTS**

### **DSM TECHNICAL INSPECTION REPORT**

**XRD-1**

This report by the DSM, the Operation Crossroads weapon effects test director, contains a broad summary of the significant information acquired from the Able and Baker events. It summarizes the results of each of the major programs within the operation and lists implications to the Navy and recommendations for future tests and ship design. Results are generally reported in terms of distances from nuclear bursts for ship survivability or lethality. More detail is provided by the several groups reporting to the DSM.

### **BuShips Group Technical Inspection Reports**

**XRD-2, XRD-3**

BuShips had overall responsibility for fielding the target fleet in Crossroads and inspecting the ships after the tests in order to report damage to the DSM. Test preparations are described and the observed damage is summarized. Types and degrees of damage are tabulated for the entire fleet. Details of the damage are described in the technical inspection reports below.

#### ***Effects of Airblast on Superstructures***

**XRD-4**

All data collected during Crossroads on blast effects on ship superstructures are assembled in this report. Damage is described in terms of structure element, type of vessel, element failure points, and distance from the bursts. (The "distance from burst" numbers should be treated with some skepticism because of uncertainty about the exact detonation point of the Able device.) Many photos of superstructure damage on several ships are presented, but little information is provided on the environments that caused the damage.

#### ***Failures of Masts, Yardarms, Booms, and Rigging***

**XRD-5**

The report is a compilation of data reporting failure of mast equipment from nuclear blast waves. During the Able test, 14 ships experienced mast element damage, but no such failures were noted during Baker. Ships near the detonation point that did not suffer mast damage are also discussed. Damage is described and photographs are provided, but blast environments leading to the damage are uncertain.

### ***Welding***

**XRD-6**

The project assessed the response of naval vessel welded joints to nuclear air and underwater shock loads. Generally, good welds survived and poor welds failed. Numerous photographs of weld failures are provided with little detail.

### ***Petroleum Products***

**XRD-7**

The objective of this project was to assess the effects of nuclear bursts on fuels and lubricants commonly used on ships. Army petroleum samples were also exposed. Tested materials included fuel oil, turbine lubricating oil, diesel fuel, and hydraulic oils taken from the target fleet. The samples were exposed to the burst in containers. XRD-7 indicates little or no change in petroleum product properties.

### ***Special Reports on Hull Items***

**XRD-8**

Special nuclear weapon effects studies on submarine salvage fittings, flooding sources, turret structures, and protective paints were performed. Evidence of problems and recommendations for solutions are presented.

### ***Special Reports on Machinery Items***

**XRD-9**

Special nuclear weapon effects studies were performed on boilers, uptakes, and stacks, piping and fittings, deck machinery, main turbines and gears, and auxiliary machinery. Results and observations relevant to future naval vessel design are presented.

### ***Special Reports on Electrical Items***

**XRD-10**

Nuclear effects on a wide variety of shipboard electrical equipment are addressed. Equipment includes propulsion systems, motors, control systems, generators, batteries, and telephone systems. Effects data from the entire target fleet are assembled and assessed.

### ***Overall Summaries of Target Vessels***

**XRD-11, -12, -13, -14**

Nuclear weapon effects on each vessel in the Able and Baker events are summarized. Specific recommendations relating to each vessel are made. Reports describing specific types of damage observed throughout the target fleet and two reports (one for Able and Baker) were submitted for each ship or set of ships exposed during the tests. The damage reports on the individual ships are numbered XRD-16 through XRD-148 and are not discussed further in this guide.

### **BuShips Instrumentation Group**

Various measuring devices were placed on vessels by BuShips Instrumentation Group to record blast and shock phenomena during the detonations. Descriptions of the devices and the resulting measurements are given in the reports below.

### ***Accelerometers, Reed Gauges and Seismic Instruments***

**XRD-193**

Instruments to measure accelerations and low-magnitude shocks were installed in vessels at various distances from GZ. The report describes the gauges, their location, and the resulting measurements.

***Underwater Pressure-Time Measurements***

**XRD-194**

Diaphragms, pistons, and piezoelectric gauges were used to measure the pressure-time profile of the underwater shock wave during Able and Baker. Able produced no readings, and Baker readings require some interpretation.

***Pressure Measurements of the Airblast Tests Able and Baker***

**XRD-195**

Airblast pressure measurements, both free field and at selected locations on ships, were made during Able and Baker. Two ships carried diaphragm and piston gauges in each test. Raw data records and processed data are reported, along with descriptions of gauge operation and data analysis.

***Strain and Displacement Measurements***

**XRD-196**

Strain and displacement gauges were installed in ten ships and submarines. XRD-196 contains a complete listing of data, location of ships and gauges, and thorough posttest analyses. Readings were universally smaller than expected.

***Velocity-Time Measurements***

**XRD-197**

Thirty-two velocity meters were installed on selected structures of four exposed vessels. The vessels varied in distance to GZ. Able produced minimal data, since one instrumented ship sank and the other three were far from the detonation. Extensive data are reported for Baker, including raw data traces. Good posttest analyses were performed.

***Impulse Velocity Gauge Measurements***

**XRD-198**

A gauge for measuring peak velocities of shock-loaded structures was developed for use in Crossroads. The rigidly mounted diaphragm deformed in proportion to the impulse propelling the structure. Since the gauge was simple, inexpensive, and self-recording, many were mounted on structural elements of several target vessels. XRD-198 describes the gauge, its operation, location, and the implied velocity measurements.

***Underwater Pressure Measurements—Ball Crusher***

**XRD-199**

A pressure-recording gauge based on the principal of ball deformation by a pressure-driven piston was used extensively in Crossroads. Gauges were deployed at various water depths near ships and on hulls. Underwater peak pressure measurements at a variety of locations from GZ are reported along with calibration curves to relate ball deformation to pressure.

***Displacements of Shock-Mounted Equipment***

**XRD-200**

The objective of this project was to measure the maximum displacement of shock-mounted equipment at various locations on ships at various distances from the nuclear burst points. Lead gauges that deformed plastically were employed. The shock mounts are described and gauge readings are reported.

***Shock Measurements***

**XRD-201**

The report describes measurements and data plots of shock-induced motions of ships. A variety of pressure, velocity, and displacement gauges were mounted aboard 25 vessels to determine the forces to which shipboard equipments are subjected.

### ***Icaroscopes***

**XRD-202**

Devices capable of presenting images of the fireball with low enough intensity for direct viewing without filtration were attached to cameras as well as for direct viewing by participants. Two such cameras obtained successful pictures on Able and fireball diameters were determined and recorded in XRD-202.

### ***Roll and Pitch Measurement***

**XRD-203**

Gyroscopes and pendulum recorders were installed on 13 target ships to measure the roll and pitch of vessels exposed to nuclear bursts. The report consists of general observations and recorded data.

### ***Measurements of Peak Pressure and Vacuum***

**XRD-204**

The objective of this project was to measure positive and negative pressures external to the ships and at various locations inside ships exposed to nuclear bursts. The report contains a significant number of pressure gauge readings, but the measuring technique is questionable.

### ***Army Group***

**XRD-149**

The document is a summary of Army activities during Operation Crossroads. Experimental details appear in reports XRD-150 through XRD-156, which follow.

### ***Engineer***

**XRD-150**

The objective of this project was to assess nuclear weapon effects on standard Corps of Engineers equipment. Test hardware included construction equipment, floating bridges, water supply equipment, mine detectors, and battlefield equipment. Photographs of test items and comments on survivability are presented.

### ***Signal***

**XRD-151**

XRD-151 contains detailed descriptions of hardware and test results. The objective of this project was to evaluate nuclear weapon effects on Signal Corps communication equipment. Experiments were passive, and assessments were made on the operability and repairability of the equipment after exposure. A complete listing of test hardware and the experiment locations is provided, along with pretest and posttest operations.

### ***Ordnance***

**XRD-152**

A number of Army tanks, guns, and artillery pieces, and ammunition were deployed on the decks of ships in Operation Crossroads. The effects from Able were more significant than those from Baker. It was generally concluded that personnel manning the ordnance were more vulnerable than the equipment. Several good, but general, observations are reported in XRD-152, along with detailed descriptions of hardware and response.

### ***Chemical***

**XRD-153**

The objective of this project was to assess the response of chemical warfare equipment to a nuclear weapon environment. Chemical weapon containers, detoxification materials, and protective clothing were exposed in the Able event at six different test stations on ships. Descriptions of test hardware and response to the nuclear environment are described.

***Quartermaster***

**XRD-154, -155**

The objective of this project was to determine the response of standard Quartermaster supplies, including subsistence, clothing, individual equipment, and repellents, to nuclear environments. Deployment included normal usage and storage conditions. Descriptions of test items, test positions, and posttest conditions, including photographs, are presented.

***Air***

**XRD-156**

The response of various Army airplane elements to nuclear environments was evaluated. Test hardware included wing panels, instruments, gasoline tanks, and flight suits. Test items and responses are described.

**Bureau of Aeronautics (BuAer) Group Final Report**

**XRD-157**

BuAer exposed 73 Navy aircraft to the Crossroads nuclear environments. These included observation planes, carrier combat planes, and moored seaplanes. The aircraft were deployed on warships and transports in normal wartime disposition. A few had fuel and ammunition. Airplane damage after each nuclear test is described and numerous photographs are provided.

**Bureau of Ordnance (BuOrd) Group Final Report**

**XRD-158**

The BuOrd objective was to assess the capability of naval ordnance systems and equipment to operate in nuclear environments. Test hardware was fielded on 14 ships. Guns, mounts, torpedoes, and fire-control systems were evaluated before and after exposure. Observed effects are summarized.

***Fire Control***

**XRD-159**

The objective of this project was to evaluate the response of fire-control optics and fire-control radar to nuclear detonations. Surface ship and submarine systems were tested. Pressure gauges and accelerometers were installed at certain ordnance locations. Several systems were energized before exposure. Postexposure condition of numerous systems is reported.

***Photographic Appendix***

**XRD-160**

This project provided photographic coverage of naval ordnance hardware positioned during testing.

***Guns and Mounts***

**XRD-161**

Naval guns and gun mounts were exposed at various ranges from the Crossroads nuclear detonations. Equipment damage is described with supporting photography.

***Armor and Metallurgy***

**XRD-162**

Damage to the armor and metal plating on five battleships exposed to nuclear detonations is described. Extensive photography is provided.

**Bureau of Medicine and Surgery (BuMed) Group Report,  
Sample Locations**

**XRD-163**

A large number of biological specimens were exposed on ships to study the biological effects of nuclear environments. Items tested included goats, pigs, rats, soils, microorganisms, plant seeds, biological warfare agents, and radiation dosimeters. XRD-163 identifies the test location of each

biological sample. Reports containing the results of the BuMed experiments follow (XRD-164, XRD-165, XRD-170 through XRD-172, and XRD-175 through XRD-178):

***Airblast Effects of An Atomic Bomb Explosion*** **XRD-164**

Live rats in cages suspended by wires were exposed on four ships during Able to study blast effects on animals. A number of the cages were blown overboard. Autopsies were performed and medical observations are reported. Possible effects of nuclear radiation, other than thermal, are not mentioned.

***Gross Autopsy Findings and a Statistical Study of the Mortality in the Animals Exposed at Bikini*** **XRD-165**

The project recorded the survival period of each of the animals exposed in Crossroads at various ranges and shipboard locations. Data tables and plots of animal mortality as a function of time and distance from detonation are presented.

***Germination of Vegetable Seeds Exposed at Bikini During the Atomic Bomb Test Able*** **XRD-170**

The objective of this project was to plant seeds that had been exposed at various distances from GZ and assess the effect of different levels of radiation exposure on plant germination and growth. Seed types included beans, cucumbers, tomatoes, lettuce, onions, carrots, cabbage, and cotton. Comparisons of control and irradiated specimens during growth are reported.

***Residual Effects of Atomic Radiation in Soil on Seed Germination*** **XRD-171**

Samples of soil from three parts of the United States were exposed to the radiation during Able. Irradiated soil was then used to grow tomatoes and grass. Plant growth in exposed soil and unexposed soil is compared.

***Effect of the Bikini Atomic Bomb Test Able on Soil Microorganisms*** **XRD-172**

Samples of soil from three parts of the United States were exposed to radiation during the Able event. The samples were then tested for the presence of natural microorganisms. The quantities of microorganisms in exposed and unexposed soils are compared.

***Analysis of Tissues for Induced Radioactivity*** **XRD-175**

Various tissues of animals exposed to the Able event were tested for radioactivity. Measurements of radioactivity from bones of rats, pigs, and goats are reported, along with position of the animals at the time of the detonation.

***Vycor Glass Gamma Ray Dosimeters*** **XRD-176**

A rugged new dosimeter capable of measuring gamma doses on animals exposed to high levels of radiation was employed during Able. Dosimeter readings, locations, and animal condition are reported.



***Aberrations Found in the Progenies of Plants  
Grown from Irradiated Cotton Seed***

**XRD-177, -178**

Second-generation seeds from those exposed in Crossroads were planted and the resulting plants analyzed.

**Electronics Coordinating Officer Reports**

**XRD-180, -181**

This project provided extensive tabular and photographic coverage of damage to antennas and electronic elements, including vacuum tubes, cables, mountings, waveguides, sonar, Army Signal Corps equipment and plastics and paint.

**Bureau of Yards and Docks Group Final Report**

**XRD-182**

The objective of this project was to measure the effects of nuclear explosions on three concrete boats in order to be able to assess the potential effects on land-based concrete structures. Concrete test hardware included a 2,800-ton dry dock, a gasoline barge, and a fuel oil barge. The damage sustained during Able and Baker is described, with comments on the implications.

**Bureau of Supplies and Accounts Group Final Report**

**XRD-183**

Effects of a nuclear burst on food (fresh, frozen, dried) and clothing stored in normal locations on four target ships are described.

**Maritime Commission Representatives Final Report**

**XRD-184**

General observations are made assessing damage to ships built by the Maritime Commission and new fabrication techniques to enhance ship survivability are identified.

**Radiological Decontamination of Vessels**

**XRD-185, -186, -187**

Vessels in the target fleet and ships supporting Crossroads had to undergo a decontamination process. XRD-185, -186, and -187 describe experimental techniques employed and the degree of success achieved.

**TECHNICAL DIRECTORS PROGRAM AND REPORTS**

This program covered such nonmeasurement areas as weapon preparation and radiological safety but also had groups making measurements of blast, wave motions, EM propagation, and thermal and optical radiation via remote measurement techniques and technical photography. In the blast area, the intent was to take measurements in free air, whereas the BuShips Instrumentation Group (above) was to take measurements "in and around" the target ships. However, it appears that there is much overlap between the instrumentation indexed in Appendix N of the Technical Directors Reports (XRD-209, -210) and that discussed in the BuShips Instrumentation Group reports (XRD-192 through XRD-204).

**XRD-209, -210**

**TEST SITE SURVEY**

The objective of this project was to provide a detailed description of the Bikini Atoll as it existed before and after the nuclear tests. XRD-212 contains detailed descriptions of sunken vessels and

residual radiation in soils, plants, and sea life. It was the result of a small expedition conducted in 1947, usually referred to as the Bikini Resurvey.

**XRD-212**

**SECTION 5**  
**SANDSTONE**  
**Enewetak Atoll, Marshall Islands**  
**1948**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
X-Ray	April 15	Enjebi Island	37 KT	200-foot tower
Yoke	May 1	Aomon Island	49 KT	200-foot tower
Zebra	May 15	Runit Island	18 KT	200-foot tower

**BACKGROUND.**

Operation Sandstone was proposed and approved as a weapon development test series. Its purpose was to advance U.S. nuclear weapon technology to the point where bombs could be efficiently fabricated on an assembly line rather than hand-assembled in the laboratory.

While this series of three tests was clearly structured for nuclear weapon design, it was agreed that nuclear weapon effects experiments could be fielded as long as they did not interfere with device operations or diagnostics. Within these constraints, the DoD designed tests to:

1. Study radioactive debris and fallout
2. Observe blast response of various concrete and steel structures
3. Assess radiation shielding provided by various structures
4. Measure nuclear blast loads on, and the response of, operating aircraft
5. Assess nuclear detonation detection concepts.

Related experiments performed during X-ray, Yoke, and Zebra were reported in single documents covering all three tests. A large number of SS documents are not discussed in this report since they are pertinent to weapon development but not nuclear weapon environment or effects.

The Sandstone tests occurred very early in the evolution of nuclear weapon effects testing, and the experiments and measurement techniques were relatively unsophisticated. Even so, potentially useful effects data were recorded. The motion picture records of the bursts in particular contain valuable data relevant to shock wave and fireball analysis.

**OPERATION SANDSTONE PROJECTS AND REPORTS**

**High-Energy Neutrons from the Sandstone Nuclear Bombs  
as Measured by Threshold Detectors**

**SS-18**

The objective of this experiment was to measure the neutron flux in various energy bands in the Sandstone events. Various types of neutron threshold detectors were deployed at ranges from about 200 to 1,000 yards from GZ. Neutron fluxes for each of the detector types at various ranges are reported.

## **Neutron Absorption Measurements**

**SS-19**

Integrated dose measurements for high-energy and low-energy neutrons were made in concrete and steel enclosures. These were compared with direct free-field neutron measurements by Los Alamos National Laboratories (SS-18), thereby indicating the neutron-shielding capacity of steel or concrete shelters. The report is an account of the conventional neutron-activation techniques employed to measure the neutron fields and foil activities vs distance from GZ, shielded and unshielded.

## **Blast Wave Measurements**

**SS-20, -21, -22**

Measurements of blast wave peak pressure and waveform were made using a variety of active and passive instruments. Techniques as unsophisticated as measuring the deformation in metal cans as an indication of pressure magnitude were used. Active displacement gauges were also used for pressure-time measurements. Records of results are provided.

## **Airplane Shock Wave Measurements**

**SS-23**

Drone B-17 aircraft were flown through the radioactive clouds to collect fission samples from the clouds for bomb diagnostics purposes. Blast and structural response instruments were installed in the aircraft. Pressure transducers and strain gauges were installed on external parts of the airplanes. An accelerometer was positioned at the center of gravity of each aircraft. Successful assessments are reported for shock transit-time between burst point and aircraft, bending moments on aircraft wings from nuclear loads, and aircraft accelerations from nuclear loads. Attempts to measure shock environments failed. Accelerometer and strain gauge data are reported.

## **Blast Protection Afforded by Structures**

**SS-24**

The Army Corps of Engineers exposed four concrete structures and one earthen barricade at various ranges from X-Ray GZ. Damage to the structures was not extensive, even though they had been moved and tumbled over significant distances. The test hardware and damage are described.

## **Blast Resistance of Structures**

**SS-25, -26**

The Navy Bureau of Yards and Docks exposed a large number of structures to nuclear blast loads with the objective of developing a model for hardened structure design, 79 units during X-Ray and 92 during Yoke. Typical models were 5 feet on a side and most were constructed of reinforced concrete, with a few of timber or steel. Shapes included cubes, prisms, cylinders, domes, and pyramids with varying wall thicknesses. Some structures were anchored or partially buried. The report describes the response of each test structure and also provides pretest and posttest photographs.

## **Technical Photography**

**SS-27, -28**

The primary objective of this project was to provide high-speed film coverage of each of the three tests to permit accurate measurements of fireball growth rate for weapon yield determination. Determining early-time shock velocity was also an objective. Two camera platforms, 75 feet high and approximately 5 miles from GZ, were deployed for each test. Excellent film coverage was achieved. SS-28 contains prints illustrating early-time fireball dimensions at various times for Operation Sandstone and for Trinity.

## **Contamination Studies**

**SS-30**

Numerous studies of radioactivity from nuclear detonations included:

1. Measuring the activity and type of radioactive debris in and around the craters were made.
2. Relating aboveground radioactivity to ground-level radioactivity via posttest (hours and days) aerial surveys to determine if survey aircraft could be employed to plot troop movements through a nuclear battlefield.
3. Measuring activity in the radioactive clouds immediately after the detonation using drone aircraft. Multiple passes were made by the aircraft at various altitudes. Activity measurements inside and outside the aircraft were recorded.
4. Measuring the sizes of radioactive particles of samples from ground and airborne collection devices.
5. Determining the efficiency of a filter system in removing radioactive particles from an air system for bomb shelters.

## **Radiological Safety Instruments**

**SS-31**

A number of radiation monitors were tested at various locations. Ruggedness was assessed. Monitor readings are compared and reported.

## **Thermal Effects and Decontamination Studies**

**SS-32**

Material samples were exposed at various distances from nuclear detonations to determine thermal effects, susceptibility to radioactive debris accumulation, and ease of decontamination. Posttest descriptions of samples are reported.

## **Biological and Animal Container Studies**

**SS-33**

A variety of seeds, insects, and bacteria were exposed to the nuclear bursts to assess the effects of ionizing radiation. Irradiated seeds were to be planted to observe the effects on plant growth. Cage designs for animal exposure in future events were tested.

## **Nuclear Explosion Detection**

**SS-34**

1. Attempts were made to discover if the light from nuclear explosions could be observed reflecting off the moon. Instruments and personal observations were employed. No reflected light was observed, and no data are reported.
2. Seismic measurements from nuclear detonations were made on islands of the Enewetak Atoll. Accelerometer readings are reported.
3. Attempts to measure perturbations to the earth's magnetic field were made at distances of tens of kilometers from GZ. No signals were noted.

**SECTION 6**  
**RANGER**  
**Nevada Test Site**  
**Frenchman Flat**  
**1951**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Able	Jan 17	NTS	1 KT	Airburst (HOB, 1,060 feet)
Baker	Jan 20	NTS	8 KT	Airburst (HOB, 1,080 feet)
Easy	Feb 1	NTS	1 KT	Airburst (HOB, 1,080 feet)
Baker-2	Feb 2	NTS	8 KT	Airburst (HOB, 1,100 feet)
Fox	Feb 6	NTS	22 KT	Airburst (HOB, 1,435 feet)

**BACKGROUND.**

Operation Ranger was conceived to support Operation Greenhouse, scheduled for the spring of 1951 in the Pacific. Operation Greenhouse supported development of thermonuclear weapons and the bomb designers concluded that additional test data were required. Operation Ranger was organized to provide that data. Testing consisted of five airbursts, with the devices dropped from aircraft. Ranger was the first nuclear test series to be conducted at what has become the Nevada Test Site (NTS).

Due to the extremely short preparation time available, Operation Ranger contained almost no weapon effects experiments. DoD activity consisted of digging foxholes to determine the protection they provided from nuclear airburst and of exposing some materials to the thermal environments.

The testing and safety procedures employed in Operation Ranger helped establish the pattern for future testing in Nevada.

**OPERATION RANGER PROJECTS AND REPORTS**

**PROGRAM REPORTS—GROSS WEAPONS MEASUREMENT WT-201**

**Report 6, Protection Afforded by Field Fortifications Against Gamma Radiation from An Air-Burst Atomic Bomb**

The objective of this project was to measure the gamma radiation dose in various types of foxholes exposed to nuclear airbursts. One- and two-man foxholes at ranges from 400 to 2,000 yards from GZ during Operation Ranger detonations were instrumented with film packs to measure gamma radiation dose. Gamma dose measurements at various locations in the foxholes are reported.

**Reports 7—9, Effects of Thermal Radiation on Materials**

The project assessed the effects of thermal radiation from nuclear bursts on various types of clothing, wood, and plastic. Samples were exposed in all Operation Ranger events. Material responses are described.

**Report 10, Thermal and Ionizing Radiation Measurements:  
Preliminary Report**

Objectives were to measure (a) the thermal radiation arriving at the skin covered by various fabrics, (b) thermal environments using temperature-sensitive paper, and (c) the gamma-ray environment at various locations. Only the gamma-ray measurements are reported.

**SECTION 7  
GREENHOUSE  
Enewetak Atoll  
1951**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Dog	April 8	Runit Island	Unannounced	300-foot tower
Easy	April 21	Enjebi Island	47 KT	300-foot tower
George	May 9	Eleleron Island	Unannounced	200-foot tower
Item	May 25	Enjebi Island	Unannounced	200-foot tower

**BACKGROUND.**

Operation Greenhouse was a key test series in the evolution of thermonuclear bombs. It also supported a significant nuclear weapons effects program. The series consisted of four nuclear detonations from towers located on islands of the Enewetak Atoll. The Easy event was the designated weapons effects test, although the other events did support some limited weapon effects activities.

Seven military effects programs, plus one Atomic Energy Commission (AEC) program were devised to provide environment and response instrumentation:

- Program 1 — AEC Tests
- Program 2 — Biomedical Tests
- Program 3 — Structures Tests
- Program 4 — Cloud Physics Tests
- Program 5 — Radiological Instrumentation Evaluation
- Program 6 — Physical Tests and Instrumentation
- Program 8 — Effects on Aircraft

Program 7, Long Range Detection is not addressed further in this guide. Results of this program were not published in available sources.

The structures program was extensive. Twenty-six separate structures were constructed, with all materials shipped across the Pacific. The Army, Navy, and Air Force each had separate structures tests, but these were integrated by a scientific guidance committee. Instrumentation for environments and structural response was provided by the AEC.

Numerous biological experiments were performed using mice, pigs, and dogs as test specimens. Plant life was also exposed.



## PROGRAM 1—AEC TESTS

### **Annex 1.1, Prompt Gamma-Ray Measurements** **WT-66, -36, -14, -17**

The objective of this program was to measure the gamma-ray intensity-time profile for weapon physics studies. Results are reported in WT-66, -36, -14 and -17.

### **Annex 1.2, Delayed Gamma Measurements** **WT-76, -107, -77, -81, -41**

The objective of this program was the measurement of the properties of the fission gamma output, primarily for weapon efficiency or diagnostic purposes.

### **Annex 1.3, Thermal Radiation Measurements** **WT-120**

Measurements of total thermal output and time-resolved and spectrally resolved output in the visible were made as well as measurements of atmospheric transmission.

### **Annex 1.4, Ball-of-Fire Observations** **WT-101**

Motion picture photographs were used to determine the growth of the fireball and in consequence the yields of the detonations. Examples of the pictures taken are included as well as growth rates.

### **Annex 1.5, Neutron Measurements** **WT-96, -97, -114, -68, -37**

Neutron measurements were made to study bomb physics.

### **Annex 1.6, Blast Measurements**

#### ***Summary Report*** **WT-64**

Measurements included overpressure, earth pressure, acceleration, displacement, and crater dimensions. Test procedures, some measured data, and discussions of implications and anomalies are presented.

#### ***Free-Air Peak Pressure Measurements***

##### ***Section 1*** **WT-54**

The objective of this project was to measure nuclear blast-wave velocity by observing its position with time using rocket-generated smoke contrails as a background matrix. Peak pressures at various ranges are calculated from the local shock velocities. The report covers the description of phenomenology, photographs of bursts and smoke contrails, and calculated pressures.

##### ***Section 2*** **WT-20**

Mach-stem region peak blast pressures were measured using foil meters and shock-velocity meters. The shock-velocity meters gave expected results, but the foil meters performed poorly. The report presents the measured data and an analysis.

#### ***Pressures Near Ground Level***

##### ***Sections 1 and 2*** **WT-55**

The aim of Section 1 was to determine Mach-region peak pressures from shock-velocity measurements. Three systems were used to measure time of arrival at a number of stations for several shots. Shot-time sound velocity measurements were also made along with determination of

sound velocity from meteorological measurements. Tables of peak pressure inferred from the time-of-arrival data are given. The aim of Section 2 was to determine peak blast pressures in the Mach region for Dog and Easy inferred from the rupture of metal foils placed over holes of various diameters in arrays at several ranges from GZ. Data presented are peak pressure variation with distance.

**Section 3**

**WT-78**

Copper indenter gauges were used to measure peak pressures in the Mach-stem region of a nuclear blast wave. The report indicates the measured values were not those expected for this measurement technique.

**Sections 4 and 5**

**WT-58**

The measurements were to be used to investigate near-earth shock-wave phenomena using photography and some form of crush-up of spheres. The report presents the results, but does not describe gauges used and no photographic results were achieved.

***Pressure Time Measurements in the Mach Region***

**WT-53**

Pressure-time measurements on Dog and Easy were made between 5 and 100 psi with a diaphragm-type inductance gauge and a spring-piston gauge. Some blast waveforms are included.

***Ground Shock Measurements***

**WT-69**

The report contains data and analyses resulting from measurements of earth acceleration and displacement as a function of time at various distances from Easy and George GZs.

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

**WT-110**

The measurements are used to define air characteristics in a nuclear shock wave. Considerable scientific speculation regarding shock-wave phenomenology is presented in this report.

***Crater Survey***

**WT-109**

Results of surveys of the craters formed by the Greenhouse events are reported.

**Annex 1.12, Long-Distance Measurement of Energy Yield  
of an Atomic Explosion**

**WT-106**

WT-106 describes a concept for determining the yield of a nuclear explosion from long distances by light measurement. Measurements were attempted with partial success. Results are discussed.

**PROGRAM 2—BIOMEDICAL TESTS**

**EVALUATION OF PROGRAM 2**

**WT-21**

The report summarizes the Greenhouse biomedical experiments, where mice, pigs, and dogs were exposed to nuclear radiation to assess the biological effects of such exposure. The results of these experiments are reported. Effects from nuclear weapons and from laboratory x-ray machines are compared. Dosimeters to measure radiation fields were tested.

**Annex 2.2, Control Studies of Operation Greenhouse Test Animals WT-6, -18**

Mice, pigs, and dogs were exposed, in laboratories, to radiation designed to simulate the exposures of Greenhouse. The report is the result of posttest observations and autopsies, presenting animal response and mortality.

**Annex 2.4, Experimental Data Obtained in the Field WT-43**

This activity had three parts:

*Part 1.* Observation of the effects of gamma radiation from a nuclear detonation on mice and compare the effects with those observed on mice exposed to x-ray machines in laboratories (Annex 2.2). Some of the mice were flown near the Greenhouse burst in drone aircraft. Selected body organs were analyzed.

*Part 2.* Identification and testing of materials that would react to gamma radiation in a manner similar to human, mouse, and pig tissue.

*Part 3.* Exposure of flowering plants to a nuclear burst to determine if they could be used as dosimeters for gamma radiation.

**Annex 2.5, Mortality Rate as a Function of Distance WT-22**

This project exposed mice, pigs, and dogs to nuclear radiation during Easy and attempted to relate observed results to human lethality in nuclear bomb environments. Test containers, positioned between 1,000 and 2,800 yards from GZ, were designed to provide protection from blast and thermal radiation since gamma effects were of primary interest. Presented in the data are gamma radiation measurements and animal response and survival as a function of exposure distance and time after detonation.

**Annex 2.6, Pathology of Radiation Injury WT-16**

Dogs and pigs exposed to nuclear environments during Greenhouse were closely observed and autopsied after death. Observations and autopsies are reported in precise medical detail.

**Annex 2.7, Thermal Radiation Injury WT-9**

This project characterized the nature of skin burns resulting from exposure to nuclear bursts. Pigs and dogs, shorn of hair in patches, were exposed to the thermal radiation during Easy and Dog. Incident thermal radiation dose and spectrum measurements were made at the exposure stations. Animal reactions and conditions after exposure are reported.

**Annex 2.9, Blast Injuries in Foxholes WT-8**

Dogs were exposed in foxholes at various distances from Item GZ, to assess biological damage. Results reported are biological damage found after autopsies and measurements of blast, thermal, and nuclear radiation environments.

**Annex 2.10, Miscellaneous Studies of Dosimeters WT-13**

The project assessed the potential of several materials for use as radiation dosimeters. Glormorella, corn, Vycor glass, potassium bromide crystals, and photoluminescent glass were exposed at stations from 300 to 2,200 yards from Easy GZ. Descriptions of dosimeters and observed responses to laboratory and field environments are reported.

## **PROGRAM 3—STRUCTURES TESTS**

### **Annex 3.0, Structures Tests Summary**

**WT-117**

WT-117 summarizes and discusses implications of the Army, Navy, and Air Force structures tests performed during Greenhouse.

### **Annex 3.1, U.S. Army Structures Test**

**WT-94**

The objective of this project was to measure the response of two steel and concrete frame buildings exposed during Easy. One was a large aboveground building consisting of several independent compartments for testing various structural elements (walls and panels) made from diverse materials. The other structure was partially buried. Pressures, accelerations, and displacements were measured. Data records, photographs, and analyses are presented. Documentation of the various pretest construction activities and pre- and posttest photography are provided. Appendices (11 and 12) are published separately as WT-118 and WT-95, respectively. These are documented below.

#### ***Results of the Second Engebi Shot***

**WT-95**

Photographs and descriptions of damage to the multistory structure and the composite shelter structure after exposure to Item are provided in this report. No instrumentation was used. These structures, previously exposed during Easy, were therefore not in virgin condition for Item. It should be noted that detonation points for the two bursts were different.

#### ***Results and Analyses Summary***

**WT-118**

WT-118 contains descriptions of the Army structures tests, results, and analyses. Measurements included pressures on members, displacements, and accelerations. References to documents describing individual experiments are included.

### **Annex 3.2, U.S. Navy Structures**

**WT-91, -23, -24, -25**

This project tested protective naval structures exposed to nuclear blast loads in order to advance structural design methodology. Full-scale square and domed buildings of concrete, brick, and steel were exposed at various ranges during Easy. Pressures, displacements, and accelerations were measured. Detailed descriptions of structure fabrication, measured and observed results, analyses, and photographs are presented.

### **Annex 3.3, U.S. Air Force Structures**

**WT-29, -30, -35, -59, -82 through -88**

The basic goal of the Air Force structures program was to develop an understanding of nuclear blast loading on structures and structural response for target planning and damage assessment purposes. Steel, brick, and concrete structures with different types of footings and girder arrangements were exposed at various ranges during Easy. Pressure loadings, displacement, strain, and acceleration were measured.

### **Annex 3.4, Instrumentation of Structures Program**

**WT-1, -10**

Instruments used for each type of measurement are described, along with operation, performance, and calibrations. Measurements included overpressure, earth pressure, strain, acceleration, displacement, and element time-of-break. Data-recording systems are described and discussed.

**Annex 3.5, The Effects of Atomic Weapons on Glazing and Window Construction**

**WT-7**

Commercially available window assemblies with screens and venetian blinds were exposed during Easy in order to assess the problem of flying glass. Window response as a function of construction is discussed, with supporting photographic coverage.

**PROGRAM 4—CLOUD PHYSICS TESTS**

**Annex 4.1, Cloud Studies**

**WT-115**

Three interrelated projects studied the internal cloud conditions and cloud growth. Instruments mounted on radio-controlled airplanes flew through the cloud stems and recorded temperatures, pressure and humidity. Cameras recorded external features, rise and growth for periods up to one-half hour after burst. Data presented are summary curves, sketches, and photographs.

**Annex 4.2, Measurement of Surface Air Movements Associated with Atomic Blasts**

**WT-105**

This project measured winds at various locations in the vicinity of nuclear bursts before, during, and after the detonations. Wind direction and speed as a function of position and time are presented.

**Annex 4.6, Atmospheric Conductivity**

**WT-71**

The objectives of this project were to characterize the radioactivity in a nuclear-bomb-generated cloud, determine the cloud movement with time, and measure the fallout. Two B-50 and one L-13 aircraft flew through the clouds during Easy, Dog, and George. Air conductivity was measured to determine the amount of radioactive material present. Radioactive cloud contours are presented for different times and locations.

**PROGRAM 5—RADIOLOGICAL INSTRUMENTATION EVALUATION**

**Annex 5.1, Evaluation of Ground Radiac**

**WT-63**

The report discusses experiments conducted during Dog, Easy, and George to evaluate field dosimeters and survey meters. The project was also tasked to operate a field radiation assessment laboratory and a laundry (clothing) radiation-measuring machine.

***Annex A, Alkali Halide and Phosphate Glass Radiological Casualty***

**WT-3**

The objective of this project was to test low-cost dosimeters that could quickly portray, by color change, the gamma dose received from exposure to a nuclear burst. Test results are inconclusive.

***Annex B, Polaroid Dosimeters***

**WT-62**

Inexpensive film dosimeters for field personnel in a nuclear environment were evaluated. Film dosimeter measurements from the nuclear test are compared with equivalent National Bureau of Standards measurements.

**Annex 5.2, Evaluation of Air-Borne Radiac Equipment**

**WT-104**

Navy and Air Force equipment for cloud tracking, surface radioactivity mapping, ground-to-air gamma telemetering, and airborne radiation detection were flown on two airplanes that did cloud tracking and surface monitoring. Recommendations for each instrument are included as well as data.

**PROGRAM 6—PHYSICAL TESTS AND INSTRUMENTATION**

**Annex 6.1, Cloud Phenomena: Study of Particulate and Gaseous Matter** **WT-72**

This project characterized the intensity of radioactivity and particle content of the nuclear clouds from the Greenhouse events. Drone B-17 aircraft were flown through the clouds to perform the necessary sampling. Measured values of radioactivity and particle characteristics are reported.

**Annex 6.2, The Effect of Thermal Radiation on Material**

**WT-70**

This project exposed identical materials to a nuclear burst and to a laboratory thermal simulator and compared the results. Test materials included cloth, wood, and metals. Procedures and results as reported are vague.

**Annex 6.3, Combat Vehicle Exposure**

**WT-90**

This experiment assessed the effect of a nuclear burst on tanks and tank personnel. Eight tanks were exposed to the Easy environment at various ranges from the detonation. Radiation levels and pressures were measured inside the tanks. It was concluded that crew members would be more vulnerable than the tanks. Measurements of shock and radiation are reported.

**Annex 6.4, Fallout Phenomenology**

**WT-4**

This project characterized the radioactive fallout from Dog, Easy, and George on various islands of Enewetak Atoll. The measured fallout is reported as a function of time.

**Annex 6.5, Interpretation of Survey-Meter Data**

**WT-26**

The objective of this project was to collect radioactive samples from Dog and Easy, measure the gamma and beta radiation from these samples using survey meters in the laboratory, and calibrate the survey meters using known radiation sources. Extracting useful data from this report requires considerable effort.

**Annex 6.7, Contamination-Decontamination Studies**

**WT-27**

Forty panels of different materials were flown through radioactive clouds on drone aircraft and decontaminated in a laboratory. Different decontamination techniques were used to investigate which were most appropriate for the various materials. Measured activities and decontamination processes are described.

**Annex 6.8, Cloud Radiation Field**

**WT-11**

The objective of this project was to relate a measured radiation level to a quantity of radioactive debris in a nuclear cloud. Instruments capable of measuring the radiation environment and the amount of radioactive debris were installed in drone aircraft that were flown through the Dog,

Easy, and George clouds. A considerable amount of data for nuclear cloud characterization was collected and presented.

**Annex 6.9, Protective Clothing, and Clothing and Personnel  
Decontamination**

**WT-12**

This project assessed the attraction of various cloth materials for radioactive debris and evaluated techniques for decontaminating clothing and personnel. Seventy-five types of materials were contaminated and evaluated for their tendency to retain radioactive debris. Effectiveness of cleaning solutions is reported.

**Annex 6.10, Evaluation of Collective-Protector Equipment**

**WT-42**

This project assessed the protection capabilities of existing shelter apparatus in a nuclear environment. The shelter and apparatus were exposed during Easy. The environment inside the shelter was monitored. Measurements and observations are reported.

**PROGRAM 8—EFFECTS ON AIRCRAFT**

**Annex 8.0, General Report of Blast Studies on Aircraft**

**WT-34**

WT-34 summarizes the Air Force program for determining nuclear blast effects on aircraft and for identifying improved survivability design techniques. Instrumented drone and piloted aircraft were flown during Dog, Easy, and George. Test apparatus was also fielded at ground sites. Project emphasis was on theory and modeling.

**Annex 8.1, Blast Effects on Aircraft in Flight**

**WT-31, -32**

The project task was to measure the aerodynamic loads on and structural response of aircraft (B-17s, T-33s, DB-50s and an XB-47) flying in the vicinity of nuclear bursts. Loads and accelerations at various locations on the aircraft were recorded during Dog, Easy, and George.

**Annex 8.2A, Effects of an Atomic Bomb Burst on Aircraft Structures  
on the Ground**

**WT-65**

Aircraft structural components and models were exposed on islands in the vicinity of Easy. The blast environment and the structural response of the hardware were measured. WT-65 describes the test hardware and presents refined measurements and data traces.

**Annex 8.2B, Interferometer Gauge Pressure-Time Measurements**

**WT-5**

Pressure-time profiles of nuclear blast waves in the low-pressure regime were measured during Dog, Easy, and George. A new, fast-response gauge was developed for this task and good data were acquired in all three events. The report gives a detailed description of the gauge.

**Annex 8.3, Special Radar, Radio and Photographic Studies  
of Weapons Effects**

**WT-33**

The objectives of this study were to assess radar returns from nuclear bursts, assess the effects of nuclear bursts on radio transmissions, assess nuclear bomb damage from Easy using airborne photography, and study the problems of film fogging for photo-reconnaissance aircraft surveying nuclear weapon damage. Data records and photographs are presented for each subproject.

**SECTION 8**  
**BUSTER-JANGLE**  
**Nevada Test Site**  
**1951**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Device Placement</u>
Able	Oct 22	Yucca Flat, Area 7	Nil	100-foot tower
Baker	Oct 28	Yucca Flat, Area 7	3.5 KT	Airdrop (HOB, 1,118 feet)
Charlie	Oct 30	Yucca Flat, Area 7	14 KT	Airdrop (HOB, 1,132 feet)
Dog	Nov 1	Yucca Flat, Area 7	21 KT	Airdrop (HOB, 1,417 feet)
Easy	Nov 5	Yucca Flat, Area 7	31 KT	Airdrop (HOB, 1,314 feet)
Sugar	Nov 19	Yucca Flat, Area 9	1.2 KT	Surface (HOB, 4 feet)
Uncle	Nov 29	Yucca Flat, Area 10	1.2 KT	Subsurface (DOB, 17 feet)

**BACKGROUND.**

Operation Buster, which constituted the first five events in Operation Buster-Jangle, was a nuclear development series with some accompanying weapon effects experiments. The concern at the time was the possible use of nuclear weapons in tactical operations and the test objectives were tactical nuclear weapon development and troop orientation for nuclear battlefield operations. A two-event nuclear weapon effects test series, Operation Jangle had been planned as Windstorm to be conducted in the Aleutian islands but was rescheduled at NTS where it was combined with the Buster series, resulting in Operation Buster-Jangle. This was the first of three double-named operations. Buster-Jangle contained both AEC weapon development tests and DoD-sponsored nuclear weapon effects tests.

Thousands of soldiers participated in these events under the name Exercise Desert Rock. The objective was for troops to become acclimated to nuclear bursts and postburst maneuvers in the vicinity of the GZ. The exercises during Buster were called Desert Rock 1 and during Jangle, Desert Rock 2.

The Operation Jangle devices were positioned to obtain information on cratering from a nuclear burst. The Sugar (also referred to as "Jangle-S") device was detonated at ground level and the Uncle (sometimes "Jangle-U") device 17 feet underground. These shots were to be of low yield to minimize fallout problems in populated areas outside NTS. The effects experiments centered on blast, thermal radiation, and nuclear radiation. Thirteen HE tests were performed at NTS in preparation for the nuclear series. One HE shot consisted of 40,000 pounds of explosives.

The first nuclear event, Able, failed to generate a significant nuclear yield. This test provided valuable information to the weapon designers.

One result from Buster-Jangle was that blast overpressures were found to be significantly lower than expected based on prior tests. This finding spurred additional tests and new theories of shock wave formation and propagation.



The nuclear effects activities designed for Buster-Jangle included:

- Program 1—Blast and Shock Measurements
- Program 2—Thermal and Nuclear Radiation
- Program 3—Blast Effects on Structures and Equipment
- Program 4—Bio-Medical
- Program 6—Test of Service Equipment and Operations
- Program 7—Long Range Detection
- Program 9—Personnel Shelter Evaluations
- Program 10—Environment Measurements

Experimental operations and results for each project were reported under an assigned WT number. However, related experiments were sometimes grouped together and reported a second time under a composite WT number. For example, WT-4 might be a grouped republication of WTs 1, 2, and 3. Project descriptions are identified by both the individual experiment WT number and the grouped WT number.

## OPERATION BUSTER PROJECTS AND REPORTS

### Final Report

WT-412

This report summarizes the objectives and results of the nuclear weapon effects activities during Baker, Charlie, Dog, and Easy. No data are presented, but observations are made and the project/report numbers are listed.

## PROGRAM 2—THERMAL AND NUCLEAR RADIATION

### *Project 2.2, Thermal and Blast Effects on Idealized Forest Fuels* WT-309

The project was tasked to investigate the effects of nuclear bursts on forests. Pine needles, leaves, logs, and other forest materials were exposed at ranges of 2,000 to 12,000 feet for Baker, Charlie, Dog, and Easy. The sample conditions before and after exposure are described.

### *Project 2.3, Effects of Geometry on Flash Thermal Damage* WT-310

This project was to determine if grooves in wood and other considerations of geometry might affect thermal response. Mahogany and balsa wood samples of different diameters were exposed to thermal radiation at different ranges for Baker and Dog. Char thickness on sample surfaces is reported. Objectives and conclusions are obscure.

### *Project 2.4a, Protective Value and Ignition Hazards of Textile Materials Exposed to Thermal Radiation* WT-312

The experiment measured the thermal protection provided by various types of military uniform fabrics. Different cloth weaves and fabric types with backing materials that would indicate thermal penetration were exposed to thermal radiation during Baker and Dog. Observations of fabric response and factors affecting results are reported.

***Project 2.4b, Thermal Radiation Effects on Paints, Plastics,  
and Coated Fabrics***

**WT-407**

Thermal effects on some common military materials were determined and effects observed in nuclear field tests were compared with those observed in laboratory simulators. Paints, plastics, and coated fabrics were exposed for Baker and Dog. Thermal environments, observed damage, and measured property changes are reported.

***Project 2.4-1, Basic Thermal Radiation Measurements***

**WT-409**

Calorimeters and other sensors were installed from 2,400 to 12,000 feet from Baker, Charlie, Dog, and Easy GZs. Thermal radiation as a function of time and total thermal pulse were measured. Total fluence and thermal intensity-time results are reported, although electrical problems reduced data acquisition in some tests.

***Project 2.4-2, The Effects of Thermal Radiation on Materials***

**WT-311**

Samples of wood, coatings, and fire-retardant materials placed in foxholes were exposed at various ranges during Baker and Dog. The objective was to record, measure, and analyze the resulting spectrum of thermal radiation and to assess thermal effects.

***Project 2.6, The Protective Effects of Field Fortification  
Against Neutron and Gamma Ray Flux***

**WT-383**

Sensors were placed at different locations in foxholes in order to measure slow-neutron, fast-neutron, and gamma-ray doses during Baker, Charlie, and Dog. Reported are radiation doses at various foxhole locations and ranges from nuclear burst.

**PROGRAM 3—BLAST EFFECTS ON STRUCTURES AND EQUIPMENT**

***Project 3.5, Minefield Clearance***

**WT-313**

The primary thrust of the project was to evaluate the Army's Universal Indicator Mine and, secondarily, to assess the utility of nuclear weapons for minefield clearance. Numerous indicator mines were deployed for Baker, Charlie, Dog, and Easy to assess their reaction to a nuclear environment.

***Project 3.8, Effects of an Atomic Detonation on Aircraft  
Structures on the Ground***

**WT-384**

This project assessed the damage to parked aircraft. A B-17 and an F-47 were exposed to Dog and Easy. Damage descriptions and photographs are presented.

***Project 3.9, Effects on Selected Water Supply Equipment***

**WT-314**

The effects of a nuclear explosion on drinking water and sea water were examined. Containers were deployed from 1,500 to 12,000 feet during Easy. Elements in the sea water became radioactive. Measured radioactivity is reported.

## PROGRAM 4—BIOMEDICAL

***Project 4.1, Radiation Dosimetry*** **WT-315**

The objective of this project was to test human body simulation materials with embedded radiation sensors. Lucite spheres containing various sensors were exposed during Baker, Charlie, and Dog. Measured doses at various locations and material depths are reported.

***Project 4.2, Thermal Effects on Animals (Dogs)*** **WT-362**

This project assessed the effects of nuclear thermal radiation on dogs. Dogs with hair shaved in patches were exposed during Baker and Dog. Blood tests and measures for healing were taken and reported. Photographs and photomicrographs of wounds are presented.

***Project 4.2a, Thermal Effects on Animals (Rats)*** **WT-316**

The objective of this project was to evaluate the thermal effect on rats exposed to a nuclear environment and to compare the effect to that experienced by rats exposed to laboratory thermal radiation. The rats were exposed to Baker and Dog and were partially protected from blast and nuclear radiation. Burn descriptions and photographs are presented.

***Project 4.3, Flash Blindness*** **WT-341**

The project examined eyesight recovery time from nuclear flash effects when various types of eye protection are employed. Human subjects in C-54 aircraft viewed Baker, Charlie, and Dog from approximately 9 miles. Only Charlie provided useful data. Visual acuity as a function of time after exposure, for each of the subjects, is presented.

## PROGRAM 6—TEST OF SERVICE EQUIPMENT AND OPERATIONS

***Project 6.1b, Evaluation of Dosimetric Materials*** **WT-317**

Evaluations were performed on several personnel dosimeters in the prompt gamma radiation environments of Baker, Charlie, and Dog. Dosimeter readings at various distances are presented, but little description of the dosimeters is provided.

***Project 6.4, Airborne Radiac Evaluation*** **WT-318**

Two airborne sensors were designed to locate radioactive clouds at long ranges. The sensors were tested in two aircraft flown during Baker, Charlie, Dog, and Easy. Due to poor performance, development of the instruments was curtailed. Sensor operation and performance are described.

***Project 6.5, Operational Tests of Techniques for Accomplishing Indirect Bomb Damage Assessment (IBDA)*** **WT-344**

This project was tasked to continue assessment of the capability of aircraft-borne radar to recognize and locate nuclear bursts. X-band and Ku-band radars were employed for all Buster-Jangle events to observe nuclear detonations. Test procedures and radar scope traces are presented.

***Project 6.9, Effects of Atomic Detonations on Radio Propagation*** **WT-319**

The objective of this project was to observe effects of nuclear bursts on radio wave propagation and to attempt to identify causes for any disturbances. Frequencies investigated ranged from 1 to

25 MHz. Measurements of the ionosphere before and after detonations were made. Transmission and receiver stations were dispersed throughout Nevada. Experiments were performed during Charlie, Dog, and Easy. Measurements of ionospheric conditions and radiowave reception are reported, along with analysis of results.

## PROGRAM 7—LONG RANGE DETECTION

### *Project 7.1, Transport of Radioactive Debris from Operations Buster and Jangle*

WT-308

The objective was to track the movement of the radioactive clouds formed by Buster-Jangle and measure the debris at significant distances from the detonation points. A large amount of meteorology input was required. Sensors on aircraft were used to monitor the clouds. Debris samples were collected in the air and at the earth's surface. Cloud locations at various times are reported.

### *Project 7.2, Long-Range Light Measurements*

WT-379

The objective of this project was to attempt to observe the light pulse from nuclear detonations at various distances from Able, Baker, Charlie, Dog, and Easy. The most distant station, Albuquerque, NM, was 550 miles away. Communications failures and bad weather degraded the effort. Measured signals are reported.

### *Project 7.3, Radiochemical, Chemical, and Physical Analysis of Atomic Bomb Debris*

WT-320

Debris samples from the Buster-Jangle events were collected and analyzed. Radioactive particles and decay processes are identified.

### *Project 7.5, Seismic Waves from A-Bombs Detonated Over a Land Mass*

WT-321

A variety of sensors were used to sense and characterize seismic waves generated by nuclear detonations in Nevada. All Buster-Jangle events were monitored. Wave amplitudes and waveforms from various stations located out to 2,700 km are provided.

### *Project 7.6, Detection of Airborne Low-Frequency Sounds*

WT-322

Ten widely dispersed receiver stations were set up to monitor all tests. Low-frequency airborne signals traveling from nuclear explosions in Nevada to long-range stations were measured. Signals were noted at distances as far as 2,300 miles. Signal amplitudes and arrival times are reported for the various stations.

## PROGRAM 9—PERSONNEL SHELTER EVALUATIONS

### *Project 9.1a, FCDA Family Shelter Evaluation*

WT-359

The objective of this project was to evaluate the effectiveness of four simple blast shelters that could be constructed by the average homeowner. Twenty-nine structures, some earth-covered, were installed at various ranges from Baker GZ. They were reexposed during Charlie and Dog.

Interior radiation was monitored with film packs. Descriptions of damage and photographs are provided, along with radiation measurements.

***Project 9.1b, AEC Communal Shelter Evaluation*** **WT-360**

The objective of this project was to evaluate the effects of nuclear bursts on a prototype large communal shelter made of concrete and steel pipe covered with 3 feet of earth. Shelter construction and response to nuclear environments are described.

**PROGRAM 10—ENVIRONMENT MEASUREMENTS**

***Project 10.3, Technical Photography*** **WT-417**

Photographic techniques were used to measure the yield of the Buster-Jangle devices. A byproduct of this procedure, the measurement of fireball growth and rise rate, is reported.

***Project 10.5, Gamma-Radiation Exposure as a Function of Distance*** **WT-408**

Film packs were used to measure the gamma-ray environments for Baker, Charlie, Dog, and Easy. Measured values and data plots are presented.

***Project 10.6, Measurement of Gamma-Ray Intensity Versus Time*** **WT-356**

Measurements of gamma-ray intensity versus time were made at ranges of approximately 1,000 and 3,000 feet from GZ for Charlie and Easy, and at 1,500 feet for Uncle. Total gamma doses from film pack absorptions are compared with integrated intensity-time doses. Gamma-ray intensity-time measurements are reported.

***Project 10.7, Measurements of the Earth's Magnetic and Electric Fields*** **WT-426**

Attempts were made to measure magnetic and electric fields in three events. No magnetic field variations were noted, but electric field changes were recorded. WT-426 is not easily understood.

***Project 10.10, Some Measurements of Overpressure-Time Versus Distance for Airburst Bombs*** **WT-304**

Pressure-time measurements were made at ground level and 15 feet altitude for Baker, Charlie, Dog and Easy. Pressure profiles are presented. The experiment description is obscure.

***Project 10.10a, Some Effects of Terrain Effects on Blast Waves*** **WT-301**

The objective of this project was to determine the effects of terrain on a nuclear shock wave traversing the earth's surface. Pressure gauges were deployed on flat segments, on slopes, and on the lee side of a hill in five nuclear events. Due to a great many hardware failures, little data was collected. Some measured pressures are reported, but the limited data do not permit firm conclusions.

***Project 10.10a, Attenuation of Earth Pressures Induced by Air Blast*** **WT-302**

Surface airblast pressures and ground pressures occurring at various depths, due to a nuclear explosion, were measured at the same test station for Able, Baker, Charlie, and Easy. The data presented consist of measurements taken at ground surface and at depths of 1, 5, 10, and 20 feet.

***Project 10.10a, Variations of Blast Pressures at Fixed Distances with Small Altitudes***

**WT-305**

The objective of this project was to determine if the blast wave pressure-time profiles or shock arrival times at a given distance from a nuclear burst vary as a function of distance above ground. Two 50-foot towers were built approximately 2,000 feet and 3,000 feet from Easy GZ. Pressure gauges were installed at 0, 5, 10, 25 and 50 feet above the ground. Recorded pressures and traces are reported.

**OPERATION JANGLE PROJECTS AND REPORTS**

**Jangle Summary Report: Weapon Effects Tests**

**WT-414**

WT-414 summarizes of the extensive nuclear weapon effects activities in the Sugar and Uncle events. Project descriptions, report numbers, observations, and some data are presented.

**PROGRAM 1—BLAST AND SHOCK MEASUREMENTS**

***Project 1.1, Ground Acceleration Measurement***

**WT-388<sup>(1)</sup>**

The objective of this experiment was to measure ground acceleration at various distances from GZ in the Sugar and Uncle events. X, Y, and Z components were measured at depths of 10, 20, and 30 feet below ground. Measurements from a 40,000-pound HE test are also reported. Data traces and analyses of forces as a function of depth are presented.

***Project 1.2a-1, Peak Air Blast Pressures from Shock Velocity Measurements Along the Ground***

**WT-323<sup>(1)</sup>**

The objective of this project was to measure the shock velocity from the Sugar, Uncle, and two HE detonations, and to calculate peak airblast pressures from the shock velocity values. Shock-arrival instruments were deployed intermittently out to ranges as great as 3,000 feet from GZ. Shock-arrival measurements and calculated peak pressures are reported.

***Project 1.2a-2, Transient Ground Mechanical Effects from HE and Nuclear Explosions***

**WT-385<sup>(1)</sup>**

The objective of this project was to make crude acceleration measurements in the ground from the Sugar and Uncle events in case more sophisticated measurements failed. The sophisticated measurements were successful. Indirect ground-pressure measurements were also made. Theoretical analyses are presented. The data in WT-385 are not easily retrieved.

***Project 1.2b, Close-In Ground Measurements***

**WT-364<sup>(2)</sup>**

The objective of this project was to measure ground shock velocity in the Uncle cratering event. Shock time-of-arrival gauges were installed at depths of 17 feet (the device detonation depth) at ranges from 0 to 333 feet from GZ. The reported data are clear and consistent.

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<sup>(1)</sup> Republished in WT-366.

<sup>(2)</sup> Republished in WT-367.

***Project 1.3a, Free-Air Shock Arrival Times***

**WT-324<sup>(2)</sup>**

This project was tasked to measure air-shock peak pressure and arrival time at an angle of 30 degrees above the ground during Sugar and Uncle. Sensors were suspended from balloons at ranges of 800 to 1,200 feet from GZ. Much data was lost due to equipment failure, but some information is reported.

***Project 1.3b, Peak Pressure Versus Distance in Free Air  
Using Smoke Rocket Photography***

**WT-389<sup>(2)</sup>**

Shock velocity in air was measured by observing shock-wave movement superimposed over a series of smoke trails at known locations in the Sugar and Uncle events. High-speed motion picture cameras were used to record the shock-wave and smoke-trail relative positions vs time. Reported are shock arrival time as a function of range and altitude, and calculated peak pressures. A power failure resulted in some data loss.

***Project 1.3c, The Measurement of Free Air Atomic Blast Pressures*** WT-325<sup>(2)</sup>

These measurements were carried out for the Sugar event. Free-air peak pressure was measured as a function of time and location using parachute-borne sensor canisters. Ground stations determined the positions of the eight deployed canisters and received telemetered data. The canisters were dropped by aircraft in the wrong locations, and little useful data was collected.

***Project 1.4, Free-Air Pressure Measurements***

**WT-306<sup>(2)</sup>**

Pressure-time profiles of the blast waves were obtained at ground level for the Sugar and Uncle events. Measurements were made at ranges of 300 to 4,200 feet from GZ. Tabular data and traces are presented.

***Project 1.5a, Transient Ground Displacement Measurement***

**WT-382<sup>(3)</sup>**

The objective of this project was to measure horizontal and vertical ground motion for the Sugar and Uncle events by viewing ground markers with high-speed cameras. Nuclear flash and dust obscured the markers, so no data were acquired.

***Project 1.5b, Detection of Time of Arrival of First Earth Motion***

**WT-326<sup>(3)</sup>**

This project employed seismic gauges to measure time of arrival of the ground shock from the Uncle event at stations between 100 feet and 600 feet from GZ. Data are presented in tabular and graphical form.

***Project 1.6, Earth Displacement (Shear Shafts)***

**WT-353<sup>(3)</sup>**

The objective of this project was to measure permanent displacement of earth, vertically and horizontally, due to nuclear ground shock. Steel tubes about 45 feet long were installed vertically in the ground at various ranges from Sugar and Uncle GZ. Posttest surveys of pipe tilt and dislocation were used to obtain ground displacement. Displacement was observed only at the two closest stations for the Uncle event. Experimental techniques and results are presented. This experiment was of marginal utility.

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<sup>(2)</sup> Republished in WT-367.

<sup>(3)</sup> Republished in WT-368.

**Project 1.7, Ground Acceleration (Shock Pins)**

**WT-357<sup>(3)</sup>**

This project was tasked with acquiring an estimate of ground acceleration during Sugar and Uncle. The reported data are generally uninterpretable and the description of the operation of the gauge is extremely vague.

**Project 1(8)a, Geologic, Hydraulic, and Thermal Features of the Sites**

**WT-343, -327<sup>(3)</sup>**

Characteristics of the media of the test sites are reported to assist in interpreting ground shock and cratering test data.

**Project 1(9)a, Ground Acceleration, Ground and Air Pressures for Underground Test**

**WT-380<sup>(3)</sup>**

Reported for this project were ground pressure and acceleration, and air pressure measured at points a few hundred feet to beyond 3,000 feet from GZ. Earth pressure and acceleration were measured 5 to 126 feet below ground and air pressure at 3 feet above ground. Tabular data and traces are presented with discussion and analyses. Comparisons with measurements for HE tests are included.

**Project 1(9)b, Base Surge Analysis for Nuclear Tests**

**WT-390<sup>(3)</sup>**

Contains a theoretical discussion regarding material thrown out by HE and nuclear detonations.

**Projects 1(9)-1 through -4, High Explosives Tests**

**WT-365, 377, -349, -410, -339**

HE tests were performed at NTS to supplement weapon effects studies. Four such tests were performed during Buster-Jangle. The projects reported a variety of earth response measurements:

- Project 1(9)-1 Scaled HE Tests (WT-377)
- Project 1(9)-2 Composition of Clouds Formed by TNT Explosions (WT-349)
- Project 1(9)-3 Tests and Observations on Craters and Base Surge (WT-410)
- Project 1(9)-4 Base Surge Analysis for HE Tests (WT-339).

**Project 1.9, Underground Explosion Theory**

**WT-369**

Theories for predicting various underground explosion phenomena are presented. No test data are reported.

**PROGRAM 2—THERMAL AND NUCLEAR RADIATION**

**Project 2.0, Predicted Scaling of Radiological Effects to Operational Weapons**

**WT-391**

The objective was to use crater and fallout data from Uncle to calibrate a model for predicting radioactive contamination profiles from surface or subsurface nuclear bursts. WT-391 contains considerable discussion of theory and modeling.

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<sup>(3)</sup> Republished in WT-368.



***Project 2.1a, Gamma Radiation as a Function of Time and Distance*** WT-329<sup>(4)</sup>

Gamma-ray dose rates were measured by placing instruments at more than 25 stations at ranges of 2,000 to 15,000 feet from Sugar and Uncle GZs. Reported are dose rates, total dose, and dose contours as a function of time and distance.

***Project 2.1b, Gamma Radiation as a Function of Time with Droppable Telemeters***

WT-392<sup>(4)</sup>

This project was to monitor gamma radiation at fixed sites near Sugar and Uncle GZs and to deploy gamma-ray monitoring instruments by aircraft near GZ after the bursts. Measurements were to be telemetered out to receiving stations. None of the aircraft-deployed instruments functioned and only a few of the fixed stations operated. Some gamma-ray data is reported for 1,000-, 1,250-, and 1,500-foot stations.

***Project 2.1c-1, Aerial Survey of Distant Contaminated Terrain***

WT-330<sup>(4)</sup>

Instrumented aircraft were used to track the radioactive clouds from the Sugar and Uncle events and guide ground monitor crews to areas of radioactive fallout. Fallout patterns at different times after burst are reported.

***Project 2.1c-2, Aerial Survey of Local Contaminated Terrain***

WT-351<sup>(4)</sup>

Air and ground radioactivity measurements were made by this project employing Navy and Air Force concepts. Aircraft were deployed to measure radioactivity at altitude and estimates were made of the radiation levels on the ground during Sugar and Uncle.

***Project 2.1d, Monitor Survey of Ground Contamination***

WT-381<sup>(4)</sup>

The radiological safety measurements of radioactivity in the vicinities of Sugar and Uncle were assembled and activity maps for various times were generated. Contours of dose rate as a function of position and time are presented.

***Project 2.3-1, Total Gamma Radiation Dosage***

WT-331<sup>(4)</sup>

This project mapped the total gamma dose at numerous locations during Sugar and Uncle. Film badges placed in open areas, foxholes, tanks, and structures were used to measure the integrated dose. The badges were recovered approximately 2 days after the detonations. Measured doses at the various stations are reported.

***Project 2.3-2, Foxhole Shielding of Gamma Radiation***

WT-393<sup>(4)</sup>

The objective of this project was to determine the radiation protection afforded by foxholes. One- and two-man foxholes were dug at various locations between 2,000 and 5,000 feet from Sugar and Uncle GZ. Film badges were installed in the bottom, middle, top, and above the foxholes. Measured radiation levels are reported.

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<sup>(4)</sup> Republished in WT-370.

***Project 2.4a, Beta-Ray and Gamma-Ray Energy of Residual Contamination***

**WT-345<sup>(5)</sup>**

Beta radiation and gamma radiation from Sugar and Uncle fallout were measured using special film-pack designs. Theory of operation, calibrations, and field measurements are presented. Particle energy dependence is discussed.

***Project 2.4b, Gamma Depth Dose Measurement in Unit-Density Material***

**WT-332<sup>(5)</sup>**

This project appears to have dealt with materials that absorb nuclear radiation in a manner similar to human body tissue. The objectives, measurements, and results are extremely obscure.

***Project 2.4c, Gamma-Ray Spectrum Measurements of Residual Radiation***

**WT-348<sup>(5)</sup>**

This project was to determine the spectral characteristics of gamma radiation in a nuclear burst region to study the threat to life. Experiments were performed during Sugar and Uncle. The Sugar experiments failed completely, but some data were acquired from Uncle at various distances from GZ.

***Project 2.5a-1, Airborne Particle Studies***

**WT-394<sup>(6)</sup>**

The project characterized the radioactive fallout in the vicinity of Sugar and Uncle using a number of particle collection techniques. Particle size, type, and activity are reported at various ranges from GZ and times after detonation.

***Project 2.5a-2, Fallout Particle Studies***

**WT-395<sup>(6)</sup>**

The project determined the chemical and physical characteristics of the radioactive fallout from Sugar and Uncle. Collections were made by aerosol samplers and fallout trays. Radioactivity as a function of time and location is reported, as well as particle size distribution.

***Project 2.5a-3, Radiochemical Studies of Large Particles***

**WT-333<sup>(6)</sup>**

Radioactive samples were collected on trays as far as 10 miles downwind from Sugar and Uncle. Through mechanical techniques, active material was separated from nonactive material. Enlarged photographs of large particles are presented.

***Project 2.6c-1, Nature and Distribution of Residual Contamination I*** WT-386<sup>(7)</sup>

Radioactive samples from various locations were collected after Sugar and Uncle. Radiochemical analyses indicated that different samples contained different types and amounts of radionuclides. Extracting useful data from WT-386 will be difficult.

***Project 2.6c-2, Nature and Distribution of Residual Contamination II*** WT-397<sup>(7)</sup>

The objectives of this project were to determine the relative significance of neutron-induced radioactivity in soils exposed to nuclear bursts and to measure the energies of beta and gamma rays

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<sup>(5)</sup> Republished in WT-372.

<sup>(6)</sup> Republished in WT-371.

<sup>(7)</sup> Republished in WT-373.

from radioactive decay. Radioactive soil samples were collected from four regions in the vicinity of Sugar and Uncle. Chemical and radiation analyses of the samples are presented.

***Project 2.7, Biological Injury from Particle Inhalation*** **WT-396<sup>(5)</sup>**

This project studied the radioactive material inhaled by animals exposed during Sugar and Uncle. Sheep and dogs fielded at various ranges were extirpated and autopsied at various times after exposure. Radioactive particle type and activity level in different body locations are reported.

***Project 2.8, Analysis of Test Site and Fallout Material*** **WT-335<sup>(6)</sup>**

The objectives of this project were to measure the amount of radioactive fallout from the Sugar and Uncle and assess possible negative effects on plant growth. Chemical and physical characteristics of the soil were measured before and after the events. Observations are made on the inclination of plants to absorb radioactive materials.

***Project 2.8 Supplement, Petrographic Studies of Fallout Material from the Surface and Underground Shots*** **WT-423**

Glassy material was observed in the soil in the vicinity of Sugar and Uncle. A detailed study of the glassy rock particles was performed. Photomicrographs and analyses of soil samples are reported.

### **PROGRAM 3—BLAST EFFECTS ON STRUCTURES AND EQUIPMENT**

***Project 3.1, Navy Underground and Surface Structures*** **WT-404**

This project evaluated the effects of a subsurface nuclear explosion on typical utilities, communication towers, steel warehouses, pavement, and concrete buried structures. Structures were exposed to the Uncle environment. Little damage was observed, but gauge measurements are presented.

***Project 3.2, Army Structures Test*** **WT-387**

Eight concrete structures (one buried) were exposed to the airblast and ground shock of Uncle to study the effects of dynamic loads. Pretest and posttest photographs are provided, along with detailed descriptions of the test hardware, measured displacements, accelerations, and environments.

***Project 3.3, Air Force Structures Program*** **WT-405**

The objective of this project was to assess nuclear shock effects on concrete buildings, walls, runways, and other structures for Uncle. Structural response and free earth measurements were made. Data records are presented, along with considerable discussion of theory.

***Project 3.29, Engineer Soil Mechanics Tests*** **WT-336**

The soil in the vicinity of the structures tests was analyzed to provide information for assessing response of structures to nuclear ground shock.

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<sup>(5)</sup> Republished in WT-372.

<sup>(6)</sup> Republished in WT-371.

***Project 4.2, Cratering Effects of Underground and Surface Detonated Atomic Bombs and Influences of Soil Characteristics on Crater*** **WT-399**

The earth's surface around GZ was measured before and after the Sugar and Uncle detonations. Crater and lip profiles are presented. Soil characteristics were measured and reported, but no use was made of those data.

***Project 4.5, Evaluation of Missile Hazard, Underground Shot*** **WT-338**

The objective of this project was to assess potential damage from rocks and boulders thrown out by a cratering test. Marked concrete specimens were placed at various distances from the Uncle GZ and recovered after the test. Some concrete debris was thrown as far as 3,000 feet, but it was concluded that this threat was minimal compared to other nuclear effects. Pretest and posttest locations of concrete chunks are reported.

**PROGRAM 6—TEST OF SERVICE EQUIPMENT AND OPERATIONS**

***Project 6.1, Evaluation of Military Radiac Equipment*** **WT-337**

This project tested a number of nuclear radiation monitoring instruments under field conditions to evaluate their capability in military operations. The equipment tests were performed for Sugar and Uncle. Evaluation factors included ruggedness, reliability, and weight as well as response to radiation. Minimal description of apparatus is provided. Relative capabilities of the sensors are presented.

***Project 6.2, Protection and Decontamination of Land Targets and Vehicles*** **WT-400**

A wide variety of materials and objects were contaminated during Sugar and Uncle. The project developed and evaluated decontamination procedures for various categories of contaminated apparatus.

***Project 6.3-1, Evaluation of Military Individual and Collective Protection Devices and Clothing*** **WT-401**

The objective of this project was to assess the effectiveness of coated and uncoated clothing, masks, tank air filter systems, and antichemical agent ointments in protecting soldiers in radiation-contaminated environments. Volunteer soldiers used the equipment in the fallout areas of Sugar and Uncle. Results of equipment effectiveness are reported.

***Project 6.3-2, Evaluation of the Potential Respiratory Hazards to Tank Crews Required to Operate in Contaminated Areas*** **WT-402**

Two tanks and one personnel carrier were exposed to the Sugar and Uncle radioactive environments by driving through contaminated regions after the tests. Activity was measured inside and outside the vehicles to assess the hazard to personnel. Radiation measurements and conclusions are reported.

**Projects 6.4, Operational Tests of Techniques for Accomplishing Indirect Bomb Damage Assessment (IBDA) WT-344**

These projects were tasked to continue assessment of the capability of aircraft-borne radar to recognize and locate nuclear bursts. X-band and Ku-band radars were employed for all Buster-Jangle events to observe nuclear detonations. Test procedures and radar scope traces are presented.

**Project 6.7, Clothing Decontamination and Evaluation of Laundry Methods WT-347**

The objective of this project was to assess different laundering techniques for washing contaminated clothing and to determine if different fabric types responded differently to contamination and decontamination. Contamination monitoring systems were also evaluated. Clothing and materials were contaminated with soil from near GZ. Items were monitored, laundered in various ways, and monitored again. Radiation measurements and laundering effectiveness are described.

**Project 6.8, Evaluation of U.S. Army Field Water Supply Equipment and Operations WT-340**

The project evaluated the capability of a 3,000-gallon fabric water storage container to withstand the blast and thermal environment from a nuclear burst and to determine how well field water purification equipment removes radioactive debris from water supplies. Radioactive soil from the Sugar crater lip was used for the water decontamination test. Procedures and results are presented.

## PROGRAM 7—LONG-RANGE DETECTION

**Project 7.1, Radiochemical, Chemical, and Physical Analysis of Atomic Bomb Debris WT-320**

Debris samples from the Buster-Jangle events were collected and analyzed. Radioactive particles and decay processes are identified.

**Projects 7.2, Seismic Waves from A-Bombs Detonated Over a Land Mass WT-321**

A variety of sensors were used to sense and characterize seismic waves generated by nuclear detonations in Nevada. All Buster-Jangle events were monitored. Wave amplitudes and waveforms from various stations located out to 2,700 km are provided.

**Projects 7.3, Detection of Airborne Low-Frequency Sounds WT-322**

Ten widely dispersed receiver stations were set up to monitor all tests. Measured were low-frequency airborne signals traveling from nuclear explosions in Nevada to long-range stations. Signals were noted at distances as far as 2,300 miles. Signal amplitudes and arrival times are reported for the various stations.

## **PROGRAM 10—ENVIRONMENT MEASUREMENTS**

### ***Project 10.3, Technical Photography***

**WT-417**

Photographic techniques were used to measure the yield of the Buster-Jangle devices. A byproduct of this procedure, the measurement of fireball growth and rise rate, is reported.

**SECTION 9**  
**TUMBLER-SNAPPER**  
**Nevada Test Site**  
**1952**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield (KT)</u>	<u>Weapon Placement</u>
Able	April 1	Frenchman Lake	1	Airdrop (HOB, 793 feet)
Baker	April 15	Yucca Flat, Area 7	1	Airdrop (HOB, 1,050 feet)
Charlie	April 22	Yucca Flat, Area 7	31	Airdrop (HOB, 3,447 feet)
Dog	May 1	Yucca Flat, Area 7	19	Airdrop (HOB, 1,040 feet)
Easy	May 7	Yucca Flat, Area 1	12	300-foot tower
Fox	May 25	Yucca Flat, Area 4	11	300-foot tower
George	June 1	Yucca Flat, Area 3	15	300-foot tower
How	June 5	Yucca Flat, Area 2	14	300-foot tower

**BACKGROUND.**

Operation Tumbler-Snapper was a joint Atomic Energy Commission (AEC) weapon development and DoD weapon effects test series. The AEC goal was to expedite development of a nuclear weapon stockpile in response to rapid Soviet nuclear weapon advances. Easy, Fox, George, and How were designated AEC tests, but DoD effects experiments were performed on a noninterference basis. DoD tests, Charlie and Dog, also had weapon development aspects. The major thrust of the DoD effects activity was to increase understanding of nuclear blast wave phenomenology near the ground. Operation Buster-Jangle experiments had indicated that near-earth overpressures from nuclear airbursts were significantly lower than previously predicted from assumptions of ideal blast waves. Lower overpressure had major implications for nuclear weapon applications and target planning. The DoD experiments were designed to obtain a reliable model for relating weapon yield, height of burst, and overpressure on the ground.

Another objective of the DoD effects program was to gain more tactical operation experience in the vicinity of nuclear detonations. This activity consisted of conducting troop movements and operations at the perimeter of the radioactive field after a test. This troop activity was designated Camp Desert Rock IV.

The effects programs included:

- Program 1—Blast Measurements
- Program 2—Nuclear Radiation Measurements and Effects
- Program 3—Structures
- Program 4—Biomedical
- Program 6—Test of Equipment and Operations
- Program 7—Long Range Detection

Program 8—Thermal Measurements and Effects

Program 9—Supporting Measurements.

## OPERATION TUMBLER-SNAPPER PROJECTS AND REPORTS

### **Tumbler Final Summary Report**

**WT-514**

WT-514 describes Tumbler effects test objectives and summarizes the results. A major thrust of this program was to develop an understanding of blast wave phenomena, since results from previous tests had appeared to be inconsistent. Considerable data are reported, and implications are discussed.

### **Snapper Final Report**

**WT-564**

WT-564 summarizes the military effects experiments in the Snapper series. Objectives of the programs are described, and a brief summary of each effects project is presented. Report numbers for the projects are listed. WT-564 contains no test data.

## **BLAST MEASUREMENTS—PROGRAM 1 AND RELATED AEC PROJECTS**

### ***Project 1.1, The Measurement of Free Air Atomic Blast Pressures***

**WT-511**

The objective of this project was to measure the free-air pressure at various locations above and on the ground in the vicinity of Easy and How. Many measurements were made by pressure gauges in parachute-borne canisters. Blast pressure and canister position information was telemetered to ground stations. Measured pressures ranged from 0.1 to 3 psi. Pressure traces are presented.

### ***Project 1.2, Air Pressure versus Time***

**WT-512**

Test data and extensive analyses are presented by this project using measured airblast data from other projects for:

1. Constructing an empirical overpressure vs height-of-burst chart
2. Assessing the blast waveform when degraded by thermal effects
3. Determining the path of the triple point
4. Comparing instrumentation techniques.

### ***Project 1.3, Free-Air and Ground-Level Pressure Measurements***

**WT-513**

Peak pressure and pressure-time measurements were made using smoke trail photography and inductance gauges in four events. Data traces and fireball smoke trail data are reported, along with analysis and discussion of theory.

### ***Project 1.4, Air Blast Measurements***

**WT-515**

The objective of this project was to measure nuclear airblast arrival time at ground level and at 10 and 50 feet aboveground at various distances from GZ for nuclear airbursts. Blast closure switches were installed at six stations out to 3,000 feet ground range for Able, Baker, and Dog. Shock arrival times at the various positions are reported.



***Project 1.6, Ground Acceleration Measurements***

**WT-516**

The project measured the peak vertical, radial, and transverse ground accelerations induced by nuclear airblast. Gauges were installed 5 feet below ground at various distances from Able, Baker, Charlie, and Dog GZs. Considerable ground acceleration data were acquired and reported.

***Project 1.7, Earth Acceleration Versus Time and Distance***

**WT-517**

Ground acceleration measurements were made at depths of 1, 5 and 50 feet below ground at ranges out to 3,000 feet during Able, Baker, Charlie, and Dog. Data traces, refined data and analyses are presented.

***Project 1.8, A Geological Survey of the Atomic Energy Commission Area, Nye County, Nevada***

**WT-518**

The geology in the area of nuclear testing was surveyed to assist in interpretation of ground-shock measurements.

***Project 1.9, Pre-Shock Dust***

**WT-519**

The objective of this project was to measure the quantity and character of the dust caused by deposition of nuclear thermal radiation onto the ground. The measurements were made after thermal pulse arrival but before arrival of the shock wave. Dust particle size and quantity were measured at ground level and 10 feet aboveground at various ranges of Able, Baker, Charlie, and Dog. Measurements of thermal-pulse dust compared to normal "background" dust are reported.

***Project 1.13, Measurement of Air Blast Pressure versus Time***

**WT-521**

Two types of gauges were employed to measure ground-level airblast pressures at various distances from GZ and in areas containing parked aircraft, to assist in aircraft damage assessment. Measurements were made during Baker, Charlie, and Dog. Pressure-time profiles at ranges from 1,000 to 10,000 feet are presented.

***Project 19.1, Earth Stresses and Earth Strains***

**WT-503**

The project was tasked to determine if nuclear-blast-induced earth pressures and stresses decrease with depth. Earth pressure and strain gauges were installed at depths as great as 20 feet below ground and 15 feet deep in an aboveground mound. Acceleration gauges were deployed at 50-foot depths. Limited data were collected.

***Project 19.1a, Air Shock Pressure-Time Versus Distance***

**WT-501**

The objective of this project was to measure airblast pressure at several distances from Able, Baker, Charlie, and Dog. Because blast data from the Buster-Jangle series were inconsistent with blast model predictions, additional test data were required. Detailed blast wave measurements are presented.

***Project 19.1b, Air Shocks at Large Distances from Atomic Explosions***

**WT-504**

The project measured very-low-pressure airblast waves at large distances from nuclear test zero points to assess potential damage to civilian property in Nevada. Measurements were made in all eight nuclear events plus some high-explosive tests. Meteorology is considered a key element in such wave propagation. Reflections from the troposphere, ozonosphere, and ionosphere were measured.

***Project 19.1c-d, Sandia Laboratory Shock-Gauge Evaluations Tests***

**WT-505**

The project was assigned to develop and test a gauge for characterizing blast waves from nuclear detonations. Gauges for measuring dynamic and static pressures, wind direction, sound and wind speeds, and temperature rise resulting from a shock wave were tested in the eight Tumbler-Snapper events. Gauge descriptions and performance are presented.

***Project 19.1e, Air Shock Pressures as Affected by Hills and Dales***

**WT-502**

The objective of this project was to determine the effect of hills on the pressure of a nuclear shock. Pressure gauges were installed on the front side and the back side of a hill exposed to the airblast environments of Baker, Charlie, Dog, and Easy. Some data were lost due to instrumentation failure. Pressure-time traces and instrument locations are presented.

***Projects 19.2A-19.2F, Blast Measurements***

**WT-556**

Part 1 of this project measured wave arrival time at a known distance from nuclear bursts in order to calculate peak overpressure. Smoke contrails or puffs were photographed during interaction with the shock waves to establish local particle velocity. Measurements were made in six of the eight Tumbler-Snapper events. Shock time-of-arrival and peak pressure vs distance plots are presented, along with descriptions of analytical procedures.

Part 2 of this experiment was to measure the density of the dust-loaded air immediately behind the shock front. Density change was determined by the change in the beta particles arriving at a receiver across a known distance from a beta emitter. Instrumentation traces are presented. Although the thrust of this activity was to show feasibility, some nuclear weapon phenomenology can be inferred.

Part 3 of this project was to obtain blast wave pressure-time profiles using interferometer gauges, which are resistant to nuclear radiation effects. Measurements were made in the Easy, Fox, George, and How events and compared with those from other types of instruments. Gauge operations and results are discussed.

Part 4 of this project was to determine air temperature by measuring the sound velocity in air near the ground in the time period after the initial thermal pulse and before shock wave arrival. The goal was to determine the air temperature rise due to ground heating by thermal radiation. Sonic transmitters and receivers were deployed at various distances from GZ in several events. Temperatures and rise times are reported for Charlie and Dog.

**NUCLEAR RADIATION MEASUREMENTS AND EFFECTS—PROGRAM 2 AND RELATED AEC EXPERIMENTS**

***Project 2.1, Total Gamma Exposure Versus Distance***

**WT-522**

The objective of this project was to measure the integrated gamma radiation dose received at various distances from Baker, Charlie, Dog, Easy, Fox, George, and How GZs. Film packs were exposed at twenty different positions at ranges between 1,000 and 3,000 yards and collected about 3 hours after each test. Measured radiation dose versus range is presented.

***Project 2.2, Gamma Ray Energy Spectrum of Residual Contamination***

**WT-523**

The project obtained data on the spectrum of the gamma radiation in a contaminated nuclear fallout area. Modified radiac instruments were used to measure spectrum components at various times and ranges from Easy, Fox, George and How GZs. Fractions of energy contributions from

gamma rays above and below 200 keV are discussed. Field measurements taken with the various modified instruments are reported.

***Project 2.3, Neutron Flux Experiments***

**WT-524**

Neutron fluxes in different energy bands were measured at various ranges from GZ. Three different measurement techniques were employed. Discussion of theory is presented with the data.

***Project 15.2, Gamma Radiation Exposure as a Function of Distance***

**WT-549**

Gamma radiation was measured at many stations in the Tumbler-Snapper series. Considerable dose vs range data are presented, with an extensive discussion of radiation scatter mechanisms.

***Project 15.3, Radiation Monitoring Measurements***

**WT-507**

Three prototype radiation monitors for measuring gamma radiation were deployed at various ranges in four events. Measurements of radiation levels versus time are presented.

**STRUCTURES—PROGRAM 3**

***Project 3.1, Vulnerability of Parked Aircraft to Atomic Bombs***

**WT-525**

Twenty-eight aircraft, fighters and bombers, old and new, were exposed during Baker, Charlie, and Easy. Instrumentation included strain gauges, accelerometers, temperature indicators, and localized pressure gauges. Motion picture films were taken. Since the aircraft were exposed in three tests, damage is reported after each event. Detailed damage descriptions, assessments of the aircraft ability to function, and photographs are presented.

***Project 3.3, Blast Damage to Trees—Isolated Conifers***

**WT-509**

Pine trees 45 feet tall were "planted" in concrete bases for exposure during Charlie and Dog. Four trees and a circular metal "lollipop" on a 14-foot aluminum post were positioned at each of four stations 5,000 to 8,000 feet from GZ. At each station, one tree and the lollipop were instrumented with strain vs time gauges. Maximum strain was recorded on each tree. Strain measurements and damage observations are reported.

***Project 3.4, Minefield Clearance***

**WT-526**

This project was part of a continuing study of the potential of nuclear detonations for clearing minefields. Mine simulators were installed at ground level and 6 inches below the surface at ranges of 300 feet to 6,000 feet from GZ during Baker, Charlie, and Dog. Probability of mine detonation as a function of location is reported, along with analyses and implications.

**BIOMEDICAL—PROGRAM 4**

***Project 4.2, Biomedical Exposure Equipment***

**WT-527**

This project developed and tested exposure cages and related equipment for animal experiments. These were exposed on Charlie and Dog. Some measurements of airblast overpressure and thermal and nuclear radiation were made within the empty cages or containers.

***Project 4.3, The Biological Effectiveness of Neutron Radiation from Nuclear Weapons***

**WT-528**

Mice were exposed to various neutron radiation fluences during Charlie, Dog, and How to assess the biological effects. Lead shields were used to reduce gamma radiation. Mortality as a function of time and autopsy information are reported.

***Project 4.4, Gamma Dose Depth Measurement in Unit Density Material***

**WT-529**

The objective and execution of this project are poorly described. It was apparently an attempt to develop instrumented spheres for use in tests to simulate human exposure. Gamma dose data measured at various depths in lucite spheres exposed at different ranges from Charlie, Dog, Easy, and How GZs are reported.

***Project 4.5, Flash Blindness***

**WT-530**

The objective of this task was to determine the recovery time required after exposure to nuclear flash to regain sufficient vision to perform specific functions. Twelve military subjects, some with protective red goggles, were tested during Charlie and Dog. Two suffered retinal burns, so the tests were terminated after Dog. Vision recovery times are reported.

***Project 4.6, The Time-Course of Thermal Radiation as Measured by Burns in Pigs***

**WT-531**

This task studied burns caused by a nuclear thermal pulse. Pigs were exposed at three Charlie stations and four Dog stations. Protection from other nuclear effects was provided. Metal shields with holes determined burn spot size, and shutters were used to vary exposure duration. Burns under the various conditions are described.

***Hasty-Type Air Raid Shelters***

**WT-560**

The objective of this unnumbered project was to assess personnel exposure to nuclear bursts. Protection provided were open and covered trenches at various distances from GZ of Charlie and Dog. Instrumentation consisted of dummies and film badges. Damage descriptions and film badge readings are presented.

**TEST OF EQUIPMENT AND OPERATIONS—PROGRAM 6**

***Project 6.1, Evaluation of Military Radiac Equipment***

**WT-532**

Evaluated were radiac and dose alarm equipment, dosimeters and associated equipment, and rapid aerial survey techniques. Equipment and operations are described and adequacy is assessed.

***Project 6.3, Evaluation of Filtration Systems for Pressurized Aircraft***

**WT-533**

An air filtration system for removing radioactive particles was installed in a B-29 and tested in cloud penetrations during Easy, Fox, and George. Radioactivity measurements of unfiltered and filtered air were made. The filter worked well. Equipment performance and measured radioactivity are reported.

***Project 6.4, Operational Tests of Radar and Photographic Techniques for IBDA***

**WT-534**

This project was part of a continuing activity to assess equipment and procedures for performing Indirect Bomb Damage Assessment (IBDA). Three B-50 bombers were flown in the vicinities of Able, Baker, Charlie, Dog, Easy, and Fox using radar and optical systems to determine bomb detonation position. Procedures and degree of success are reported.

***Project 6.5, Decontamination of Aircraft***

**WT-535**

The objective of this project was to assess methods and materials for cleaning aircraft that had flown through radioactive clouds. Cleaning compounds and conditions of exposed surfaces were identified. Optimum cleaning procedures and cleaning solutions are described.

***Project 6.7, Evaluation of Air Monitoring Instruments***

**WT-536**

Two different types of radioactivity monitoring instruments were evaluated. Each operates by filtering a known quantity of air and measuring the radioactivity of the filter paper. Instruments and operations are described, and strengths and weakness of each type are presented.

**PROGRAM 7—LONG RANGE DETECTION**

***Project 7.1a, Electromagnetic Effects from Atomic Explosions***

**WT-537**

Electromagnetic signals were recorded close-in to nuclear bursts and as far away as Germany. Communication frequencies were monitored. Recorded signals at particular frequencies for the various monitoring stations are presented.

***Project 7.1b, Long Range Light Measurements***

**WT-538**

The objective of this project was to investigate the possibility of measuring the light from nuclear bursts for detection and yield determination. Sensors for detecting light changes were deployed at ranges from 250 to 1,000 miles from the nuclear test area. Assessments were made in all events except Able. The report conclusions are negative. Data records are provided.

***Project 7.2, Detection of Airborne Low-Frequency Sound from Atomic Explosions***

**WT-539**

Low-frequency air waves from the Tumbler-Snapper events were monitored at six stations in the United States. Measurements were made at distances up to 2,000 miles from the explosions. Data records and observations are presented.

***Project 7.3, Radiochemical and Physical Analysis of Atomic Bomb Debris***

**WT-540**

Debris samples from all Tumbler-Snapper events were analyzed. Debris components are listed. Comparative measurements from other nuclear test operations are presented.

***Project 7.4, Seismic Waves from A-bombs Detonated Over a Desert Valley***

**WT-541**

The objective of this project was to investigate nuclear energy coupling into the ground and seismic propagation of that energy. Acceleration and displacement gauges were installed near the detonation points and other seismic sensors were employed at distant locations for the Baker, Charlie, Dog, Easy, Fox, George, and How. Measured values and analyses are presented.

## **THERMAL MEASUREMENTS AND EFFECTS—PROGRAM 8 AND RELATED AEC EXPERIMENTS**

### ***Project 8.1, Effects of Atomic Explosions on Forest Fuels***

**WT-506**

Project objectives were threefold: to determine the minimum thermal pulse energies required to ignite common forest fuels, to determine blast wave effects on the fires, and to calibrate laboratory simulators. Pine needles, leaves, grasses, and rotted wood were exposed at various ranges from Charlie and Dog GZs. Conclusions are presented, along with a report of the observed thermal effects on test materials.

### ***Project 8.2, Air Temperatures in the Vicinity of a Nuclear Detonation***

**WT-542**

The project measured the air temperature in nuclear tests in the vicinity of pressure gauges, particularly in the time period after detonation but before shock-wave arrival. A fast-response thermocouple was developed for this project. Measurements were made during Able, Baker, Charlie, and Dog at ground level and above, and at various ranges from GZ. Temperature-time records for a large number of cases and measured thermal fluxes are reported.

### ***Project 8.3 Thermal Radiation from a Nuclear Detonation***

**WT-543**

Instruments for measuring total thermal radiation and rate of delivery were set up near the ground on the airdrop shots. Thermal radiation received by the bomb-drop airplane was also measured. Tabulations of total thermal radiation are presented and scaling with yield is discussed. Curves of thermal delivery vs time are given. Results from auxiliary measurements of air transmission and ground reflectivity are also presented.

### ***Project 8.3a, Thermal Radiation Measurements Using Passive Indicators***

**WT-544**

The objective of this project was to test a simple passive sensor for measuring thermal radiation. The concept is based on the relationship between damage to specific materials and the thermal environment. The concept is described, and measured results are reported and compared with other thermal measurements using other techniques.

### ***Project 8.4, Atmospheric Transmissions and Weather Measurements***

**WT-545**

Weather conditions such as temperature, humidity, and barometric pressure, and optical transmissivity of the atmosphere were recorded on the days before, during, and after the nuclear tests, to aid in the interpretation of nuclear effects data.

### ***Project 8.5, Incendiary Effects of Atomic Bomb Tests on Building Sections at Yucca Flat***

**WT-510**

The objective of this project was to assess nuclear thermal effects on conventional buildings. Roofs, room segments, and typical furniture and household articles in normal settings were exposed at various ranges from GZ during Charlie and Dog. Other flammable materials such as newspapers were also present. Nuclear airblast affected the propagation of fires. Observations and photographs of results are presented.

### ***Project 8.6, Sound Velocity Changes Near the Ground in the Vicinity of an Atomic Explosion***

**WT-546**

In order to determine local air temperature, sound velocity was measured in air at various locations after thermal pulse irradiation but before shock-wave arrival. Measurements were made

during Able, Baker, Charlie, and Dog at ranges from GZ out to 2,000 feet and heights above ground from 1.5 to 54 feet. Sound velocity traces are reported. Much data was lost due to equipment failure.

***Project 8.7, Thermal Radiation Measurements***

**WT-565**

Experiments were performed to measure thermal output from nuclear weapons as a function of energy-band and time. Ranges for the test measurements exceeded 8 miles for Fox, George, and How. Refined data are presented.

***Project 18.5, Mechanically Recorded Measurements of Air Temperature Near the Ground***

**WT-559**

A mechanical technique for recording the air temperature near the ground before and after shock-wave arrival was employed for Able, Baker, Charlie, and Dog. Temperature-time records at various ranges from the bursts are presented.

**SUPPORTING MEASUREMENTS—PROGRAM 9**

***Project 9.4, Effects of Atomic Explosions on the Ionosphere***

**WT-547**

The project objective was to measure the effect of nuclear explosions on the ionosphere and on radio transmissions. Pulsed and continuous waves of various frequencies were reflected off the ionosphere during and after each of the Tumbler-Snapper events. Signal records and observations of signal reception are presented.

***Project 9.5, Electromagnetic Radiation Over the Radio Spectrum from Nuclear Detonations***

**WT-548**

The objective of this project was to determine the waveform and amplitude of radiofrequency energy from a nuclear detonation. Receiver stations were established at 60, 450, and 2,500 miles from the detonation area. Frequencies from 50 Hz to 100 MHz were monitored. Numerous data tapes with measured signals are presented.

***Project 12, Technical Photography***

**WT-563, -569**

WT-563 reports efforts to develop photo instrumentation for weapon performance diagnostics. WT-569 contains records of types of photographic support provided to the various projects. However, it also contains data from photographic records on fireball growth and shock velocity.

**SECTION 10**  
**IVY**  
**Enewetak Atoll**  
**1952**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Mike	Oct 31	Eluklab Island	10.4 MT	Surface
King	Nov 15	Runit Island	500 KT	Airdrop (HOB, 1,480 feet)

**BACKGROUND.**

Operation Ivy was a nuclear weapon development test series intended to verify the thermonuclear weapon concept. The Mike device was the first U.S. fusion device, and its yield was at the upper limit of pretest predictions. The King device was a new high-yield fission design. While King was a technological advancement, it was also intended as a consolation exhibit in case the Mike test failed. This operation was conducted at Enewetak Atoll in the Pacific Ocean because the predicted high yields precluded testing at the Nevada Test Site.

The emphasis in the Ivy series was clearly on nuclear weapon development. Effects programs, such as nuclear detonation effects on communications, participated on a noninterference basis. Device diagnostics and nuclear environment measurements were emphasized. Airblast measurements were made to help define precursor wave phenomenology, but no instrumented structures were fielded for damage and response testing. Measurements were made of the nuclear craters.

Surveys of radioactivity present in plants, animals, fish, birds, and plankton at the Enewetak Atoll were made before and after Mike event. The Ivy programs yielding information for nuclear weapon effects investigations include:

- Program 5—Gamma-Ray Measurements
- Program 6—Blast Measurements
- Program 7—Long Range Detection
- Program 9—Electromagnetic Phenomenology.

**OPERATION IVY PROJECTS AND REPORTS**

**GAMMA RAY MEASUREMENTS—PROGRAM 5**

*Project 5.1, Gamma Radiation as a Function of Distance*

**WT-643**

Film badges to measure gamma radiation were deployed at island test stations. Some instrument packs were designed to measure dose during the first 0.2 second and at 60-second periods after Mike to provide some gross dose rate information. A large number of the measurement stations were destroyed. The data from Mike was acquired in the range of 12,600 feet to 19,200 feet. Measured gamma doses versus distance are reported.



**Projects 5.1 and 5.2, Gamma Intensity as a Function of Time** **WT-634**

Instruments to measure gamma intensity vs time were deployed at two distances from Mike and King. Measurements on Mike ran from 1  $\mu$ sec to 12 seconds and on King from 1 msec to 20 seconds. Tables of measured data are presented.

**Project 5.3, Fall-out Gamma Ray Intensity** **WT-649**

The objective of this project was to measure fallout from the Ivy events at Enewetak and surrounding atolls. Due to unexpected wind currents and considerable loss of equipment, limited data was acquired. Gamma dose rate vs time is reported for Mike from some of the islands.

**Project 5.4a, Nature, Intensity, and Distribution of Fallout from Mike Shot** **WT-615**

Radioactive fallout collection stations, on ships and moored rafts, were established on several islands of Enewetak Atoll and on islands hundreds of miles from Mike. Reported are fallout patterns as a function of time and position, and characteristics of fallout material.

**Project 5.4b, Fallout and Cloud-Particle Studies** **WT-617**

Particle collections were made on land areas of Enewetak Atoll shortly after Mike and King. Fallout as a function of time after detonation was measured. Cloud samples were collected by aircraft. Fallout and cloud characteristics, including particle size and radiation intensities are reported.

**BLAST MEASUREMENTS—PROGRAM 6 AND RELATED PROJECTS**

**Project 6.1, Air Shock Pressure-Time versus Distance** **WT-602**

The objective of this project was to measure the airblast pressure-time profile at various ranges from Mike and King. Measurements of shock waves that had traveled over water were made to compare with those affected by thermal radiation heating of the ground. The very high yield of Mike made it difficult to predict the appropriate settings for gauges, resulting in some data loss. Except for close-in measurements of Mike, considerable data was collected and presented in the form of data traces and tables.

**Project 6.2, Blast-Wave Mass-Motion Measurements** **WT-627**

Observation of shock wave interactions with puffs of smoke were used to determine the peak pressure of nuclear shock waves. Smoke markers were launched to high altitudes by cannons, and the shock arrival time at the smoke clouds was determined by high-speed motion picture photography. The test technique is discussed, and calculated pressures are reported.

**Project 6.3, Shock Winds, Afterwinds, and Changes in Air Temperature Resulting from Large Atomic Bursts Near the Earth's Surface** **WT-603, -628**

The project was tasked to measure the static and dynamic pressures, waveforms, and temperatures of the shock waves from Mike and King, as well as after-shock wind velocities recorded by a variety of instruments. Most of the project experiments located on seven islands from 5,900 to 114,240 feet from Mike and from four stations from 5,491 to 55,132 feet from King surface zero are reported in WT-603. Special instrumentation to measure afterwinds with a sonic anemometer are reported in WT-628. The reports contain refined data.

***Project 6.4a, Water-Wave Motion Pictures Over Shallow Water*** **WT-611**

The report consists of motion picture records of water-wave motion from the Mike detonation on island beaches inside Enewetak Atoll.

***Project 6.4b, Barometric and Water-Surface Waves Produced by Mike Shot*** **WT-635**

The objective of this project was to study the nearby and distant water-wave activity created by Mike. The effects, which were not dramatic, are described.

***Project 6.5, Ground Motion Studies on Operations Ivy and Castle*** **WT-9002**

Ground motion during Mike was measured using three axis accelerometers at ranges between 8,000 and 114,000 feet. Gauges were deployed 17 feet below ground and also in a bunker at a range of 30,000 feet. A limited amount of data was acquired, but conclusions can be drawn. Reported are some shock magnitude and arrival time measurements, as well as acceleration traces.

***Project 6.7a, Pressure-Time Measurements in Deep Water*** **WT-629**

Underwater pressure-time recording stations were placed from 1 to 2 miles from the Mike surface zero but none were recovered so no data resulted from this project.

***Project 6.7b, Underwater Pressure Measurement in Lagoon*** **WT-605**

Four underwater pressure gauges were installed at a 100-foot depth in the Enewetak Atoll lagoon for the Mike event. One record showing two major pressure spikes is presented but not explained.

***Project 6.9, Measurement of Material Density with a Beta Densitometer*** **WT-610**

The objective of this project was to measure the air-density increase near the ground due to the dust raised by nuclear thermal radiation deposition. Four air-density gauges were deployed, three of which failed. The record of the fourth gauge is presented.

***Project 6.10, Blast Effects on Inflight Aircraft*** **WT-750**

A B36D was exposed to Mike at a slant range of 132,800 feet (approximately 0.2 psi) tail on. Wing, stabilizer, and fuselage bending was recorded and is reported in an Upshot-Knothole report. A B36D was exposed to King tail on at a slant range of 85,200 feet as was a B-47 at a slant range of 42,670 feet. Peak overpressure levels were 0.16 and 0.34 psi, respectively. Recorded wing, stabilizer, and fuselage response by both airplanes are reported in WT-750.

***Project 6.11, Free-Air Atomic Blast Pressure and Thermal Measurements*** **WT-631**

Pressure and thermal environment measurements at upper altitudes were made from canisters deployed by aircraft shortly before the Mike and King detonations. Two B-29 aircraft each deployed six parachute-borne canisters with pressure and thermal sensors and telemetry systems to transmit acquired data. Data traces and measured values of pressure and thermal environments are reported.

***Project 6.13, Peak Overpressure Versus Distance in Free Air*** **WT-613**

Peak pressure were determined for King by using rocket smoke trails as a template for measuring shock velocity. High-speed motion picture cameras were used to measure shock wave position vs time. Observations of shock motion and calculations of peak pressure are presented.

***Instrumentation for Blast Measurements by Sandia Corporation*** **WT-606**

Discusses instruments and placement for Projects 6.1, 6.3, 6.5, and 6.7b.

***Damage Survey and Analysis of Structures*** **WT-641**

In 1953, some 8 months after the Mike shot, the Army structures on Enjebi were surveyed in order to study effects of the Mike and possibly King tests on these structures. These were reinforced concrete structures originally built for exposure to the Easy shot of Greenhouse. Other structures on the test and support islands were also surveyed for damage. These varied from instrumentation structures exposed at about 75 psi to industrial sheet metal buildings on the support islands exposed to a fraction of a psi. The structures on Enjebi experienced about 18 psi. Data are in the form of measurements, comments on damaged elements, and photographs.

***Project 11.4, Underwater Pressures of Seismic Waves*** **WT-633**

These pressures were recorded in the 4- to 12-Hz band on the *USS Lipan* 48 km easterly from Mike with a hydrophone at 200 feet depth and from King from a microphone in a drill hole on Medreu Island. Results are presented.

**LONG RANGE DETECTION—PROGRAM 7**

***Project 7.1, Electromagnetic Effects from Nuclear Explosions*** **WT-644**

This project was tasked to sense the electromagnetic signals at long distances from the Ivy nuclear detonations, and to determine characteristics and location of the bursts. Electromagnetic pulse characteristics recorded at various stations are presented.

***Project 7.2, Detection of Airborne Low-Frequency Sound from Nuclear Explosions*** **WT-632**

Low-frequency sound measurements were made at 12 locations worldwide for Mike and King. Station locations and recorded measurements are reported.

***Project 7.3, Dispersion of Gaseous Debris from Nuclear Explosions*** **WT-647**

This project tracked airborne debris movement after Mike and King to assess worldwide debris distribution vs time. Water samples from various stations were monitored for fallout for 6 months after the tests with negative results.

***Project 7.6, Detection of Fireball Light at Distances*** **WT-646**

The objective of this project was to detect the light from Mike and King at ground stations on Kwajalein and Johnston islands and from an aircraft at high altitude. Due to several system malfunctions, only one recorded signal is presented.

## **ELECTROMAGNETIC PHENOMENA—PROGRAM 9**

### ***Project 9.2, Effects of Atomic Explosions on the Ionosphere***

**WT-642**

Recorded are observed effects of the Ivy nuclear explosions on the ionosphere and on high-frequency (HF) radio transmissions in the vicinity of the tests. The report provides data from ionosphere probes from various islands in the Pacific and measurements of HF transmission signal strength across different paths.

### ***Project 9.3, Radio-Frequency Characteristics of EM Radiation***

**WT-648**

The objective of this project was to study the radiofrequency emanations from the electromagnetic energy in nuclear detonations. Signatures were measured at Enewetak, Bikini, and Okinawa.

## **RADIOBIOLOGY STUDIES**

### ***Project 11.5, Radiobiological Studies at Emewetak Before and After Mike***

**WT-616**

Surveys of plant and animal were made by collection, ashing, and radiological counting before and after this test. Tabular results are presented.

**SECTION 11**  
**UPSHOT-KNOTHOLE**  
**Nevada Test Site**  
**1953**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield (KT)</u>	<u>Weapon Placement</u>
Annie	Mar 17	Yucca Flat, Area 3	16	300-foot tower
Nancy	Mar 24	Yucca Flat, Area 4	24	300-foot tower
Ruth	Mar 31	Yucca Flat, Area 7	0.2	300-foot tower
Dixie	Apr 6	Yucca Flat, Area 7	11	Airdrop (HOB, 6,020 feet)
Ray	Apr 11	Yucca Flat, Area 4	0.2	100-foot tower
Badger	Apr 18	Yucca Flat, Area 2	23	300-foot tower
Simon	Apr 25	Yucca Flat, Area 1	43	300-foot tower
Encore	May 8	Frenchman Lake	27	Airdrop (HOB, 2,425 feet)
Harry	May 19	Yucca Flat, Area 3	32	300-foot tower
Grable	May 25	Frenchman Lake	15	Gun-launched (HOB, 524 feet)
Climax	Jun 4	Yucca Flat, Area 7	61	Airdrop (HOB, 1,334 feet)

**BACKGROUND.**

Operation Upshot-Knothole was a series of eleven tests at NTS that supported both weapon development and weapon effects studies. Weapon effects testing technologies were in the early stages of evolution, and many of the experiments may be considered naive based on the current state of knowledge. However, measurements were made that cannot be made today because of the atmospheric test ban, and these data might have value beyond the comprehension and experience of early experimenters. Many of the projects were extensions of experiments performed during Greenhouse, Buster-Jangle, and Tumbler-Snapper events.

About eighty Military Effects Test Program projects are reported under Operation Upshot-Knothole. They are divided into 9 programs:

- Program 1—Blast and Shock Measurements
- Program 2—Nuclear Measurements and Effects
- Program 3—Structures, Materials, and Equipment
- Program 4—Biomedical Effects
- Program 5—Aircraft Structures Tests
- Program 6—Tests of Service Equipment and Operations
- Program 7—Detonation Signatures
- Program 8—Thermal Measurements and Effects
- Program 9—Technical Photography

Among the AEC projects were several that are pertinent to DoD effects experiments. Descriptions of these experiments have been added to the related sections of the DoD effects experiments.

In addition, Upshot-Knothole had a large Civil Effects Program with project numbers in the twenties. Descriptions of these experiments is included after the Technical Photography experiments.

Many military effects experiments were designed for Encore and Grable. An identical GZ was planned for these tests, but the airdropped Encore device was detonated many hundreds of feet off target. This greatly complicated data reduction. However, these two tests did significantly enhance the understanding of nuclear blast wave phenomenology.

Most of the weapon test reports containing data from Upshot-Knothole have been declassified.

## **OPERATION UPSHOT-KNOTHOLE PROJECTS AND REPORTS**

### **Summary Report of the Technical Director, Military Effects Program WT-782**

A summary of the military effects programs objectives and findings is presented. A considerable amount of reduced data supports conclusions and airblast phenomenology is discussed in great detail.

### **BLAST AND SHOCK MEASUREMENTS—PROGRAM 1**

#### ***Projects 1.1a and 1.2, Air Blast Measurements WT-710***

The objective of this project was to study nuclear bomb airblast characteristics for different yields and heights of burst. A variety of pressure gauges were installed at the surface and several feet above the ground. Photographic techniques were used to study airblast formation and propagation. Effects of ground heating by nuclear radiation were investigated. Numerous pressure measurements and photographic observations of shock waves are reported.

#### ***Project 1.1a-1, Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements WT-784***

The project evaluated pressure-measuring instruments and supporting circuitry for use in nuclear environments. Transistor and tube systems were evaluated. The report contains descriptions of the instruments and some sample pressure-time traces.

#### ***Project 1.1a-2, Development of Mechanical Pressure-Time and Peak Pressure Recorders for Atomic Blast Measurements WT-785***

The purpose of this project was to evaluate the performance of two mechanical blast gauges. Gauge descriptions and operations are presented, but specific pressure data are not reported.

#### ***Project 1.1b, Basic Air Blast Measurements WT-711***

Measurements were made of the shock wave profile near ground level at various ranges from five nuclear devices with different yields and burst altitudes. Precursor wave phenomena were observed. Air pressure measurements, pressure-time traces, and ground acceleration measurements are presented.

***Project 1.1c-1, Air Shock Pressure Time versus Distance for a Tower Shot*** **WT-712**

The objective of this project was to study nuclear airblast characteristics. Shock wave profiles were measured at ground level and 10 feet aboveground. Processed data traces are presented, along with data from previous nuclear tests.

***Project 1.1c-2, Air Shock Pressures as Affected by Hills and Dales*** **WT-713**

The purpose of this project was to measure the peak pressure of an airblast wave traveling up the positive slope of a hill and then down the negative slope on the back side of the hill. Sixteen Wiancko pressure gauges were mounted flush with the ground on a ray extending approximately 3 miles from GZ. Refined data and analyses from Simon, as well as from a Tumbler-Snapper event, are presented.

***Project 1.1d, Dynamic Pressure versus Time and Supporting Air Blast Measurements*** **WT-714**

Reported are considerable refined data from measurement of the dynamic pressure in airblasts and precursor waves and assessment of other airblast parameters such as density, temperature, and particle velocity. Experiments were fielded for Annie, Encore, Grable, and Climax.

***Project 1.3, Free Air Blast Pressure Measurements*** **WT-715**

The high-altitude, free-air low-pressure blast environment that might be encountered by aircraft on a nuclear bombing run and the ground-reflected shock wave were measured. Another objective was to determine the line defining the triple point. Experiments were performed in the two higher-altitude nuclear tests, Dixie and Encore. Canisters containing overpressure measuring sensors, altimeters, and data transmitters were parachute-deployed from B-29s prior to the shots. The pressure-time traces measured by each of the canisters, showing both the direct shock and the reflected shock are presented. Also reported is relevant data from Greenhouse and Tumbler-Snapper.

***Project 1.4, Free-Field Measurements of Earth Stress, Strain, and Ground Motion*** **WT-716**

A large body of refined data is reported for this project. The objectives of this project were to measure airblast-induced stress as a function of depth in the ground and to study ground shock phenomenology. For the former, stress gauges were buried at three different depths and five separate distances from GZ of Encore and Grable. The latter objective was achieved during Annie, Encore, and Grable by burying stress and strain gauges and accelerometers at 5-foot depths and placing air-pressure devices on the surface.

***Project 1.5, Test Procedures and Instrumentation for Projects 1.1c, 1.1d, 1.4a, and 1.4b*** **WT-787**

Documents instrumentation of various blast gages for cited projects.

**NUCLEAR MEASUREMENTS AND EFFECTS—PROGRAM 2 AND RELATED AEC EXPERIMENTS**

***Project 2.1, Radioactive Particle Studies Inside an Aircraft*** **WT-717**

The objective of this project was to measure the type and quantity of radioactive particulate matter a pilot might ingest while flying through a nuclear cloud. Two drone F-80 aircraft flying

at different altitudes penetrated the clouds of Dixie and Encore. Samples of debris inside the cockpit were collected. Particle type, size, and activity are reported.

***Project 2.2a, Gamma Radiation Spectrum of Residual Contamination*** **WT-718**

The project was tasked to determine the gamma radiation spectra prevalent in residual contamination in the vicinity of nuclear bursts. Measurements were made at various times and locations after the tests. Plots of gamma radiation dose rate vs photon energy are presented for different sampling time and position conditions, but most of the measurements that were made are not reported in WT-718.

***Project 2.2b, Residual Gamma Depth Dose Measurements in Unit Density Material*** **WT-719**

The objective of this project was to measure gamma-ray absorption vs depth in materials having radiation absorption characteristics similar to the human body to establish nuclear radiation effects on man. Thick lucite and masonite samples were exposed after detonations in the nuclear test areas. The information presented is not coherent.

***Project 2.3, Neutron Flux and Spectrum Versus Range*** **WT-720**

Reported are reduced data resulting from measurements of the neutron environment in the vicinity of nuclear bursts. Standard neutron absorption and activation techniques were employed using gold, tantalum, and sulfur absorbers.

***Project 10.3, Gamma Radiation as a Function of Distance*** **WT-827**

Film was exposed at slant ranges of 300 to 3,960 yards from the Ray, Badger, Grable, and Climax shots. The film was in thin aluminum holders at ground level, except for a few shielded with varying amounts of iron and lead, or at varying heights slightly above or below the ground surface. Tables of exposures read from the film are presented along with some yield-scaling whose development was the purpose of the experiment.

***Project 17.1, External Neutron Measurements with Threshold Detectors*** **WT-826**

Measurements from 50 to 2,000 yards were made with various activation materials on several shots, including Grable. High-energy gamma radiation was also measured. Tabulations of data are presented.

**STRUCTURES, MATERIALS AND EQUIPMENT—PROGRAM 3**

***Project 3.1, Tests on the Loading of Building and Equipment Shapes*** **WT-721**

The objective of this project was to improve the model for predicting blast loading on structures exposed to nuclear blast. Seventeen square and rectangular reinforced-concrete structures of various dimensions were exposed to Encore and Grable. Fourteen were deployed at a constant radius from the projected GZ, and three were placed at decreasing distances from GZ. Each structure was instrumented with air-pressure gauges; free-stream air-pressure measurements were also made. Numerous pressure-time traces are presented but some data are inconsistent.

***Project 3.1u, Shock Diffraction in the Vicinity of a Structure*** **WT-786**

The task for this project was to measure the distortion of a nuclear shock wave by a structure and to determine where the shock wave returns to free-field form after passing over the structure.



Fourteen pressure-time gauges were installed at ground level and 5 feet aboveground at the side and rear of a building exposed during Encore and Grable. Pressure-time traces at various locations on and around the structure are presented.

***Project 3.3, Tests on the Loading of Horizontal Cylindrical Shapes***

**WT-722**

The objective of this project was to study blast loadings on cylindrical structures. Five steel cylinders with capped ends, suspended horizontally, were exposed at 2,000 feet from the projected GZ of Encore and Grable. Traces from pressure and strain gauges are provided.

***Project 3.4, Tests on the Loading of Truss Systems Common to Open-Framed Structures***

**WT-723**

Measurements were made of the loads on open-frame bridge structures caused by nuclear blasts. Segments of bridge trusses were exposed 2,000 feet from the projected GZ of Encore and Grable. Most strain gauge records were lost, and the experiment was generally considered a failure. Some reduced data are presented.

***Projects 3.5, Tests on the Response of Wall and Roof Panels and the Transmission of Load to Supporting Structures***

**WT-724**

This project was to assess the response of typical building components to nuclear blast. Test components included wall and roof panels made of traditional materials installed at three different stations of Encore. Instrumentation included pressure gauges, strain gauges, and motion-picture cameras. Reduced data and photographs are presented.

***Project 3.6, Tests of Railroad Equipment***

**WT-725**

The objective of this project was to assess the response of railroad equipment to nuclear airblast. Test articles included loaded and unloaded boxcars and tank cars and a diesel locomotive, which was exposed on Grable. Instrumentation included pressure gauges, accelerometers, and motion-picture cameras. Extensive pretest and posttest photography and analyses are presented.

***Project 3.7, Effectiveness of Blast Baffles at Shelter Entrances, Air Intakes and Outlets***

**WT-726**

Unexpectedly high pressure destroyed most of the apparatus, causing severe degradation of the experiment. The goal had been to acquire data to develop design criteria for underground shelters. Shelter components such as baffles were exposed. Data from pretest shock tube experiments are presented.

***Project 3.8, Effects of Air Blast on Underground Structures***

**WT-727**

Reported are extensive refined data and sensor traces assessing the response of buried structures to nuclear airblast. Three concrete structures with different support configurations were buried at three different depths for testing during Encore and Grable. Pressure gauges were used to measure pressure in the soil and on the structures. Strain, deflection, and acceleration were also measured.

***Project 3.9, Field Fortifications***

**WT-728**

These tests were part of a series begun in 1951. The objective of this project was to assess the effects of a nuclear airblast on military fortifications such as foxholes and bunkers. Effects of interest include blast, thermal radiation, and gamma radiation. A wide variety of military field

fortifications were constructed 500, 1,500, and 4,000 feet from the planned GZ of Encore and Grable. Pressure gauges, calorimeters, and film badges inside the fortifications were used to measure the nuclear environments. Previous tests are described along with measurements and extensive photographic coverage from Upshot-Knothole.

***Projects 3.11 - 3.16, Navy Structures***

**WT-729**

The objective of these projects was to measure shock response of a number of naval structures in order to improve design models for blast-resistant structures. Experiments were fielded for Encore and Grable. Pressure-time and deflection measurements were made on test structures and hardware, which included steel and concrete warehouses; brick, wood, and concrete buildings; earth-covered arched shelters; and windows. The report contains data traces, pretest and posttest photographs, and extensive analyses.

***Project 3.18, Minefield Clearance***

**WT-730**

This study investigated the detonation of pressure-activated land mines by the nuclear airblast. Arrayed in patterns out to 2,700 feet from Grable GZ were 1,200 live mines and 2,000 indicator mines. Mine burial ranged from 0 to 15 inches. Mine detonation patterns are reported. The indicator mines were found to be inadequate simulators of live mines.

***Project 3.19, Blast Damage to Coniferous Tree Stands by Atomic Explosions***

**WT-731**

This project studied the effects of nuclear weapons on forested areas. Pine trees, 8 to 18 inches in diameter were cut, transported to NTS, and concreted in place for Encore and Grable. Most were bunched to form a stand, but individual trees were "planted" on a ray extending from 1,500 to 8,000 feet from GZ. Instrumentation consisted of strain gauges and accelerometers installed on trees, as well as pressure gauges and pendulums. Strain and displacement data and a few photographs are presented.

***Project 3.20, Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communications Systems***

**WT-732**

The objective of this project was to determine the effects of a nuclear burst on tactical radio equipment. Telecommunications apparatus, including an extensive array of telephone poles, were deployed and exposed for Encore and Grable. No data other than photographs of undamaged and damaged equipment are reported.

***Project 3.21, Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts***

**WT-733, -821**

Two-and-one-half-ton and quarter-ton trucks, 57-mm guns, 105-mm howitzers, 90-mm AA guns, and armored cars were exposed to Encore and Grable to provide a statistical basis for predicting nuclear-blast-induced damage. Accelerometer measurements were made on some vehicles. Pretest and posttest motion-picture photography and vehicle displacement measurements are presented. The detailed damage reports are published in WT-821.

***Project 3.22, Effects on Engineer Bridging Equipment***

**WT-734**

Assessed in this project was the vulnerability of prefabricated fixed bridging to atomic airblast. Results were to aid in determining means to reduce vulnerability. Bridges and bridge elements were exposed to Encore and Grable. Instrumentation included accelerometers and motion-picture cameras. Reported are pretest and posttest accelerometer records and photographs.

***Project 3.24, Effects of an Air Burst Atomic Explosion on Landing Vehicles Tracked (LVT)***

**WT-735**

The objective of this project was to assess the vulnerability of LVTs to nuclear airblast and to evaluate the protection from prompt radiation afforded passengers inside the vehicles. Six LVTs were exposed to Encore and Grable. Measurements included vehicle displacements, radiation dosage inside and outside the vehicles, and approximate internal temperature rise. Motion-picture coverage was provided. Environments and responses are described.

***Project 3.26, Tests on the Effects on POL Installations***

**WT-736**

This project evaluated the effects of atomic weapon environments on fuels and equipment typical of military petroleum, oil, and lubricant (POL) facilities. Gasoline and diesel fuels stored in a wide variety of containers were exposed at different ranges from Encore and Grable GZs. Container restraints such as tiedowns, clamps, and revetments were assessed. Thermal and blast effects were evaluated, and environments were quantified. WT-736 contains detailed descriptions of test hardware and photographic coverage of results.

***Project 3.27, Effects of Atomic Explosions on Field Medical Installations Equipment***

**WT-737**

This task assessed the damage to a medical field unit exposed to nuclear airblast in the standard deployment configuration and in a dug-in configuration. Complete medical facilities were erected at various distances from the planned GZ of Encore. Pretest and posttest photographs of medical facilities are presented.

***Project 3.28.1, Structures Instrumentation***

**WT-738**

The objective of this project was to provide environment and structures response instrumentation for Encore and Grable. Measurements included air pressure, earth pressure, displacement, acceleration, panel time-of-break, and angular velocity for Army, Navy, Air Force, and Federal Civil Defense Administration experiments. Data traces are illustrated in the report.

***Project 3.28.2, Pressure Measurements for Various Projects in Program 3***

**WT-739**

Pressure measurements were made in three aboveground structures, one underground structure, five foxholes, a tree stand, and in the general area of one aboveground structure for Encore and Grable. Gauge readings and gauge descriptions are included in WT-739.

***Project 3.28.3, Pressure Measurements on Structures***

**WT-740**

The objective of this project was to measure pressure on structures during Encore and Grable in support of other experiments. Data traces from some instruments are included in WT-740, but the traces also appear in the WT reports describing the actual experiments.

***Project 3.29, Blast Effects of Atomic Weapons Upon Curtain Walls and Partitions of Masonry and Other Materials***

**WT-741**

The Federal Civil Defense Administration was to assess the ability of various interior wall structures to resist nuclear airblast. Four concrete structures, each about 300 feet long, were divided into 18 "cells" by interior wall elements and exposed in the Encore event. The structures were deployed at pretest projected overpressures of 4.5 and 7.5 psi, with two structures at each level. Detailed descriptions of all test elements and extensive pretest and posttest photographic coverage are presented.

***Project 3.30, Air Blast Gauge Studies***

**WT-742**

The project was tasked to develop and proof-test self-recording gauges that measure nuclear airblast pressure-time and peak pressures. Three types of gauges were tested for Annie, Simon, Harry, Encore, Grable, and Climax. Gauge descriptions and reduced data are presented.

**BIOMEDICAL EFFECTS—PROGRAM 4**

***Project 4.1, Evaluation of the Hazard of Flying Through the Atomic Cloud***

**WT-743**

Drone aircraft carrying mice and monkeys flew through the Dixie and Encore clouds to determine the magnitude of the hazard to pilots flying through a nuclear cloud shortly after the detonation. Environments and biological data are reported.

***Project 4.2, Direct Air Blast Exposure in Animals***

**WT-744**

Nuclear airblast effects were measured in order to estimate such effects on humans. Dogs and rats were shielded from radiation effects and exposed at overpressures from 10 to 100 psi for Harry, Encore, and Grable. Damage to the specimens is described.

***Project 4.5, Ocular Effects of Thermal Radiation from Atomic Detonation—Flashblindness and Chorioretinal Burns***

**WT-745**

The objective of this project was to assess the effects of the atomic flash on the eyes. These experiments were part of a series begun in earlier operations. Human subjects were used to investigate flashblindness. Rabbits were employed for assessment of chorioretinal burns. Experiments were performed for Annie, Nancy, Badger, Simon, Harry, and Climax. Medical assessments of the exposed subjects are reported, with some photographic coverage of microscopic damage.

***Project 4.7, Beta-Gamma Skin Hazard in the Postshot Contaminated Area***

**WT-746**

The project was to determine if the residual gamma radiation measured in the vicinity of a nuclear burst underestimated the radiation threat to humans due to the unmonitored beta radiation threat. Contaminated areas from Upshot-Knothole events were monitored with standard gamma radiation measurement instruments and with instruments that were also capable of measuring the beta radiation. The theory of the phenomena and radiation measurements are reported.

***Project 4.8, Biological Effects of Neutrons***

**WT-747**

Assessment was made of the biological effects of neutron radiation on humans aboveground and in foxholes in the vicinity of nuclear detonation. Mice were used as test subjects. Some gamma-ray shielding for test specimens was provided. Posttest analyses consisted of observations and blood analysis. Biological information is presented.

**AIRCRAFT STRUCTURES TESTS—PROGRAM 5**

***Project 5.1, Naval Aircraft Structures***

**WT-748**

Drone aircraft were deployed in the vicinity of Annie, Nancy, Simon, Harry, and Encore. Observed was the response of aircraft at positions and ranges simulating nuclear weapon post-delivery maneuvers. Some aircraft experienced heavy damage due to unexpectedly high loads. Extensive photographic coverage of aircraft damage and photomicrographs of damaged components are provided.

***Project 5.2, Atomic Weapon Effects on B-50 Type Aircraft in Flight***

**WT-749**

It was necessary to determine safe-separation distances for B-50s delivering nuclear weapons to targets. A formation of three B-50 bombers was programmed to fly in the vicinity of Dixie and Encore to assess and report effects of airblast on the aircraft. Aircraft were instrumented to measure environment and response.

***Project 5.3, Blast Effects on B-36 Type Aircraft in Flight***

**WT-750**

The purpose of this experiment was to increase the database on the response of the B-36 bomber to a nuclear airblast environment. A B-36 bomber instrumented to measure environment and structural response was flown in the vicinity of the Encore detonation. Response data from Encore and from the Ivy operations are reported.

**TESTS OF SERVICE EQUIPMENT AND OPERATIONS—PROGRAM 6**

***Project 6.2, Indirect Bomb Damage Assessment (IBDA)***

***Phenomena and Techniques***

**WT-751**

This continuing project was to determine if aircraft-borne radars and bhangmeters could be used to measure nuclear bomb yield, GZ location, and height of burst. Tests were performed for all Upshot-Knothole events. Three B-29 aircraft equipped with X-band and Ku-band radar and ground-based radar systems were employed. Observations of responses are reported. Documents containing data are referenced.

***Project 6.2, Interim IBDA Capabilities of Strategic Air Command***

**WT-752**

Using existing equipment, the Strategic Air Command (SAC) project developed procedures for performing Indirect Bomb Damage Assessment (IBDA) for U.S. nuclear bombing runs over enemy targets. Radar observations of nuclear bursts are reported.

***Project 6.4, Evaluation of Chemical Dosimeters***

**WT-753**

The objective of this project was to evaluate developmental radiation dosimeters for battlefield use. Three dosimeters were tested for Simon and Encore. The dosimeters, tests, and readings are described.

***Project 6.7, Measurements and Analysis of Electromagnetic Radiation from Nuclear Radiation***

**WT-754**

The project task was to detect and measure the electromagnetic signals from nuclear detonations and from the bomb HE detonation immediately preceding the fission process. Instrumentation included antennas, shielded loops, and short vertical probes. Measured signals were very distorted and difficult to interpret. Some data traces are provided.

***Project 6.8, Evaluation of Military Radiac Equipment***

**WT-755**

Survey teams operated sensors in radioactive fields after each of the Upshot-Knothole events to test and evaluate radiac survey equipment and dosimeters for possible use in tactical situations. Descriptions of the equipment and their operations are reported.

***Project 6.8a, Initial Gamma Exposure versus Distances***

**WT-756**

The objective of this project was to provide precise total gamma radiation measurements as a function of distance from the Upshot-Knothole detonations. Reliable National Bureau of Standards dosimeters were employed. Corrections for neutron radiation were made where appropriate. Dosimeter readings of measured radiation are reported.

***Project 6.9, Evaluation of Naval Airborne Radiac Equipment***

**WT-757**

Project tasks assessed the possibility of determining ground-level nuclear radiation levels through areal radiation measurements and evaluated airdropped monitors for indicating radiation levels on the ground. A U.S. Navy aircraft (P2V-2) made aerial surveys and deployed-radiation-monitoring equipment designed to map radiation levels in the air and near the ground. Experiments were performed for Annie, Nancy, Ruth, Badger, and Simon. The monitors did not provide the desired information.

***Project 6.10, Evaluation of Rapid Aerial Radiological Survey Techniques***

**WT-758**

This project assessed the use of aircraft to measure radioactivity above a nuclear burst GZ to estimate the level of radioactivity on the ground. The aircraft flew clover-leaf patterns above GZ at various altitudes and used data from prior tests to extrapolate ground-level radioactivity. Experiments were performed for eight of the Upshot-Knothole events. Radiation isocontours are presented.

***Project 6.11, Indoctrination of Tactical Air Command Air Crews in the Delivery and Effects of Atomic Weapons***

**WT-759**

The objective of this project was to indoctrinate Tactical Air Command (TAC) pilots with nuclear weapon delivery experience. The pilots observed the flash from Nancy, flew flight patterns appropriate for weapon delivery during Dixie, and flew postdetonation damage assessment flights after Encore. Pretest and posttest aerial photos of the Encore test site are presented.

***Project 6.12, Determination of Height of Burst and Ground Zero***

**WT-760**

This project tested tactical methods for determining atomic burst location and yield over enemy-held terrain. Measurement systems included sound ranging, seismic height-of-burst determination, photographic flash ranging, and bhngmeters for yield determination. Participation occurred in all Upshot-Knothole events. Equipment, analytical processes, and results are reported.

***Project 6.13, Effectiveness of Fast Scan Radar for Fireball Studies and Weapon Tracking***

**WT-761**

Assessment was made of the utility of a fast-scan radar (20 scans/second) in tracking an incoming nuclear weapon and measuring burst phenomena. This Navy radar was mounted on a van and used to observe the Simon, Harry, Encore, and Grable bursts. Results were ambiguous, but radar scope traces are presented.

## **NUCLEAR DETONATION SIGNATURES—PROGRAM 7 AND RELATED AEC EXPERIMENTS**

### ***Project 7.1, Electromagnetic Effects from Nuclear Explosions***

**WT-762**

The objective of this project was to investigate electromagnetic signals from nuclear bursts. Experiments were performed in all Upshot-Knothole events. Traces of electromagnetic signals in different frequency bands are presented.

### ***Project 7.3, Detection of Airborne Low-Frequency Sound Waves from Nuclear Explosions***

**WT-763**

This project measured acoustic signals from nuclear bursts at long distances. Measurements were made from 15 locations in each of the Upshot-Knothole events. Tables of signal magnitude and times of arrival for the various sensor locations are reported.

### ***Project 7.4, Seismic Measurements***

**WT-764**

The objective of this project was to investigate the seismic signals from nuclear explosions. Experiments were performed in all Upshot-Knothole events. WT-764 contains seismic signal data and analyses.

### ***Project 7.5, Calibration Analysis of Close-In A-Bomb Debris***

**WT-765**

This project was assigned to perform chemical and physical analyses of the debris from nuclear explosions. Samples were analyzed from all Upshot-Knothole events. Descriptions of samples and analyses of results are presented.

### ***Project 15.2, Measurements of Electric Transients in the Earth***

**WT-813**

Potential and current measurements were made in the earth in conjunction with several tower shots at Yucca Flat and the Climax airdrop there. The motivation was a better understanding of transients affecting instrumentation records rather than a careful mathematical depiction of the induced field.

### ***Project 15.3, A Survey of Electromagnetic Effects***

**WT-797**

Measurement of EMP in coax cable (above and below ground), in electronic test equipment inside a blockhouse, and in power, signal, and telephone lines was made on Annie, Nancy, Ray, Badger, Harry, and Climax. Polaroid scope photos and tabulations are included. The authors opined that this was the first such experiment in nuclear testing.

### ***Project 15.4, Investigation of Early Electromagnetic Signals***

**WT-791**

Two antennas were set up on each of the eight shots this experiment participated in. One station was a close-in station, 1.8 to 3.5 miles from GZ, and the other was 10 miles away. The antennas' frequency response was from 22 to 350 MHz. Signals received by the antennas were amplified and recorded with oscilloscope photography. The project participated on Nancy, Dixie, Badger, Simon, Encore, Harry, Grable, and Climax.

## **THERMAL MEASUREMENTS AND EFFECTS—PROGRAM 8 AND RELATED AEC EXPERIMENTS**

### ***Project 8.1a, Effects of Thermal and Blast Forces from Nuclear Detonations on Basic Aircraft Structures and Components***

**WT-766**

The task involved measuring the vulnerability and response of various aircraft structural components to nuclear thermal and blast effects. A large number of components, some stressed to simulate flight loads, were exposed to four events. Some experiments contained three identical elements: one protected from thermal effects, one protected from blast effects, and one exposed to combined blast and thermal effects. Since instrumentation was extensive, large quantities of instrument records as well as photographs are provided.

### ***Project 8.1b, Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs***

**WT-809**

Five fighter planes and three bombers were deployed in six Upshot-Knothole events. A total of 16 aircraft were exposed to nuclear detonations. Tie-downs were used in some tests. Surface temperature measurements were made and motion pictures were taken. WT-809 contains photographs, thermal measurements, and extensive damage analyses.

### ***Project 8.2, Measurement of Thermal Radiation with a Vacuum Microphone***

**WT-767**

The objective of this project was to evaluate a concept for using optical radiation pressure on a surface to determine the thermal radiation environment from a nuclear burst. Essentially, optical radiation from a burst was passed through a transparent plate into a vacuum containing a highly reflective diaphragm and the "light pressure" on the reflective surface measured. Tests were performed in the first ten Upshot-Knothole events, usually involving two sensors. The measured data are reported.

### ***Project 8.4-1, Protection Afforded by Operational Smoke Screens Against Thermal Radiation***

**WT-768**

A fog-oil smoke screen was used to measure the reduction in thermal radiation from the Grable nuclear burst. Photographs indicate that a carbon smoke screen was also in the exposure field. Smoke screen characteristics and thermal radiation measurements are presented.

### ***Project 8.4-2, Evaluation of a Thermal Absorbing Carbon Smoke Screen***

**WT-769**

An extensive smoke screen was generated in one segment of the Grable exposure field. The project assessed the characteristics of a nuclear airblast when thermal radiation is prevented from heating the ground, and determined thermal radiation attenuation due to an absorbing smoke screen. Thermometers and calorimeters were deployed. Thermal pulse attenuation was significant, and the airblast was clearly modified. Photographs, thermal measurements, and analyses are presented.

### ***Project 8.5, Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies***

**WT-770**

The objective of this experiment was to assess the thermal radiation protection provided by various types of military clothing. White pigs were dressed in various combinations of clothing and placed at different distances from the Encore, Nancy, and Grable GZs. Descriptions of clothing combinations and effects on test subjects are presented.



***Project 8.6, Performance Characteristics of Clothing Material  
Exposed to Thermal Radiation***

**WT-771**

This project was tasked with assessing the response of military and other fabrics to nuclear thermal radiation. These fabrics were used for the clothing tested in Project 8.5. Effects of spacing between fabric layers were evaluated. Experiment descriptions and photographs of exposed fabrics are presented.

***Project 8.9, Effects of Thermal Radiation on Materials***

**WT-772**

The purpose of this project was to evaluate a physical skin simulant to be used in tests for determining burn severity behind irradiated clothing barriers and to correlate nuclear environment response of the simulant with laboratory testing. Spectral measurements of absorbed radiation were made. Tests were performed for Encore and Grable at various distances from GZ. Temperatures of the skin simulant under various conditions are reported.

***Project 8.10, Physical Characteristics of Thermal Radiation  
from an Atomic Bomb Detonation***

**WT-773**

Measurements were made of thermal radiation due to nuclear tests in terms of total thermal radiation as a function of distance, pulse shape, spectral distribution, ground reflection, and atmospheric scatter. Tests were performed for Ruth, Dixie, Encore, Grable, and Climax. Instruments were deployed at various ranges on the ground and in a B-50 aircraft. Disc calorimeters and foil radiometers were employed. Considerable reduced data are presented.

***Project 8.11a, Incendiary Effects on Building and Interior Kindling Fuels***

**WT-774**

This project assessed the flammability of structures and common materials found around structures exposed to the thermal environment of a nuclear burst. Test articles were exposed to the thermal environments of Encore and Grable. Test hardware included common articles such as brooms, brushes, draperies, and miniature houses with windows. Photographic coverage of some of the houses shortly after nuclear detonation is provided. Test article response as a function of thermal environment is reported.

***Project 8.11b, Ignition and Persistent Fires Resulting  
from Atomic Explosions—Exterior Kindling Fuels***

**WT-775**

The objective of this project was to determine thermal environments that might ignite debris or flammable materials whose combustion could initiate fire storms. Such materials were referred to as kindling fuels. Newspapers, boxes, paper bags, rags, etc., as well as cars with torn upholstery, were exposed to the various thermal environments of Dixie, Encore, and Grable. Responses of test articles as a function of thermal environment are reported.

***Project 8.12a, Sound Velocities Near the Ground in the  
Vicinity of an Atomic Explosion***

**WT-776**

The project measured the sound velocities near the ground over a variety of surface materials during a nuclear explosion. Experiments were performed at various distances from Encore and Grable GZs at aboveground elevations of 3-1/2 feet and 10 feet. Ground surface materials included desert soil, fir boughs, black iron, and asphalt. Measurements of sound velocity vs time under a wide variety of test conditions and locations are reported.

***Project 8.12b, Supplementary Pressure Measurements***

**WT-777**

This task investigated evidence of preshock pressures generated due to thermal radiation absorption at the earth's surface. Panels covered with black tile, asphalt, and adobe were exposed at two ranges from GZ during Encore and Grable, with pressure gauges installed in the center of each panel. No air pressure increases were noted. WT-277 presents data traces of pressure before and after arrival of the main nuclear shock. Early-time transient perturbations to the electromagnetic signal are recorded. Descriptions of material response to the nuclear thermal environment are also provided.

***Project 8.13, A Study of Fire Retardant Paints***

**WT-778**

Panels of bare wood, wood painted with standard paint, and wood painted with fire-retardant paint were exposed at energy levels from 3 to 31 cal/cm<sup>2</sup> during Encore. The effectiveness of fire-retardant paints in reducing damage caused by thermal radiation from a nuclear burst was assessed. The fire-retardant paints provided more than twice as much protection as standard paints. WT-778 contains photographs of the test panels and the chemical formulations for the fire-retardant paints.

***Project 18.3 (I and II), Spectrographic Observations***

**WT-829, -828**

Spectrographic observations of the fireballs and surrounding air were made for the series. Emitting and absorbing lines were identified. Time histories of several air species were recorded as well as the color temperature history of the fireball.

**TECHNICAL PHOTOGRAPHY—PROGRAM 9 AND RELATED AEC EXPERIMENTS**

***Project 9.1, Technical Photography***

**WT-779**

The objective of this project was to provide motion picture and still photography for all effects projects performed for Upshot-Knothole. WT-779 contains descriptions of the photographic support given to each of the projects, including details of the equipment used. Most of the motion-picture films listed are held by DASIAC.

***Project 9.6, Production Stabilization***

**WT-780**

The ground in critical areas was treated to reduce the dust environment, which would degrade test photographic coverage. WT-780 describes methods used for soil stabilization, but contains no weapon effects data.

***Project 9.7, Experimental Soil Stabilization***

**WT-781**

Panels containing soils stabilized by different methods were exposed to Encore and Grable. Evaluation was made of materials and techniques used to stabilize the soils and reduce dust cloud generation in nuclear tests. Motion-picture coverage was provided. Photos from motion-picture strips are presented in WT-781.

***Project 12.1, Technical Photography***

**WT-824**

This project provided motion-picture coverage for the phenomenology of the detonations, that is high speed coverage of fireball and nuclear cloud growth and motion.

## **CIVIL EFFECTS PROGRAM**

### ***Project 21.1, Effects of an Atomic Explosion on Underground and Basement Types of Home Shelters***

**WT-801**

Eight outdoor and four indoor house-type shelters were exposed on Annie at ranges from 1,230 feet from GZ, and basement-type shelters in test houses were exposed at 3,500 and 7,500 feet from GZ. Instrumentation was meager. It consisted of gamma-sensitive film badges, and paraffin blocks, nylon cloth and temperature-sensitive paper strips for thermal registration. Some roof slab deflection data was collected. Mannequins were placed in the shelters. Data presented is primarily photographic.

### ***Project 21.2, Effects of an Atomic Explosion on Two Typical Two-Story-and-Basement Wood-Frame Houses***

**WT-792**

Two frame houses without utilities were built at 3,500 and 7,500 feet from shot Annie tower. Instrumentation was limited to gamma-sensitive film badges and temperature-sensitive paper strips. Data are primarily before and after photographs of the buildings and contents, furniture, and mannequins. Motion pictures of the response of these houses were made and these are the classic "house being blown apart" films that have been in the public domain since shortly after the tests.

### ***Project 22.4, Exposure of Drugs to Nuclear Explosion***

**WT-810**

Forty-two drug preparations, from antibiotics to vitamins, were exposed in their commercial packaging at ranges from 400 to 2,500 yards from Simon and Harry tests. After prompt recovery, drugs were tested for potency, safety, and induced radioactivity. Tables of results are presented.

### ***Project 23-24 (series), Communal Shelter Tests***      **WT-789, -790, -793, -794, -795, -798, -820**

Two underground communal shelters were built in Yucca Flat, Area 3, at a slant range of 510 yards from shot Annie. A similar shelter built for Buster-Jangle in Area 7 was also used by these projects. This shelter was so located that it was exposed at various slant ranges from 666 yards upward on shots Climax, Dixie, and Ruth. In addition, a semi-buried communal shelter was built in Area 3 at the same slant range, 776 yards from the Harry shot. These structures were used to house various biological specimens during the noted tests. As part of this program, small biological specimens were housed in hollow lead hemispheres at various slant ranges from 493 to 1,970 yards from shots Encore and Grable in Frenchmans Flat. The documentation of the placement and instrumentation and the response of these biological specimens to the blast, thermal and radiation environments within these structures is the subject of the following WT reports.

#### **Project 23.1, Biological Effectiveness of Ionizing Radiation Within Shelters**

**WT-793**

#### **Project 23.2, Bacteriological Studies on Animals Exposed to Neutron Radiation**

**WT-794**

#### **Projects 23.4-23.14, 23.16, Genetic Effects of Fast Neutrons from Nuclear Detonations**

**WT-820**

#### **Project 23.15, Effects of Overpressures in Group Shelters on Animals and Dummies**

**WT-798**

**Project 23.17, Neutron-Flux Measurements in AEC  
Group Shelters and Lead Hemispheres**

**WT-795**

**Project 24.2, Physical Measurements of Gamma and  
Neutron Radiation in Shelter and Instrumentation Evaluation**

**WT-789**

**Project 24.3, AEC Shelter Instrumentation**

**WT-790**

**SECTION 12**  
**CASTLE**  
**Bikini and Enewetak Atolls**  
**1954**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield (MT)</u>	<u>Weapon Placement</u>
Bravo	Feb 18	Sandspit off Nam Island, Bikini	15	Surface
Romeo	Mar 26	Bravo Crater, Bikini	11	Barge
Koon	Apr 6	Eneman Island, Bikini	0.110	Surface
Union	Apr 25	Lagoon off Iroij, Bikini	6.9	Barge
Yankee	May 4	Union Crater, Bikini	13.5	Barge
Nectar	May 13	Mike Crater, Enewetak	1.69	Barge

**BACKGROUND.**

Operation Castle was a follow-on to Operation Ivy in development of thermonuclear weapons. Ivy essentially demonstrated the concept, and Castle included tests of engineering solutions required for creating practical weapons. It was generally accepted that the Soviets were ahead of the United States in the development of thermonuclear weapons, so there was some urgency in the prosecution of Castle.

Enewetak Atoll had become established as the U.S. nuclear Pacific test site, but after the Ivy-Mike event essentially eliminated an island, it was recognized that more land was needed to perform high-yield weapon testing. Since Bikini Atoll was nearby and was available because the natives had been moved, it was decided that testing would be shared by these two atolls. Castle had five tests at Bikini and one at Enewetak. Four devices were detonated on barges near islands and two were on land. Barges were used to save land and hopefully reduce radioactive fallout.

Unlike Ivy, Castle had an extensive array of DoD nuclear effects projects. Even so, the effects activity was second priority behind weapon development work. Some last-minute operations changes to accommodate weapon development experiments did perturb some weapon effects programs.

Originally there were no biomedical projects in Castle, but the first test, Bravo, had a yield about 2.5 times higher than predicted, and unfavorable winds carried the large radioactive cloud to populated areas. American support personnel, natives at other atolls, and Japanese fishermen were exposed to high levels of radioactive fallout. Medical doctors and researchers were rushed to the area to treat and study the victims. A program for biomedical studies was devised and implemented.

Another result of the unexpectedly high yield for Bravo was that blast damage occurred to support structures that were supposedly outside the damage radius. These became objects of structural response studies.

Los Alamos Scientific Laboratories performed some experiments not reported in the Weapon Test (WT) documents, but could be of value to some weapon effects analysts. These include measurements of the thermal environments from the Castle devices and studies of radioactivity present in the organic life at Enewetak before and after the nuclear test.

Castle provided the first real opportunity for the U.S. weapons effects community to acquire data from high-yield detonations. DoD environment and effects activities included:

- Program 1—Blast and Shock Measurements
- Program 2—Nuclear Radiation Effects
- Program 3—Structures, Equipment and Techniques
- Program 4—Biomedical
- Program 7—Long Range Detection
- Program 9—Cloud Detection.

## OPERATION CASTLE PROJECTS AND REPORTS

### **Program 1-9, Summary Report of the Commander, Task Unit 13—Military Effects**

**WT-934**

This report summarizes each of the effects programs and presents results and general conclusions. Comments on problems encountered and real time changes in plans and operations are included. A considerable amount of reduced data is presented.

### **BLAST AND SHOCK MEASUREMENTS—PROGRAM 1**

#### ***Project 1.1a, b, & d, Blast Pressures and Shock Phenomena Measurements by Photography***

**WT-902**

The objectives of these projects were to use smoke photography to calculate peak shock overpressure, observe airblast precursors in the photographs, and search for shock phenomena in photographs taken at long ranges from GZ. Measurements were made for all Castle events, with varying degrees of success. Observed shock phenomena, scientific photographs, and analyses are presented.

#### ***Project 1.2a, Ground Level Pressures from Surface Bursts***

**WT-904**

During all Castle events, overpressure was measured at ground level under various airblast propagation conditions. Some pressures were measured after the airblast had traveled over water, and others after the airblast traveled over land. Some airblasts traveling over land exhibited precursor wave formation. Peak pressures from 1 to 75 psi were recorded. Pressure-time measurements and analyses are reported. A separate report, WT-907 discusses the instrumentation used in this project as well as Projects 1.3 and 1.7 (below).

#### ***Project 1.2b, Ground Surface Air Pressure Versus Distance from High Yield Detonations***

**WT-905**

The objective of this project was to the measure pressure-time profiles and dynamic pressures near ground level for the Castle events. Overpressures as high as 250 psi were recorded. The report provides pressure profiles of dynamic pressure vs distance from bursts, and peak overpressure vs distance from bursts.

#### ***Project 1.3, Dynamic Pressure Measurements***

**WT-906**

The project performed pressure measurements in order to assess blast wave theory. A limited number of measurements were achieved. Peak pressures, dynamic pressures, and pressure-time traces are presented, and theory is discussed.

***Project 1.4, Underwater Pressure Measurements***

**WT-908**

The project was tasked to measure the underwater peak pressures and pressure-time histories from surface nuclear explosions at various ranges and water depths. In spite of considerable equipment failure, some data were acquired and the report furnishes peak pressures and pressure-time traces.

***Project 1.5, Acoustic Signals in Water (SOFAR)***

**WT-909**

Attempts were made to record the sound signal injected into the ocean water by the detonations. The recording stations were at Point Arena and Point Sur on the Pacific coast of the United States. No data were collected.

***Project 1.6, Water-Wave Measurements***

**WT-910**

The objective of this project was to measure the water-wave activity generated by the Castle events in Bikini Atoll. Wave height measurements and characteristics are reported.

***Project 1.7, Ground Motion Studies***

**WT-9002**

WT-9002 is a compilation of results from ground motion experiments in a number of nuclear operations, including Castle.

***Project 1.8, Dynamic Pressure Investigation***

**WT-911**

The project was assigned to observe the response of jeeps to the drag forces of a nuclear blast wave. Twenty-seven jeeps were exposed to Koon and Nectar. The unexpectedly low yield of Koon provided no usable data, but descriptions of jeep response and photographs from Nectar and prior tests are presented. Similar experiments had been performed during Operation Upshot-Knothole.

**NUCLEAR RADIATION EFFECTS—PROGRAM 2 AND RELATED  
AEC EXPERIMENTS**

***Project 2.1, Gamma Radiation Exposure***

**WT-912**

The objective of this project was to measure the initial and total gamma dose from Bravo, Romeo, Koon, Union, and Nectar. Gamma dose sensors were placed at various ranges from GZ. Many of the close-in sensors were destroyed by the blasts. Reported measurements are of initial and total gamma dose.

***Project 2.2, Gamma Rate Versus Time***

**WT-913**

Measurements made by this project were gamma dose rates at various ranges from high-yield thermonuclear detonations. Scintillation-type detectors with recording devices were employed for Bravo, Romeo, Koon, Union, and Nectar. Plots of gamma rate vs time at various stations are presented.

***Project 2.3, Neutron Flux Measurements***

**WT-914**

During all Castle events, neutron flux measurements were taken in various energy bands. Although delays in collecting the activation materials reduced measurement accuracies, data were acquired for Bravo and Romeo. The report contains the data and discussion of theory.

***Project 2.5a, Distribution and Intensity of Fallout***

**WT-915**

The objective of this project was to map and characterize the radioactive fallout from the five events that took place on Bikini Atoll. An extensive array of collectors were deployed on islands, in the lagoon, and in the open ocean. Fallout profiles and physical characteristics of the fallout particles are presented.

***Project 2.5b, Fallout Studies***

**WT-916**

The objective of this project was to characterize close-in radioactive fallout from surface bursts of high-yield nuclear devices. Collectors with timing devices were employed to measure fallout as a function of time. Solid particle and liquid samples were assessed. Measurements were made and reported for Bravo, Romeo, Koon, Union, and Nectar. A discussion of results is presented.

***Project 2.6a, Chemical, Physical, and Radiochemiccal Characteristics of the Contaminant***

**WT-917**

Characteristics of Castle radioactive fallout were investigated in great detail. Results from observations and analyses are reported.

***Project 2.6b, Radiochemical Analysis of Fallout***

**WT-918**

This project determined the physical and chemical characteristics of the radioactive fallout material from Castle. Particle size measurements were made and the samples were tested for presence of various radionuclides. Physical, chemical, and radioactive characteristics of fallout samples are reported.

***Project 2.7, Distribution of Radioactive Fallout by Survey and Analysis of Sea Water***

**WT-935**

Measurements of radioactivity in ocean waters on the surface and at various depths were made over periods of several days after Yankee and Nectar. The activity was found to be high. Tables of measurements of radioactivity as a function of time and sample source location are reported. The information is well-organized and presented clearly.

***Project 2.7a, Radioactivity of Open-Sea Plankton Samples***

**WT-954**

The objective of this project was to determine if various types of plankton and microorganisms in the ocean adjacent to Bikini Atoll tended to accumulate radioactivity. Some organisms had activity 1,000 times greater than their seawater environment. Radioactivity levels for a variety of organisms are reported.

***Project 14.1, External Neutron Measurements***

**WT-952**

Measurements of activation in several materials were used to determine neutron output up to 2,000 yards or more from the detonation.

**STRUCTURES, EQUIPMENT, AND TECHNIQUES—PROGRAM 3**

***Project 3.1, Air Pressure Measurements***

**WT-919**

A 6- by 6- by 12-foot concrete structure was instrumented with pressure gauges to assess loads generated by a nuclear airblast. Free-field dynamic pressure and overpressure measurements were made near the structure. Experiments were performed during Koon. The device yield was



much lower than predicted; therefore, measured data are of little value. Pressure-time traces and data tables are presented. Comparisons are made with previous, similar experiments.

***Project 3.2, Crater Survey***

**WT-920**

Measurements were made of the crater dimensions for Bravo, Koon, and Union. Crater dimensions and crater prediction techniques are presented.

***Project 3.3, Blast Effects on Tree Stand***

**WT-921**

The objective of this project was to assess the effects of nuclear airblast on tree stands, and, conversely, to determine the effects of tree stands on airblast wave shape. Pre- and posttest surveys were made of tree stands on three Bikini islands for Bravo and Koon. Dynamic and static pressure gauges were fielded in and around the stands, and some trees were instrumented with deflection gauges. Gauge readings and tree damage are reported, and pretest and posttest photographs are presented.

***Project 3.4, Sea Minefield Neutralization by Means of Surface Detonated Nuclear Explosion***

**WT-922**

Naval mines were deployed in the vicinity of Union to evaluate nuclear explosions for clearing minefields. High explosives were removed from 121 mines, which were then deployed in water out to ranges of 13,000 feet from GZ. Condition of the recovered mines is reported.

***Project 3.5, Blast Effects on Miscellaneous Structures***

**WT-901**

The objective of this project was to record and report inadvertent damage to buildings at Bikini due to the unexpectedly high yield of the Bravo device. The Bravo yield was about 2.5 times greater than predicted, and many support buildings were within the Bravo explosion damage radius. Structural damage is described, and numerous photographs of damaged buildings are presented.

**BIOMEDICAL—PROGRAM 4**

***Project 4.1, Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation***

**WT-923**

This project assessed the damage to the human beings accidentally exposed to high levels of radioactive fallout from the Bravo test and also provided necessary medical care. No biomedical program had been planned for the Castle operation; hence, this program was hastily organized after Bravo. WT-923 provides detailed medical descriptions of the observed injuries and treatments over the first 76 exposure days. A series of addenda documented other aspects of the exposure and the effects.

***Project 4.1 Addendum, Nature and Extent of Internal Radioactive Contamination of Human Beings, Plants, and Animals Exposed to Fallout***

**WT-936**

***Project 4.1A Addendum, Medical Examination of Rongelap People Six Months After Exposure to Fallout***

**WT-937**

***Project 4.1 Addendum, Exposure of Marshall Islands and American Military Personnel to Fallout***

**WT-938**

***Project 4.1 Addendum, Physical Factors and Dosimetry  
in Marshall Island Radiation Exposure***

**WT-939**

**SERVICE EQUIPMENT AND TECHNIQUES—PROGRAM 6**

***Project 6.1, Test of Interim IBDA Procedures***

**WT-924**

The objective of this project was to determine if Indirect Bomb Damage Assessment (IBDA) procedures and equipment used for atomic bursts would work for thermonuclear detonations. Radar observations were made for all Castle nuclear detonations. Radar scope photos for the nuclear bursts are presented.

***Project 6.2a, Blast and Thermal Effects on Aircraft in Flight***

**WT-925**

This project evaluated the performance of the B-36 aircraft in harsh nuclear environments. The B-36 was flown for all Castle tests and was instrumented for blast and thermal environments and responses. Temperatures, pressures, bending moments, shears, and accelerations are reported along with photos of damage.

***Project 6.2b, Thermal Effects on B-47 Aircraft in Flight***

**WT-926**

This project was to study nuclear weapon effects on a B-47B aircraft. The test aircraft flew for Bravo, Romeo, Koon, Union, and Nectar. Since thermal effects were of utmost concern, the reported data consist primarily of thermal environment, thermal strains, and aircraft component temperatures during nuclear exposure.

***Project 6.4, Proof Testing of Atomic Weapons Ship Countermeasures***

**WT-927**

The effectiveness of countermeasures to radioactive fallout is assessed. Remotely controlled ships sailed through fallout areas. One ship was equipped with washdown equipment. Gamma-ray activities at various locations are presented, and comparisons of residual activity on two ships are reported.

***Project 6.5, Decontamination and Protection***

**WT-928**

The objective of this project was to expose common construction materials to radioactive fallout and to evaluate the effectiveness of different decontamination techniques for those materials. Exposed on remotely controlled ships, the material included wood, metal, concrete, asphalt, and brick. Measurements of contamination and clean-up procedures are presented.

***Project 6.6, Effects of Nuclear Detonations on the Ionosphere***

**WT-929**

The project was tasked to assess the effects of high-yield nuclear weapons on the ionosphere (and therefore on communications) by probing the ionosphere at close and far ranges during and after detonation. Data and hypotheses of phenomena are presented.

**LONG RANGE DETECTION—PROGRAM 7 AND RELATED EXPERIMENTS**

***Project 7.1, Electromagnetic Radiation Calibration***

**WT-930**

Detailed measurements of electromagnetic signals from the Castle detonations were made at various ranges from the test sites. It was found that considerable information about the devices could be derived. Data and analytical processes are presented.

***Project 7.2, Detection of Airborne Low-Frequency Sound  
from Nuclear Explosions***

**WT-931**

Measurements of low-frequency sound waves were made at remote locations around the world for all Castle events. Sensor locations and descriptions of signals received are presented.

***Project 7.4, Nuclear Calibration Analysis of Atomic Device Debris***

**WT-932**

Nuclear debris from the Castle events were collected at close and long ranges and analyzed for chemical and isotope content. These measurements were then associated with known characteristics of the detonated devices to calibrate the nuclear device assessment model. Analyses of collected debris are presented.

***Project 15.2, Electromagnetic Measurements***

**WT-949**

EMP measurements were attempted using large antennas at ranges to 200 miles. Some appear to have been successful.

**CLOUD PHOTOGRAPHY—PROGRAM 9 AND RELATED EXPERIMENTS**

***Project 9.1, Cloud Photography***

**WT-933**

The objective of this project was to measure nuclear cloud phenomena for the Castle events. Filming was done from four aircraft. No data were collected for Koon due to cloud cover. Details of nuclear cloud characteristics as a function of altitude and time after detonation are presented, along with photographic coverage.

***Projects 13.1, 13.2, 13.3, and 23.2, Technical Photography***

**WT-955**

High-speed film cameras were used to provide nuclear yield and device characteristics for the Castle events. Measurements of fireball dimensions vs time, and cloud dimensions with time and altitude are reported. Photographic documentation is provided.

***Documentary Photography***

**WT-943**

Remotely operated ground-based and motion picture cameras in orbiting airplanes were used to document the detonations. A few examples are provided in the cited WT and a photo plan for Bravo only is included.

***Project 1.1c, Base Surge Measurements by Photography***

**WT-903**

This project intended to photograph the early cloud in order to study base surge phenomena but as the shots were all pre-dawn or in bad weather, no data for analysis exist. However, the project report does reproduce some later time (h + 25 minutes) cloud photos for several events as well as radar scope (PPI) photos of several of these events at about h + 15 minutes.

***Total Hydrodynamic Yield***

**WT-947**

Early-time fireball pictures were analyzed for growth dimensions, which are used in yield estimations. Report contains examples of these photos and discusses anomalies and presents tabulations of dimensions.

**SECTION 13**  
**TEAPOT**  
**Nevada Test Site**  
**1955**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield (KT)</u>	<u>Weapon Placement</u>
Wasp	Feb 18	Yucca Flat, Area 7	1	Airdrop (HOB, 762 feet)
Moth	Feb 22	Yucca Flat, Area 3	2	300-foot tower
Tesla	Mar 1	Yucca Flat, Area 9	7	300-foot tower
Turk	Mar 7	Yucca Flat, Area 2	43	500-foot tower
Hornet	Mar 12	Yucca Flat, Area 3	4	300-foot tower
Bee	Mar 22	Yucca Flat, Area 7	8	500-foot tower
ESS	Mar 23	Yucca Flat, Area 10	1	Buried (DOB, 67 feet)
Apple 1	Mar 29	Yucca Flat, Area 4	14	500-foot tower
Wasp Prime	Mar 29	Yucca Flat, Area 7	3	Airdrop (HOB, 740 feet)
HA	Apr 6	Yucca Flat, Area 1	3	Airdrop (HOB, 36,600 feet MSL)
Post	Apr 9	Yucca Flat, Area 9	2	300-foot tower
MET	Apr 15	Frenchman Lake	22	400-foot tower
Apple 2	May 5	Yucca Flat, Area 1	29	500-foot tower
Zucchini	May 15	Yucca Flat, Area 7	28	500-foot tower

**BACKGROUND.**

Concern for an evolving Soviet nuclear bomber force was a prime motivator for DoD experiments in Operation Teapot. The Nike-Hercules nuclear-tipped rocket for intercepting bombers was under development, but there was lack of agreement as to what kill mechanism should be employed—bomber kill, crew kill, or nuclear warhead melt. A significant portion of the Teapot experiments addressed these issues. The other major experimental thrust was toward resolving uncertainties surrounding airblast phenomenology. As in previous NTS series, there was an exercise for troop orientation and indoctrination. This was designated Desert Rock VI and had over 6,000 participants.

Even though there were nuclear weapon effects experiments for all the Teapot events, three of these were designated as DoD nuclear effects tests. ESS (Effects SubSurface) was designed as a subsurface burst to provide information on nuclear cratering applicable to disabling Soviet airstrips. HA (High Altitude) was designed to provide nuclear environment information in the 30,000- to 40,000-foot altitude regime where Soviet bombers might be expected to cruise. It would have been preferable if nuclear effects data on bomber-type aircraft could have been acquired in the HA event, but controlling drone bombers with great precision at such high altitudes was considered too difficult. Therefore, a low-altitude nuclear test was employed for aircraft effects data. MET (Military Effects Test) was designed to provide blast environments for drone aircraft to assess shock damage. ESS was detonated at 67 feet below ground, HA at 36,600 feet above sea level, and MET 400 feet above ground level.

In the HA event, pressure measurements ranged from 800 psi (200 feet from detonation) down to 0.14 psi at 11,300 feet from the detonation. Highly instrumented drone airplanes flew near the MET burst. Overall, a large number of aircraft were involved, either for diagnostics or effects studies.

Studies of airblast propagation over various media were performed. Media included desert (where dust would be entrained in the shock wave), asphalt (where a precursor wave would form but without dust entrainment), and water (where no precursor would form). Creating the water field was particularly interesting. A lake hundreds of feet wide, a few thousand feet long, and less than a foot deep was made before the test but the grading was somewhat uneven and there were dry islands left. Test delays caused the lake to evaporate and seep into the desert.

Specific programs, each encompassing a number of individual experiments, included:

Program 1—Blast and Shock Measurements

Program 2—Nuclear Measurements and Effects

Program 3—Blast Effects on Structures and Equipment

Program 5—Effects on Aircraft

Program 6—Tests of Service Equipment and Operations

Program 8—Thermal Measurements and Effects

Program 9—Technical Photography

Program 32—Exposure of Food and Foodstuffs to Nuclear Radiation.

## OPERATION TEAPOT PROJECTS AND REPORTS

### SUMMARY REPORTS

WT-1153, WT-1158

A technical summary of military effects was prepared by the Armed Forces Special Weapons Project (AFSWP). This report (WT-1153) summarizes the AFSWP projects and presents selected results extracted from the project reports. A summary emphasizing the operational aspects was published as WT-1158.

### BLAST AND SHOCK MEASUREMENTS—PROGRAM 1

#### *Project 1.1, Measurement of Free Air Atomic Blast Pressures*

WT-1101

The objectives of this project were to measure peak free-air overpressure as a function of time and distance above low-altitude detonations, and to measure peak overpressure vs distance for a high-altitude burst. Parachute-borne canisters containing pressure gauges were deployed by aircraft for Turk, Apple, and HA. Overpressures from a few tenths to over 10 psi were measured. Overpressure traces, canister positions, and shock arrival times are presented.

#### *Project 1.2, Shock Wave Photography*

WT-1102

The objective of this project was to determine nuclear airblast pressure as a function of distance for HA, and to study the effects of ground heating on the formation and propagation of airblast waves. Peak pressures were calculated from measurements of airblast arrival time at points in

space as determined by optical techniques. High-speed cameras were used to observe shock fronts. Measurements were performed for Wasp, Tesla, Turk, Bee, Apple, Wasp Prime, HA, and MET. WT-1102 contains tabulated data of airblast arrival-time measurements as well as analysis for converting these measurements to overpressure.

***Project 1.3, Ground-Level Microbarographic Pressure Measurements from a High-Altitude Shot***

**WT-1103**

Measurements were made of the incident and reflected airblast overpressures near ground level during HA. Gauges were placed tens of feet aboveground to measure both incident and reflected waves. Ground range for gauge sites was from near GZ out to 135,000 feet. Pressure measurements, arrival times, and data traces are presented.

***Project 1.4, Preshock Sound Velocities Near the Ground in the Vicinity of an Atomic Explosion***

**WT-1104**

This experiment measured preshock sound speed at 1.5, 3 and 6 feet aboveground over various ground media during MET. Media included desert soil, water, asphalt, concrete, fir boughs, and ivy. Speed of sound measurements are reported.

***Project 1.6, Crater Measurements***

**WT-1105**

This project mapped the "true" crater from ESS using colored pillars to indicate crater depth. Colored sand columns buried vertically in the ground were sheared off at the true crater interface. True and apparent crater measurements are reported.

***Project 1.7, Underground Explosion Effects***

**WT-1106**

This project was tasked to measure overpressure, earth acceleration, earth stress and strain, and permanent earth displacement for ESS. The report includes gauge traces plus experiments from other nuclear and high-explosive tests and extensive discussions of theory.

***Project 1.9, Material Velocity Measurements of High-Altitude Shot***

**WT-1108**

The objective of this project was to attempt to infer close-in characteristics of a nuclear airblast through observations of smoke puffs in the vicinity of the HA detonation. Because the smoke puffs were not positioned correctly, no useful data were recorded. This concept for blast wave diagnostics is described.

***Project 1.10, Airblast Overpressure and Dynamic Pressure Over Various Surfaces***

**WT-1109**

These experiments were performed for Bee and MET. The objective was to measure characteristics of airblast traveling over desert, water, and asphalt media. Overpressure and dynamic pressure measurements were made at ground level, and at heights of 3 and 10 feet at various distances from GZ. Numerous data traces as well as extensive data analyses and correlation are presented.

***Project 1.11, Special Measurements of Dynamic Pressure Versus Time and Distance***

**WT-1110**

These experiments were performed during MET for blast waves traveling over desert, water, and asphalt. The objective of this project was to measure pitch and yaw of a propagating blast wave

and to determine the contributions of entrained dust to measured dynamic pressure. Gauge descriptions, gauge traces, and data analyses are presented.

***Project 1.12, Drag-Force Measurements***

**WT-1111**

The objective of this project was to measure the drag forces on simple spheres exposed to blast waves propagating over desert, water, and asphalt media in the MET event. Spheres measuring 3 and 10 inches were mounted on strings 3 feet above ground. Three component force gauges were installed in the spheres. WT-1111 contains refined data from MET and wind tunnel results from sensor development tests. See Project 1.14a (WT-1114).

***Project 1.13, Dust Density Versus Time and Distance in the Shock Wave***

**WT-1113**

The project had a twofold objective: to measure air density and to characterize the dust in the shock wave at heights of 3 feet and 10 feet over desert and asphalt media. Measurements were made at the 2,000-, 2,500-, and 3,000-foot stations of MET. Measured densities and particle content are reported.

***Project 1.14a, Transient Drag Characteristics of a Spherical Model***

**WT-1114**

This project measured the drag forces on simple spheres exposed to blast waves traveling over desert, water, and asphalt media of MET. Spheres measuring 3 and 10 inches were mounted on strings at 2,000, 2,500, 2,750 and 4,500 feet from GZ. Strain gauges were used to determine the loads on the spheres. Drag coefficients computed from strain measurements are reported.

***Project 1.14b, Measurements of Air-Blast Phenomena with Self-Recording Gauges***

**WT-1155**

Self-recording gauges were used to measure blast-wave parameters along blast lines. The gauges measured overpressure vs time, and dynamic pressure vs time. The report provides a large number of gauge traces.

***Project 33.4, Distribution and Density of Missiles from Nuclear Detonations***

**WT-1168, -1217**

The objective was to study the properties of secondary missiles produced in houses, shelters, and open areas by the blast wave of Apple 1 and Apple 2. Missiles were trapped in styrofoam and masses, velocities, and distributions were analyzed statistically.

***Project 39.2, Static and Dynamic Overpressure Measurements***

**ITR-1192**

This project provided measurements of pressure for Apple 1 and Apple 2 for use by the civil defense projects. Some temperature and noise measurements were also made. ITR-1192 contains plots of pressure vs distance from GZ plus pressure-time traces, both free-field and in-shelter.

**NUCLEAR MEASUREMENTS AND EFFECTS—PROGRAM 2 AND RELATED AEC EXPERIMENTS**

***Project 2.1, Gamma Exposure Versus Distance***

**WT-1115**

The objective of this project was to measure the gamma radiation environment in the vicinity of the nuclear bursts of all Teapot events. Film badge dosimeters were employed. Measured total gamma doses as a function of distance are reported.

***Project 2.2, Neutron Flux Measurements***

**WT-1116**

This project was to measure the neutron flux and spectrum as a function of distance for all Teapot events. Neutron activation of gold, sulfur, and fissile materials provided flux and energy distribution data. Neutron environments in the vicinity of the HA event were measured by sensors in parachute-borne canisters. Measured neutron environment vs distance are reported.

***Project 2.3a, Neutron-Induced Radioactive Isotopes in Soils***

**WT-1117**

The activity of soil samples taken from Wasp, Tesla, Turk, and ESS GZs was measured to assess the radioactivity generated through exposure to neutrons from a nuclear detonation. Additionally, ten soil samples brought from various locations in the United States were exposed to the neutrons of the Hornet test. Sodium and manganese activity were measured. Soil analyses and activities are presented.

***Project 2.3b, Gamma Radiation Field Above Fallout Contaminated Ground***

**WT-1225**

The objective of this project was to measure the spectrum and intensity of gamma radiation 3.5 feet above a field contaminated with radioactive fallout and attempt to relate those gamma measurements with gamma-ray sources in the fallout soil. The experiment was performed for ESS. Extensive data analysis and interpretation are presented.

***Project 2.4, Gamma Dose Rate versus Time and Distance***

**WT-1118**

This project mapped the gamma radiation intensity in the vicinity of five Teapot events, including ESS, the subterranean cratering burst. Instruments included scintillation detectors and ion-chamber detectors. Gamma dose rate as a function of time and distance are reported.

***Project 2.5.1, Fallout Studies***

**WT-1119**

Soil and airborne particle activity was measured hours and days after detonation of ESS. Mapping of radioactive fallout and particle size measurements were made near GZ shortly after detonation. Extensive data on radioactivity measured as a function of position and time are presented.

***Project 2.5.2, Distribution and Intensity of Fallout  
from the Underground Shot***

**WT-1154**

The objective of this project was to map the radioactive fallout from ESS. Sampling was performed at numerous ground stations. Multiple samples were taken from individual stations to assess the accuracy of measuring a single sample. A variety of collectors were employed. Test procedures and measured activity as a function of location and time were reported.

***Project 2.6, Radiation Energy Absorbed by Human Phantoms  
in a Fission Fallout Field***

**WT-1120**

The project placed mannequins with absorption characteristics similar to the human body in a nuclear environment and measured body absorption of radiation. While not reported, it is likely that the samples were exposed to ESS. Data and results from this experiment are obscure. The concern seems to be that there might be considerable beta radiation present in the fallout field that is not measured through normal monitoring techniques.



***Project 2.7, Shielding Studies***

**WT-1121**

This study was to determine the degree of shielding from nuclear radiation provided by foxholes, covered bunkers, and armored vehicles. Experiments were fielded in 9 of 14 Teapot events. Film and chemical dosimeters were used to measure total gamma dose inside and outside shelters. Neutron activation sensors (gold, sulfur, and fission threshold) were employed to measure neutron environments. Measured radiation environment data and shielding analyses are presented.

***Project 2.8a, Contact Radiation Hazard Associated with Contaminated Aircraft***

**WT-1122**

The project was tasked to determine if standard radiation meters adequately described the hazard to personnel who came into contact with aircraft that had penetrated radioactive clouds. Data, results, and conclusions are obscure.

***Project 2.8b, Manned Penetrations of Atomic Clouds***

**WT-1156**

The objectives of this project were to measure the radiation aircraft personnel would receive when flying through radioactive clouds and also to experience the flight conditions inside the cloud. Seven manned aircraft cloud penetrations were made for five events. The highest individual radiation dose was 17r. Flight conditions and measured radiation doses are reported.

***Project 13.3a, Gamma Radiation as a Function of Distance***

**WT-1208**

The objective of this project was to measure the gamma radiation environment at various ranges from GZ for Bee, Apple 1, Wasp Prime, Apple 2, and Zucchini using a variety of dose-measuring devices. Environments and comparisons of sensor performance are reported.

***Project 24.1, External Neutron Measurements***

**WT-1221**

Measurements of neutrons received at close in carefully collimated instrument stations are presented for the Post shot. Interest was in weapon development.

***Project 30.1, Measurement of Off-Site Fall-Out by Automatic Monitoring Stations***

**WT-1186**

Interest in instrumentation but histograms of infinite [gamma] dose are given for a number of off-site locations.

***Project 30.2, Utilization of Telemetering Technique in Evaluating Residual Radioactive Contamination***

**WT-1182**

The purpose of this experiment was to test various ways to send or relay information and therefore the main results are of interest only to students of 1950's communications technology. However tables of maximum fallout rates for a number of close in and far out stations is presented with times of maximum. Data is for ten shots.

***Project 37.1, Factors Influencing the Biological Fate and Persistence of Radioactive Fallout***

**WT-1177**

Samples of soils, plants, and animals were collected in fallout areas of the Teapot tests. The nature of the fallout particulate matter was assessed, and the locations and intensities of radioactive materials in various animals were determined.

***Project 37.2, Distribution and Characterization of Fall-out and Airborne Activity from 10 to 160 miles from Ground Zero, Spring 1955*** **WT-1178A**

The objective was to characterize and understand the nuclear fallout phenomena. Extensive collections of air and soil samples were made for Tesla, Turk, Bee, Apple 1, MET, and Apple 2. The cloud movements were monitored to guide the collectors. Physical and chemical characteristics of the collected particles were measured. Numerous tables of fallout activity, as a function of location and time, are presented.

***Project 37.2, Beta Skin-Dose Measurements by Specially Designed Film-Back Dosimeters*** **WT-1178**

This project tested a film badge capable of measuring beta radiation levels. Experiments were performed for Turk, Apple 1, MET, and Apple 2. The report contains a description of the monitor and readings acquired in the tests.

***Project 37.3, Evaluation of the Acute Inhalation Hazard from Radioactive Fall-Out Materials by Analysis of Results from Field Operations and Controlled Inhalation Studies in the Laboratory*** **WT-1172**

Rabbits and rats were placed in radioactive fallout environments and studied for adverse effects.

***Project 38.1, Civil Defense Monitoring Techniques*** **WT-1164**

The objective of this project was to develop and evaluate techniques for radiation monitoring during civil defense emergencies. Aerial, automotive, and ground monitoring techniques were employed. Some radiation mapping is presented.

***Project 38.3, Evaluation of Civil Defense Radiological Defense Instruments*** **WT-1190**

Although the main emphasis of this project was on potential instrument material some dose information for close-in stations is presented.

***Project 39.1, Gamma and Neutron Radiation Measurements*** **WT-1174**

Film dosimeters and activation materials mainly in structures and shelters recorded gamma and neutron radiation from eight events. Results are tabulated and presented.

***Project 39.5, Measurement and Permanent Recording of Fast Neutrons by Effects of Semiconductors*** **WT-1170**

The objective of this project was to demonstrate that changes in the properties of germanium crystals after exposure to a nuclear environment could quantify the fast neutron field. Twenty-five hundred detectors were deployed for Wasp, Moth, Bee, HA, Apple 1, and Apple 2. Conductivity change as a function of environment is represented. This information could be of use in the study of radiation effects on crystals.

***Project 39.6, Measurement of Initial and Residual Radiations by Chemical Means*** **ITR-1174**

Chemical dosimeters and film packs were used to measure gamma and neutron radiation on site for many of the Teapot tests.

***Project 39.7, Physical Measurement of Neutron and Gamma Radiation Dose from High Neutron Yield Weapons and Correlation of Dose with Biological Effects***

**ITR-1167**

Tests were performed for Wasp, Hornet, Bee, and Wasp Prime measuring the nuclear radiation free-field and inside blast-shielded chambers containing mice. Radiation monitors were evaluated and radiation effects on mice are reported.

***Project 39.7 (Part 2), Ionization Chamber Dose Measurements in Lead Hemispheres***

**WT-1228**

This experiment measured effects on the insulators in ionization chambers used in detecting radiation. Dose vs distance curves are derived for several shots.

***Radiological Safety***

**WT-1166**

A Rad-Safe group was responsible for monitoring the radiation levels in the vicinity of the Teapot nuclear tests. WT-1166 contains radiation contours as a function of time for the various nuclear events.

**EFFECTS ON STRUCTURES AND EQUIPMENT—PROGRAM 3 AND RELATED AEC EXPERIMENTS**

***Project 3.1, Response on Drag Type Equipment Targets in the Precursor Zone***

**WT-1123**

Common battlefield hardware was exposed to precursor and nonprecursor nuclear blast waves. The observed response of such hardware was used as an indication of blast wave phenomenology. Jeeps had been exposed in prior tests and were therefore used extensively in 9 of 14 Teapot events. Jeeps were exposed to blast waves that had propagated over desert, water, and asphalt media for MET. Jeep translation and rollover are reported, along with photographic records.

***Project 3.2, Study of Drag Loading of Structures in the Precursor Zone***

**WT-1124**

This project measured the blast loads on four identical structures at the same distance from a nuclear burst but with different intervening surface media that might affect the blast waveform. The concrete structures were located 2,000 feet from MET GZ. Pressure measurements were made on the front and back of each structure. Media for airblast propagation included water, asphalt, compacted desert soil, and loosened desert soil. Pressure records are presented.

***Project 3.3.1, Flexible Measuring Devices and Inspection of Operation Jangle Structures***

**WT-1125**

The objective of this project was to determine the relationship between the flexibility of a structure and the ground-shock loads experienced by the structure. Structures exposed during ESS and Operation Jangle are discussed. The experiment description in WT-1125 is unclear, but extraction of useful pressure and structural response data might be possible.

***Project 3.3.2, Behavior of Underground Structures Subjected to an Underground Explosion***

**WT-1126**

Two concrete structures were buried in the vicinity of the ESS test. The project investigated the loads delivered to buried structures by an underground nuclear explosion and the response of the structures to the loads. Instrumentation included earth stress gauges, earth acceleration gauges,

deflection gauges, structure pressure gauges, and structure acceleration gauges. WT-1126 contains data listings, traces, and a discussion of results.

***Project 3.4, Air Blast Effects on Underground Structures***

**WT-1127**

This project, a continuation of similar tests in Upshot-Knothole, determined the nature of the forces transmitted through earth to buried structures from a nuclear detonation in air. Three concrete boxes with steel beam roofs were buried with roof levels 1, 4, and 8 feet below ground level. The structures were all the same distance from MET GZ. Surface pressure and beam deflection are reported.

***Project 3.6, Evaluation of Earth Cover as Protection to Above Ground Structures***

**WT-1128**

Two full-scale structures and six smaller model structures were tested for MET. Assessment was made of the capability of earth-covered corrugated steel structures to provide blast and radiation protection to personnel. Deflection gauges and radiation monitors were employed. WT-1128 contains photographs and analyses of damage, as well as comparison with the results from Upshot-Knothole.

***Project 3.7, Effect of Positive Phase Length of Blast on Drag and Semidrag Industrial Buildings, Part One***

**WT-1129**

The objective of this project was to determine how damage to a drag-type structure changes as a function of the shape of the positive blast wave from a nuclear explosion. This objective required participation in a low-yield test during Teapot and a high-yield shot of Redwing. Four structures, each 30 feet high by 40 feet wide, were exposed to MET. Instrumentation included deflection gauges, strain and acceleration gauges, and pressure-time gauges. Refined data and analyses are presented.

***Project 3.8, Test of Concrete Panels***

**WT-1130**

The objective of this project was to assess the response of concrete panels to nuclear blast loads. Plain and rib-reinforced concrete panels were tested at two different ground ranges of MET. Pressure, deflection, acceleration, and strain measurements were made. Refined data and extensive analyses are presented.

***Project 3.9, Response of Small Petroleum Products Storage Tanks***

**WT-1131**

Four small steel petroleum tanks, left over from a previous test, were exposed to a nuclear blast environment. These items were placed at four different ranges from MET GZ. The tanks were not instrumented. Damage descriptions and photographs are provided.

***Project 3.10, Structures Instrumentation***

**WT-1107**

The objective of this project was to provide structural instrumentation for Projects 3.2 (WT-1124), 3.4 (WT-1127) and 3.7 (WT-1129). Samples of pressure-time, displacement-time, acceleration-time, and strain-time data traces for these projects are presented.

***Project 31.1, Damage to Conventional and Special Types of Residences Exposed to Nuclear Effects***

**WT-1194**

A variety of houses were tested for the effects of a nuclear detonation. One- and two-story houses of wood, brick, masonry block, and reinforced concrete were exposed at airblast levels

from 1.7 to 5.1 psi during Apple 2. Ten houses were tested. Pretest and posttest photography is provided.

***Project 31.2, Damage to Commercial and Industrial Buildings Exposed to Nuclear Effects***

**WT-1189**

The objective of this project was to expose a variety of full-size industrial structures to a nuclear blast wave in order to assess their survivability. The buildings were exposed during Apple 2 at overpressure levels ranging from 1.3 to 4.1 psi. Extensive photographic coverage and analyses are presented.

***Project 31.4, Comparison of Responses of Structural Slabs to Static and Atomic Blast Loadings***

**IIR-1195**

Dynamic deflection of slabs in a nuclear environment was measured and the static load that would cause the same deflection was determined. Concrete, steel, and cellular steel slabs were placed over pits at the 1-, 5-, and 10-psi stations of a Teapot event. Deflections were measured. After the nuclear test, identical slabs were statically loaded to create the same deflections. Deflection loads and photographs are presented.

***Project 33.1, Biological Effects of Pressure Phenomena Occurring Inside Protective Shelters Following a Nuclear Detonation***

**WT-1179**

This project studied the biological effects of high airblast nuclear overpressures inside shelters. Animals in various shelters were exposed in two Teapot events. Observations and biological effects are reported.

***Project 33.2, The Effects of Noise in Blast-Resistant Shelters***

**WT-1180**

This project assessed the effects of nuclear explosion noise on rats in blast-resistant shelters. Exposures were made in two Teapot events. Biological observations are reported.

***Projects 34.1 and 34.3, Effects of an Atomic Explosion on Group and Family Type Shelters***

**WT-1161**

The objective of these projects was to test the adequacy of a wide variety of shelters in providing protection against a nuclear explosion. Structures included large underground shelters, basement shelters, aboveground concrete and masonry block shelters, bathroom shelters in frame houses, and basement shelters in brick houses. Pressure, temperature, noise, gamma-ray, and neutron radiation were monitored. No structural response gauges were employed. Experiments were fielded in Apple 1 and Apple 2. WT-1161 contains descriptions of the structures, measured environments, and extensive pretest and posttest photography. Identical data are presented in WT-1218.

***Project 34.2, Effects of a Non-Ideal Shock Wave on Blast Loading of a Structure***

**WT-1162**

This experiment was designed for observation of the response of a 6- by 6- by 36-foot concrete structure to a non-ideal blast load. The structure, with the 36-foot span facing GZ, was deployed 1,850 feet from Turk GZ. Pressure gauges were installed on and around the structure, which was demolished by the blast. Pressure measurements and photographs are presented.

***Project 34.4, Nuclear Effects on Machine Tools***

**WT-1184**

A variety of machine tools were exposed inside and outside of buildings during a Teapot nuclear test. Considerable damage by flying debris was observed. WT-1184 contains photographic records.

***Project 35.1, Effects of Atomic Weapons on Electric Utilities***

**WT-1173**

The objective was to evaluate damage that would be sustained by electrical power station apparatus in a nuclear detonation and procedures required to accomplish repairs. Two identical electrical facilities, plus transmission apparatus, were exposed at two different ranges from Apple 2 GZ. Damage description is primarily pictorial.

***Project 35.2, The Effects of a Nuclear Explosion on Commercial Communications Equipment***

**ITR-1193**

The project was to determine the nuclear survivability of the elements of civilian radio and communication systems. Experiments were performed at two Apple 2 stations. Test hardware included mobile radio communications units, AM transmitters and receivers, antenna towers, electrical components, and sirens. Response of test items is described.

***Project 35.4a, Effects of a Nuclear Explosion on Typical Liquefied Petroleum Gas (LP Gas) Installations and Facilities***

**WT-1175**

This project tested the response of ordinary LP gas tanks and facilities to a nuclear environment. Filling facilities and a large number of storage tanks up to 18,000 gallons in size were exposed to Apple 2. The tanks demonstrated a high degree of survivability. Photographs and damage descriptions are presented.

***Project 35.4b, Effects of a Nuclear Explosion on Typical Natural and Manufactured Gas Underground and Above-Ground Installations, Including Appliances in Houses***

**WT-1176**

The objective of this project was to determine the effects of a nuclear explosion on ordinary natural gas installations and appliances. Underground and aboveground facilities were exposed at various distances from Apple 2 GZ. Descriptions of test hardware response and photographs are presented.

***Projects 36.1 and 36.2, Exposure of Mobile Homes and Emergency Vehicles to Nuclear Explosions***

**WT-1181**

Mobile homes and emergency vehicles were exposed at various distances from Apple 2 GZ. Photographs, damage descriptions, and implications are presented.

**EFFECTS ON AIRCRAFT—PROGRAM 5**

***Project 5.1, Destructive Loads on Aircraft in Flight***

**WT-1132**

Three QF-80 drone aircraft were flown in the vicinity of the MET detonation. The aircraft were instrumented to measure nuclear environment and structural response to a nuclear burst. All three drones survived the nuclear environment but were damaged upon landing. The data canisters were recovered. WT-1132 contains film sequences of horizontal stabilizer response to the shock wave and structure response measurements.

***Project 5.2, Structural Response of the F-84F Aircraft in Flight*** **WT-1133**

The objective was to study structural behavior of F-84 aircraft in a nuclear environment. Piloted F-84 aircraft were flown in the vicinity of Turk, Hornet, Bee, Apple, MET and Apple 2. Thermal and structural measurements were made on the aircraft. Refined data on aircraft response are reported.

***Project 5.4, Evaluation of Fireball Lethality Using Basic Missile Structures*** **WT-1134**

This project studied the thermal effects from a nuclear interceptor on an ICBM. Steel and aluminum spheres were placed at five different ranges within the MET fireball. Small samples of molybdenum, graphite, and ceramics were exposed outside the fireball. Sample weight loss and recession and posttest photography are presented.

***Project 5.5a, Effects of Nuclear Explosions on Fighter Aircraft Components*** **WT-1135**

The project measured aircraft horizontal stabilizer response to nuclear airblast loads. Six F-80 and three F-86D horizontal stabilizer assemblies were exposed to MET. They were fielded at five different stations, intended to show effects ranging from failure to undamaged. Strain and deflection gauges were employed. Extensive lists of response records, data traces, and posttest photographs are presented.

***Project 5.5b, Thermoelastic Response of an Aluminum Box Beam*** **WT-1136**

The objective of this project was to measure the nuclear thermal response of an aluminum box beam, typical of an airplane support structure. An aluminum beam, painted black to maximize thermal absorption and shielded from the blast environment, was exposed to MET in a thermal environment of 30 cal/cm<sup>2</sup>. Temperature and strain measurements were made. Data tables and traces and appendices regarding heat resistant parts and radome materials are presented.

**TEST OF SERVICE EQUIPMENT AND OPERATIONS—PROGRAM 6 AND RELATED AEC EXPERIMENTS**

***Project 6.1.1a, Evaluation of Military Radiac Equipment*** **WT-1137**

The objective of this project was to assess, under operational conditions, radiac equipment and dosimeters. Monitoring hardware was employed for Turk, Hornet, Bee, Apple, and MET. Monitor descriptions and performances are reported.

***Project 6.1.1b, Evaluation of a Radiological Defense Warning System (Project Cloudburst)*** **WT-1112**

This project was intended to test low-intensity gamma radiation sensors, thermal radiation sensors, and blast sensors that could trigger closure of air intakes for deep underground bunkers. Sensors were tested for Moth, Tesla, Turk, Hornet, Bee, and Apple. The sensors are reported to have operated satisfactorily, but little data is provided.

***Project 6.1.2, Accuracy of Military Radiacs*** **WT-1138**

The project assessed errors in field radiac equipment and determined directional properties. The test monitors were employed to measure residual radiation from MET shortly after detonation. WT-1138 contains equipment descriptions and measurements and describes sources of errors.

***Project 6.2, Radiation Effects on Selected Components and Materials***

**WT-1139**

Quantities of electron tubes, radar beacons, and crystal units were exposed to the neutron and gamma radiation from Apple and MET. Assessed was the performance of selected Signal Corps equipment and materials after exposure to nuclear weapon radiation. Electrical characteristics were measured before and after exposure. Changes in electrical characteristics are reported.

***Project 6.3, Missile Detonation Locator***

**WT-1140**

The objective of this project was to test the feasibility of a tactical system for locating the GZ of a nuclear detonation via analysis of the electromagnetic radiation. Electromagnetic signal receiving stations operated at distances of 60 and 200 miles from the test site during all Teapot events. WT-1140 concludes the feasibility of the concept and contains data and analysis.

***Project 6.4, Test of IBDA Equipment***

**WT-1141**

The purpose of this project was to acquire evaluation data for a complete Indirect Bomb Damage Assessment (IBDA) system. The system is designed to provide information to a bomber about yield and burst position of a deployed nuclear bomb. IBDA equipment was installed in B-50 and F-94 aircraft, which flew in the vicinity of 12 Teapot events. WT-1141 contains data of interest only to those intimately familiar with this IBDA system.

***Project 6.5, Test of Airborne Naval Radars for IBDA***

**WT-1142**

The purpose of this project was to assess the suitability of an operational naval radar for IBDA as well as provide fleet personnel with IBDA analysis experience. Two Navy aircraft using onboard radar for IBDA flew in Turk, Bee, Apple, MET, and Apple 2 with moderate success. Some radar return data are presented.

***Project 13.3c, Electromagnetic Measurements***

**WT-1223**

The objective of this project was to measure electromagnetic signals from Teapot events. Relationships are drawn between features of these signals and nuclear device operations.

***Project 16.3, Electromagnetic Observations***

**WT-1207**

This project recorded the electromagnetic signal from several Teapot shots at ranges of 10 to 19 km from GZ. Measured traces are presented for Hornet, Bee, Apple, Wasp Prime, HA, Post, MET, Apple 2 and Zucchini.

***Project 30.3, Measurements of Beta and Gamma Ray Characteristics of Shot Debris and Fall-out of Nuclear Weapons***

**ITR-1185**

The objective of this project was to determine the characteristics of radioactive debris in the vicinity of nuclear bursts and to compare ground-level radioactivity measurements obtained via aircraft with those obtained on the ground. Tests were performed at the Tesla, Turk, and Hornet sites. Soil samples were collected, and aircraft surveys were performed. Radiation measurements and analyses are presented.



## **THERMAL MEASUREMENTS AND EFFECTS—PROGRAM 8 AND RELATED AEC EXPERIMENTS**

### ***Project 8.1, Measurement of Direct and Ground-Reflected Thermal Radiation at Altitude***

**WT-1143**

The project measured the thermal energy received by aircraft at various distances from nuclear detonations. Measurements were made of direct and reflected radiation and of reflected radiation only for Turk, Bee, Apple 1, MET, and Apple 2. Thermal spectrum measurements were made. Aircraft skin temperature was measured. Considerable well-presented data and analyses are provided.

### ***Project 8.3, Protection Afforded by Operational Smoke Screens Against Thermal Radiation***

**WT-1144**

Evaluation was made of the effectiveness of an oil-fog smoke screen in attenuating nuclear thermal radiation, and the effect of thermal radiation attenuation on the nuclear blast wave. A smoke screen was generated over four of five stations ranging from 1,000 feet to 1,400 feet from Hornet GZ. Total thermal radiation and spectral measurements were made under the smoke screen at each station. Shock waveform and time of arrival were measured under the smoke screen. Refined calorimeter and shock parameter data are presented.

### ***Project 8.4a, Thermal Measurements from Aircraft in Flight***

**WT-1145**

The objective of this project was to measure the characteristics of the thermal radiation from a high-altitude nuclear burst at a high-altitude platform. The B-36 aircraft that delivered the HA device was used to measure HA thermal output, spectrum, and time between first and second pulses. WT-1145 contains thermal measurements from HA and from previous nuclear test operations.

### ***Project 8.4b, Basic Thermal Radiation Measurements***

**WT-1146**

The objective of this project was to measure the thermal radiation environment for a variety of nuclear detonations. Spectral thermal measurements as a function of time were made for Wasp, Moth, Tesla, Hornet, Bee, Wasp Prime and HA from ground stations. WT-1146 contains extensive lists of data, still photographs from motion pictures, and an analysis of results.

### ***Project 8.4c, Radiant Energy Delivered Prior to the First Minimum***

**WT-1147**

This project employed a new sensitive instrument to measure the initial part of the thermal pulse from a nuclear detonation. The instrument is described. No usable data were collected.

### ***Project 8.4d, Spectrometer Measurements***

**WT-1148**

The task for this project was to measure the thermal power and spectrum as a function of time for low-altitude and high-altitude nuclear detonations and to characterize radiant output as a function of burst altitude. Measurements were made from the ground in the Wasp, Wasp Prime, and HA events. Collection of shorter wavelength data (0.3 to 0.7 micron) was unsuccessful. WT-1147 contains refined spectral data.

### ***Project 8.4e, Air Temperature Measurements Over Several Surfaces***

**WT-1149**

This project mapped the air temperature above various surfaces exposed to a nuclear thermal environment in order to help explain blast precursor wave phenomena. Fast response devices

were used to measure air temperature from 0.5 to 10 feet aboveground over surfaces of desert, water, asphalt, ivy, fir boughs, wood and concrete. Time of interest was before shock arrival. Motion-picture coverage of surfaces response to the thermal pulse was provided. Experiments were performed for Turk and MET. Limited data were acquired. Temperature plots and film sequences are reported.

***Project 8.4f, Irradiance Measurements with High Time Resolution*** WT-1150, WT-1229

Experiments were performed for Wasp, Wasp Prime, and HA. The objective was to measure the time-resolved thermal emissions from nuclear detonations using a high-speed bolometer. Data plots clearly showing the first and second pulses are presented in WT-1150 and WT-1229.

***Project 31.5, Thermal Ignition and Response of Materials*** WT-1198

The objective of this project was to expose a wide variety of common materials to the thermal environment of a nuclear detonation to assess their flammability. Test articles included untreated and treated wooden posts, window coverings, fabrics, flammable material in containers, and a variety of plastics. Descriptions of samples and responses are not very detailed.

***Project 39.3, Thermal Radiation Measurements*** WT-1187

Measurements were made of the thermal radiation as a function of distance from a nuclear explosion. The event is not specified. Thermal flux vs distance is reported.

**TECHNICAL PHOTOGRAPHY—PROGRAM 9 AND RELATED AEC EXPERIMENTS**

***Project 9.1, Technical Photography*** WT-1151

The objective of this project was to provide photographic support as needed by the various programs. WT-1151 contains a listing of all photographic activities for Teapot events, and a complete description of the photographic equipment.

***Project 9.4, Atomic Cloud Growth Study*** WT-1152

This project was to photographically document atomic cloud formation, dimensions, and rise for Teapot and correlate cloud characteristics with meteorological data. WT-1152 deals extensively with cloud characteristics and weather conditions.

***Project 10.1, Fireball Yields*** WT-1230

Fireball growth at early time as measured from high-speed film are tabulated for ten of the Teapot shots.

***Projects 15.1 and 23.1, Technical Photography of Fireball Growth and Light Intensity*** WT-1209

In order to perform yield assessments for the Teapot events, fireball growth and light intensity were measured. Refined data plots of fireball growth are presented.

***Project 15.2, Photonephography*** WT-1220

Cloud height data for all shots except ESS are derived from films for the first ten seconds. Later cloud growth is derived and reported in Project 9.4 (WT-1152).

***Project 39.4, Technical Photography, Documentary***

High speed and still coverage of the civil effects portion of Teapot largely focussed on Apple 2 structures is reported in three reports on the general coverage (WT-1169), blast biology (WT-1197) and structure response, exterior and interior (ITR-1188).

**PROGRAM 32—EXPOSURE OF FOOD AND FOODSTUFFS TO NUCLEAR RADIATION**

**Summary of Results** **WT-1222**

Summarizes the more detailed reports cited below for Projects 32.1 through 32.5.

***Project 32.1, Effects of Nuclear Explosions on Bulk Food Staples*** **WT-1163**

A wide variety of foods were exposed to neutron, gamma, and blast effects. The effects on the foods are reported, but the events in which the experiments were fielded are not identified.

***Project 32.2, Effects of Nuclear Explosions on Canned Foods*** **WT-1212**

A wide variety of canned foods in tin and glass containers were exposed to nuclear environments in a number of settings and storage conditions. The foods were generally unaffected if the containers survived. Tables of response information and photographs are presented.

***Project 32.2a, The Effects of Nuclear Explosions on Commercially Packaged Beverages*** **WT-1213**

Soft drinks and beer in metal and glass containers were exposed to nuclear environments. Environments and observations are reported.

***Project 32.3, The Effect of Nuclear Explosions on Meat and Meat Products*** **WT-1216**

Fresh and processed meats were exposed to nuclear environments. Perishable meats were stored in cold boxes. Assessments of nuclear effects on taste and texture are reported.

***Project 32.4, The Effect of Nuclear Explosions on Semiperishable Foods and Food Packaging*** **WT-1214**

Semiperishable foods such as apples, oranges, potatoes, beans, cereals, and candy were exposed at various distances and conditions from a nuclear burst. Observations on food quality after exposure are presented.

***Project 32.5, Effects of Nuclear Explosions on Frozen Foods*** **WT-1215**

Containers of frozen foods, packed in dry ice, were placed in underground compartments and in refrigerators in test houses and exposed to a nuclear burst. The food appeared to be unaffected by the nuclear environment. Observations on food quality are provided.

**SECTION 14**  
**WIGWAM**  
**Open Pacific**  
**1955**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Wigwam	May 14	N29° W126°	30 KT	Submerged (DOB, ~2,000 feet)

**BACKGROUND.**

Wigwam was a Navy nuclear effects test. The primary objective was to study the effects of a deep underwater nuclear explosion on submerged submarines. The device was detonated at a depth of 2,000 feet about 500 miles west of San Diego, California. Three simulated submarines, referred to as SQUAWs, were towed to the test area. Each was to be attached to a barge that contained the recorders for environment and response data taken on the SQUAWs. The highly instrumented SQUAWs were to be positioned at depths of over 200 feet at various distances from the detonation. The hulls of the barges contained sensors, and buoys and balloons were to be deployed for measurements of environments.

Due to rough seas and various unforeseen events, most of the experiments of this operation were partial or total failures. One of the SQUAWs could not be submerged, and the other two were not recovered after the test. Numerous instrumentation cables broke. Instrumented buoys and balloons were lost. However, some environment and structure response data were collected.

**OPERATION WIGWAM PROJECTS AND REPORTS**

**Scientific Directors Summary Report**

**WT-1003**

This document summarizes the program goals, history, and general results. It describes each project and presents data. It also describes programs that failed to acquire data.

**UNDERWATER ENVIRONMENT—PROGRAM 1**

***Project 1.2, Underwater Free-Field Pressures to Just Beyond Target Locations***

**WT-1005**

The objective of this project was to map the peak pressure and pressure-time from 2,000 to 12,000 feet horizontally from the detonation point at ocean depths down to 2,000 feet. A variety of gauges were employed. Tables of pressure measurements at various locations and pressure-time plots are presented.

***Project 1.2.1, Free-Field Pressures, Station Zero***

**WT-1006**

The objective of this project was to measure peak pressure at various water depths very near surface zero. Pressure measurements at different depths and distances from the detonation point are reported. Raw data records are provided.

***Project 1.3, Underwater Free-Field Pressure Measurements*** **WT-1007**

This project was to measure underwater pressure at depths down to 1,000 feet at horizontal ranges from 5,000 to 50,000 feet. Some test stations were not operational at test time. Peak pressures and pressure-time profiles are presented.

***Project 1.5, Photographic Measurements of Surface Phenomena*** **WT-1009**

The project was to record the visible surface effects from a deep underwater nuclear detonation. The shock "slick," spray dome, plumes, base surge, and waves were observed and reported photographically.

**RADIOACTIVE CONTAMINATION—PROGRAM 2**

***Project 2.3, Radiochemical and Physical Chemical Properties of Products of a Deep Underwater Nuclear Detonation*** **WT-1011**

Water samples were collected at the ocean surface and at various depths after the Wigwam detonation. These samples were analyzed for radioactivity level and presence of various radionuclides. Chemical analyses and measured activities and reported.

***Project 2.4, Determination of Radiological Hazard to Personnel*** **WT-1012**

The project was to map the radiation levels, free-field and aboard ships, as a function of time after the Wigwam detonation in order to assess safe traversal of nuclear battle areas in tactical situations. Radiation measurements of the water and air were made by three ships and two aircraft. Ship decontamination exercises were performed. Radiation levels at numerous locations and times are reported, and procedures for minimizing crew exposure are discussed.

***Project 2.5, Effects of Nuclear Explosion on Marine Biology*** **WT-1013**

The objective of this project was to study the makeup of the sea food chain in the Wigwam test area to assess the possibility of radiation-contaminated fish entering fishing regions. Consumption of radioactive organisms by other sea life was studied. Measured radioactivity in a wide variety of sea life at different times after detonation is reported.

***Projects 2.6 and 2.6-1, Mechanisms and Extent of the Early Dispersion of Radioactive Products in Water*** **ITR-1064, WT-1014**

This project studied underwater mixing and distribution of radioactive materials from a deep underwater nuclear detonation. Measured activity in water at a number of locations and times after detonation are reported, but a model for predicting mixing and migration could not be developed.

***Project 2.6 (Part II), Mechanism and Extent of the Dispersion of Fission Products by Oceanographic Processes and Locating and Measuring Surface and Underwater Radioactive Contamination*** **WT-1015**

The project was tasked with locating the radioactive water mass from Wigwam weeks after detonation. It was reported that the radioactive water mass was found, but the data presentation is not clear.

***Project 2.7, Fallout and Airborne Activity in Operation Wigwam,  
with Notes on Surface Effects***

**WT-1017**

The objective of this project was to collect and measure radioactive fallout from Wigwam. Most of the collection stations were destroyed, but a small amount of data is described.

***Project 2.8 (Part II), Physical Oceanography of the Test Area***

**WT-1019**

The project mapped the ocean currents of the Wigwam test area prior to the event to support tracking of the radioactive water mass. Tracks of the active water mass are reported.

***Project 2.9, Measurement of Secondary Effects: Water Waves***

**WT-1020**

The objective of this project was to measure the water wave action from Wigwam. Project instruments were inoperative at test time, but wave analyses were performed using data from other projects.

**LOADING AND RESPONSE OF SUBMARINES AND BARGES—PROGRAM 3**

***Project 3.1 (Parts I and II), Lethal Range of Wigwam Targets  
Based on Hull Response and Applied Pressure Measurements***

**WT-1021**

The task was to measure the loads and response of simulated submarines (called SQUAWs) exposed to the Wigwam environment. Two of the SQUAWs were submerged. External pressure gauges and internal strain and displacement gauges were installed. Instrument signals were transmitted through cables to barges. There was considerable equipment failure, but numerous pressure and strain profiles are reported. Lethality assessments are presented.

***Project 3.2, Hull Response and Shock Motion—  
Background, Instrumentation, and Test Results***

**WT-1023, -1024, -1025, -1026, ITR-1073**

Velocity meters, accelerometers, shock-spectrum recorders, and displacement gauges were employed to measure the shock loading and response of hulls of three simulated submarines and three barges exposed to the Wigwam environment. Despite hardware failures, a significant amount of environment and response data was collected. Data tables and traces are reported in WT-1023, and data and analyses are reported in WT-1024, WT-1025, and ITR-1073.

***Project 3.4, High Speed Photography of the Interior of Wigwam Targets***

**WT-1027**

The objective of this project was to observe component response inside three simulated submarines during Wigwam using high-speed motion picture equipment. The two submerged SQUAWs were lost during or shortly after the test, with no film recovered. The third SQUAW was on the ocean surface, and film was recovered. Still photographs from film clips are presented.

**MEASURED AIR PRESSURE—PROGRAM 4**

***Project 4.4, Close-in Time of Arrival of Underwater Shock Wave***

**WT-1034**

This project measured blast wave time of arrival at ranges of 15 feet out to 2,000 feet from the underwater detonation. This measurement makes possible the determination of blast velocity and pressure as a function of distance from the burst. In spite of much equipment failure, some data were acquired. Blast velocities and peak pressures are reported.

***Project 4.5, Air Pressures from a Deep Underwater Burst***

**WT-1035**

The objective of this project was to measure the airblast resulting from a deep underwater nuclear burst. The concern was that the shock wave traveling through the water would reach the ocean surface and generate an air shock. Measurements were attempted from surface level up to 500 feet altitude. Due to equipment failures, pressures were recorded only at two locations and those data points are presented.

**SECTION 15**  
**REDWING**  
**Enewetak and Bikini Atolls**  
**1956**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Lacrosse	May 5	Runit Island, Enewetak	40 KT	Surface
Cherokee	May 21	Off Nam Island, Bikini	Several MT	Airdrop (HOB, 5,000 feet)
Zuni	May 28	Eneman Island, Bikini	3.5 MT	Surface
Yuma	May 28	Aomon Island, Enewetak	*	Tower
Erie	May 31	Runit Island, Enewetak	*	Tower
Seminole	June 6	Boken Island, Enewetak	13.7 KT	Surface
Flathead	June 12	Lagoon, Union site, Bikini	*	Barge
Blackfoot	June 12	Runit Island, Enewetak	*	Tower
Kickapoo	June 14	Aomon Island, Enewetak	*	Tower
Osage	June 16	Over Runit, Enewetak	*	Airdrop (HOB, 700 feet)
Inca	June 22	Lujop Island, Enewetak	*	Tower
Dakota	June 26	Lagoon, Union site, Bikini	*	Barge
Mohawk	July 3	Eleleron Island, Enewetak	*	Tower
Apache	July 9	Mike crater, Enewetak	*	Barge
Navajo	July 11	Lagoon, Union site, Bikini	*	Barge
Tewa	July 21	Over reef off Iroij, Bikini	5 MT	Barge
Huron	July 22	Mike crater, Enewetak	*	Barge

**BACKGROUND.**

The test priorities for Operation Redwing were proof testing of thermonuclear (TN) weapons, research and development for new TN weapon technology, and high-yield nuclear weapon effects. Some specific weapon development goals included demonstration of an airplane-deliverable TN bomb and research on a lightweight TN warhead that could be delivered in the nosecone of a long-range missile.

The predicted yields for the Redwing devices were too large for detonation in Nevada. Therefore, the series tests had to be performed at the Pacific Proving Ground. The higher yield tests were detonated at Bikini Atoll and the lower yields at Enewetak Atoll.

The second Redwing event, Cherokee, involved dropping a TN bomb from a B-52 aircraft. This was the first bomber deployment of a TN weapon by the United States. The Soviet Union had accomplished this feat 7 months earlier. Unfortunately, the bomb was delivered miles from the designated target. This resulted in the loss of a considerable amount of nuclear weapon effects data.

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\*yields not announced



Two years prior to Redwing, an unexpectedly extensive radioactive cloud had been created by the Castle/Bravo event, causing fallout problems over a wide area in the Pacific. The Redwing planners were sensitive to this potential problem, and major efforts were made to monitor radioactive fallout. The fallout measurements for Zuni were the most comprehensive of any nuclear test in U.S. history.

There was considerable DoD nuclear weapon effects activity in Redwing. Weapon effects and environment data were generated in the following programs:

- Program 1—Blast Effects
- Program 2—Nuclear Radiation
- Program 3—Effects on Structures
- Program 4—Biological Effects
- Program 5—Effects on Aircraft Structures
- Program 6—Studies of Electromagnetic Effects
- Program 8—Thermal Radiation and Effects
- Program 9—Supporting Photography.

## OPERATION REDWING PROJECTS AND REPORTS

### **Programs 1-9, Technical Summary of Military Effects** **WT-1344**

This document describes the broad goals of each program and summarizes each project. Data extracted from the WT reports are presented, and implications of the results are discussed.

### **BLAST EFFECTS—PROGRAM 1 AND RELATED AEC EXPERIMENTS**

#### ***Project 1.1, Ground Surface Air-Blast Pressure Versus Distance*** **WT-1301**

The objective of this project was to measure ground-level pressure profiles of nuclear blast waves that had traveled over land and over water. Measurements were made for Lacrosse, Cherokee, Zuni, Yuma, and Inca. The report contains numerous overpressure vs time and dynamic pressure-time traces, and tables of peak pressure and shock arrival time.

#### ***Project 1.2, Blast Measurements on a Medium-Yield Surface Burst*** **WT-1302**

The project task was to measure overpressure and dynamic pressure vs time in the precursor regime of a nuclear shock wave. Instrumentation was fielded in the Lacrosse event. The precursor was observed. Numerous overpressure vs time and dynamic pressure vs time traces are presented.

#### ***Project 1.3, Air Blast and Shock Phenomena by Photography*** **WT-1303**

The objective of this project was to measure the early blast wave position vs time relationship using smoke trails at known locations as a reference grid. The resultant shock velocity profile permits calculation of the peak pressure vs distance from the detonation point. Data from Zuni and Lacrosse are presented.

***Project 1.4, Free-Air Pressure Measurements at Altitude*** **WT-1304**

Twelve canisters with sensors were deployed with parachutes in the vicinity of Cherokee to measure pressures at various altitudes. Unfortunately, the bomber dropped the nuclear bomb off target, and the canisters with the pressure sensors were not in the correct positions with regard to the detonation. Some overpressure vs time data were acquired, but there was some uncertainty as to the position of the canisters at detonation time.

***Project 1.5, Transient Drag Loading of Actual and Idealized Shapes*** **WT-1305**

This project was to determine the drag loads from a nuclear burst by observing the response of hardware susceptible to drag loads. Military vehicles and structural components were deployed on the ground for Lacrosse, Yuma, Cherokee, and Zuni. Using jeeps to measure drag loads was not very successful. Photographs of damaged military equipment are presented.

***Project 1.6, Drag Loading on Model Targets*** **WT-1306**

The objective of this project was to measure the drag loads from nuclear airblast on spheres, cubes, and other geometric shapes to develop drag coefficients that could be compared with coefficients measured in laboratory facilities. The instrumented shapes were deployed at ranges from 2,500 to 5,200 feet from the Lacrosse GZ. A large number of force vs time records are presented.

***Project 1.8, Crater Measurements*** **WT-1307**

Crater radius, depth, and profiles were measured using aerial photographs and crater soundings before and after Lacrosse, Seminole, Mohawk, Zuni, and Tewa. Profiles and dimensions are reported.

***Project 1.9a, Direct Water-Wave Measurements*** **WT-1369**

Measurements were taken during Redwing to assess the water wave activity in Enewetak and Bikini Atolls. Gauges to measure bottom water pressure vs time near shores were deployed. Photography was also used. Maps of wave height at various times and locations are presented.

***Project 1.9b, Indirect Water Waves from Large-Yield Bursts*** **RW-1308**

The objective of this project was to measure water wave activity at long distances from nuclear bursts. Sensitive instruments to observe wave actions from the Bikini nuclear detonations were installed at Ailinginae, Wake, Johnston, and Enewetak. Wave heights, periods, and numbers are presented along with analyses.

***Project 1.10, Blast Over Vegetated and Cleared Areas*** **WT-1309**

The project measured and compared blast waves propagating over vegetated and sandy surfaces. Overpressure and dynamic pressure were measured for each medium during Inca. Vegetation tended to reduce the precursor. Pressure measurements are reported.

***Project 30.2, Ground-Motion Studies*** **WT-1364**

The objective of this project was to measure overpressure vs time and ground acceleration close in to nuclear bursts. Measurements were made for Lacrosse and Blackhawk. Acceleration and overpressure traces are presented.

## **NUCLEAR RADIATION—PROGRAM 2 AND RELATED AEC EXPERIMENTS**

### ***Project 2.1, Gamma Exposure Versus Distance***

**WT-1310**

The project was tasked to measure the initial and total gamma radiation doses at various distances from the Bikini tests. Some dosimeters were shielded seconds after detonation to differentiate between the prompt gamma radiation dose and the prompt plus fallout radiation dose. Total dose and early dose measurements are presented for various dosimeters and ranges.

### ***Project 2.2, Gamma Exposure Rate Versus Time***

**WT-1311**

Measurements of gamma dose rate and total gamma dose were made at various distances from the nuclear detonations of Zuni, Flathead, Navajo, and Tewa. Plots of gamma dose rate versus time at various locations are presented.

### ***Project 2.4, Decontamination and Protection***

**WT-1312**

The objective of this project was to measure the propensity of various building materials to retain radioactive debris in a fallout region and to evaluate chemicals and methods for decontamination. Panels of materials were mounted on ships exposed to fallout from Cherokee, Zuni, Flathead, Navajo, and Tewa. Since only small amounts of fallout reached the ships, few data were acquired. Plots of activity as a function of depth in materials are presented, and decontamination effectiveness for various processes is reported.

### ***Project 2.51, Neutron Flux Measurements***

**WT-1313**

Various types of neutron dosimeters were fielded for Cherokee, Yuma, Erie, Blackfoot, Kickapoo, and Osage. Neutron flux and spectrum were measured at ranges from 200 to 1,000 yards from nuclear detonations. No data was acquired from Cherokee because the bomb did not detonate at the intended location. Neutron flux vs distance is presented for various sensors.

### ***Project 2.52, Neutron Induced Soil Radioactivity***

**WT-1314**

The objective of this project was to measure soil sample radioactivity induced by the neutrons from nuclear detonations. Soil samples were exposed for Cherokee and Yuma. The failure to place the bomb at the proper location for Cherokee degraded data acquisition. The soil activities are reported, but the information is not presented clearly.

### ***Project 2.61, Rocket Determination of Activity Distribution within the Stabilized Cloud***

**WT-1315**

Rockets with sensors to measure radioactivity were fired through the nuclear clouds in Cherokee, Zuni, Navajo, and Tewa. The project was to measure the radioactivity in clouds from nuclear bursts. Radioactivity measurements were telemetered to ground-based and ship-based receivers. Measured activity at various times and positions is reported.

### ***Projects 2.62a, 2.62b, Fallout Studies by Oceanographic Methods***

**WT-1316, -1349**

The objectives of this project were to measure the radioactivity in the water and organisms in and around the Bikini Atoll before and after the Redwing tests and to study the oceanographic characteristics of the waters.

***Project 2.63, Characterization of Fallout***

**WT-1317**

Fallout samples from the Redwing Bikini tests were collected in trays on islands, rafts, and ships. The objective was to perform physical, chemical, and elemental analyses. Particle size and chemistry is reported for a large number of samples.

***Project 2.64, Fallout Location and Delineation by Aerial Surveys***

**WT-1318**

The migration of radioactive fallout over time was mapped using aircraft-mounted radiation detectors. Measurements were made after Seminole, Mohawk, Cherokee, Zuni, Flathead, Navajo, and Tewa. Numerous gamma-ray isodose contours are presented.

***Project 2.65, Land Fallout Studies***

**WT-1319**

The objective of this project was to characterize fallout and generate dose rate contours. Samples were collected on islands and ships, and dose rate measurements were taken near the ground using probes on helicopters. Fallout chemistry and particle size was assessed. Much of the dose rate data is reported in units difficult to interpret.

***Project 2.66a, Early Cloud Penetrations***

**WT-1320**

Aircraft with radiation monitors were flown through the Apache, Cherokee, Zuni, Flathead, Dakota, and Navajo nuclear clouds to measure radioactive exposure of aircraft flying through the clouds. Total doses and dose rates are reported.

***Project 2.66b, Contact Radiation Hazard Associated with Aircraft Contaminated by Early Cloud Penetrations***

**WT-1368**

The objective of this project was to measure the radioactivity on aircraft that had penetrated nuclear clouds. Activities at various locations on the aircraft are reported, and the advantages of using various types of gloves for postflight aircraft maintenance are discussed.

***Project 2.71, Ship-Shielding Studies***

**WT-1321**

The gamma radiation field was measured at various shielded and unshielded positions on ships traversing nuclear fallout fields. Results of decontamination washing are reported, plus gamma dose and dose rate on ships for a variety of fallout exposure conditions.

***Project 2.72, Evaluation of Standard Navy Dosimeters DT-60/PD and IM-170/PD in Residual Radiation Fields Aboard Ships***

**WT-1350**

This project was tasked to compare gamma doses indicated by standard personnel dosimeters exposed to fallout radiation to doses received at various depths inside human body simulators. Radiation monitors were affixed on the surface and inside mannequins that were exposed to fallout from Flathead and Tewa. The doses measured at various locations on the simulated bodies are reported.

***Project 2.8, Shipboard Radiological-Countermeasure Methods***

**WT-1322**

The objective of this project was to assess the inclination of various shipboard materials to collect and retain radioactive fallout material and to evaluate various ship decontamination procedures. Ships were exposed to fallout from Zuni, Flathead, Navajo, and Tewa, and radiation from the fallout was measured at numerous locations and on various material surfaces. Radiation

levels and decontamination process effectiveness are reported. The information provided is extensive and clearly presented.

***Project 2.9, Standard Recovery Procedure for Tactical Decontamination of Ships***

**WT-1323, -1324**

Ships contaminated but not used for Project 2.8 (WT-1322) were employed for this project in order to evaluate the Navy standard ship decontamination procedures. Decontamination procedures and effectiveness are reported.

***Project 12.1, Neutron Measurements with Threshold Detectors***

**WT-1365**

Neutron measurements of particular interest to weapon design questions were measured on LaCrosse, Erie, Seminole, and Blackfoot.

***Project 13.4, Gamma Radiation as a Function of Distances***

**WT-1361**

The objective of this project was to measure gamma radiation as a function of time at various distances from Navajo GZ. Film packs (some with shielding mechanisms after early exposure) were used for the measurements. Gamma environments for a fraction of the first second, the first seven minutes, and later times are reported for various ranges.

**EFFECTS ON STRUCTURES—PROGRAM 3**

***Project 3.1, Effect of Length of Positive Phase of Blast on Drag-Type and Semidrag-Type Buildings***

**WT-1325**

This project was the companion to Teapot Project 3.7. Six steel-frame buildings were fielded at various ranges from the projected GZ for Cherokee. Environment and building response instrumentation was installed. The bomb for Cherokee missed the intended target point, falling close to the steel structures and destroying them completely. No useful measurements were acquired, but photographs of the damaged structures are presented.

**BIOMEDICAL EFFECTS—PROGRAM 4**

***Project 4.1, Chorioretinal Burns***

**WT-1326**

The objective of this project was to study the effects of thermal radiation from nuclear detonations on eyes. Rabbits and monkeys, constrained to face the fireballs, were exposed to Lacrosse, Erie, Mohawk, Cherokee, Zuni, and Navajo. Results are presented in terms of medical observation and assessments.

**EFFECTS ON AIRCRAFT STRUCTURES—PROGRAM 5**

***Project 5.1, Thermal and Blast Load Effects on a B-47E Aircraft in Flight***

**WT-1327**

B-47E aircraft were flown in nine of the Redwing events to observe response to thermal and blast loads. Aircraft were instrumented to measure environments and structure response. Temperature histories, gust loads, strain gauge, and accelerometer measurements are reported.

***Project 5.2, In-Flight Participation of a B-52***

**WT-1328**

A B-52 was flown in eight Redwing events to assess response to nuclear airblast and thermal loads. Measured environments, strains, moments, and accelerations are presented, along with photographs of damaged aircraft elements.

***Project 5.3, In-Flight Participation of a B-66 Aircraft***

**WT-1329**

An instrumented B-66 aircraft was flown in 12 Redwing events to assess response to nuclear airblast and thermal environments. Measurements of temperatures, overpressure, bending moments, and acceleration are reported.

***Project 8.4, In-Flight Participation of a B-57B***

**WT-1330**

An instrumented B-57B aircraft was flown in eight Redwing events to assess response to nuclear airblast and thermal environments. Records of temperature, pressure, acceleration, and bending moments are presented.

***Project 5.5, In-Flight Participation of F-84F***

**WT-1331**

Two instrumented F-84F aircraft were flown in ten Redwing events to study response to nuclear airblast and thermal environments. Measured environments and thermal and structural responses are reported.

***Project 5.6, In-Flight Participation of F-101A Aircraft***

**WT-1332**

An instrumented F-101A aircraft was flown in eight Redwing events to assess response to nuclear airblast and thermal environments. Thermal and overpressure environments, temperatures, and structural response are reported.

***Project 5.7, Thermal Flux and Albedo Measurements from Aircraft***

**WT-1333**

The objective of this project was to measure the thermal radiation flux and spectrum from Redwing detonations. Four aircraft were instrumented with calorimeters, radiometers, spectrographs, and high-speed cameras. Total thermal flux, irradiance, and some spectral data are reported, along with photographs.

***Project 5.8, Evaluation of the A3D-1 Aircraft for Special Weapons Delivery***

**WT-1334**

An A3D-1 aircraft was instrumented to measure thermal, blast, and gamma environments and structural response of aircraft elements. The aircraft flew in seven Redwing events. Environment and structural response data are reported.

***Project 5.9, Weapon Effects on Missile Structures and Materials***

**WT-1335**

The objective was to evaluate the response of missile structure materials to the thermal effects from nuclear detonations. Spheres of metals and plastics used in missile parts were exposed at various distances from Erie and Mohawk GZ. Amounts of material ablation and depth of melt in metals are reported.

**STUDIES OF ELECTROMAGNETIC EFFECTS—PROGRAM 6**

***Project 6.1a, Short-Baseline Narol Measurements***

**WT-1336**

The objective of this project was to evaluate the feasibility of measuring the arrival time of the nuclear electromagnetic pulse at widely separated and distant locations to determine the location of the detonation. Measurements were made in all Redwing events. Signals received at various sites in Hawaii and California are reported.

***Project 6.1b, Field-Strength Measurement for Accurate Location of EMP Sources***

**WT-1351**

The project was tasked to use the measured field strength of EMP signals from nuclear explosions to determine the location of the detonation. EMP signals were monitored in all Redwing events. Signals measured at Central Pacific and continental U.S. stations are reported.

***Project 6.3, Ionospheric Effects of Nuclear Detonations***

**WT-1337**

This project studied the effects of nuclear explosions on the ionosphere. Probes of the ionosphere were made from nearby Pacific islands and from an aircraft within 400 km of the Mohawk, Apache, Huron, Cherokee, Zuni, Flathead, Dakota, Navajo, and Tewa detonations. Reflected signal strengths at various frequencies and times are reported.

***Project 6.4, Airborne Antennas and Phototubes for Determination of Nuclear-Weapon Yield***

**WT-1352**

Airborne and ground-based monitors were employed to determine the location and yield of nuclear detonations via measurements of electromagnetic and thermal signals. Signals are reported, but the data analysis is obscure.

***Project 6.5, Measurement of Radiofrequency Electromagnetic Radiation from Nuclear Detonations***

**WT-1353**

The objective of this project was to study the radiofrequency signals from nuclear detonations. Sensors and recorders were deployed at Enewetak and Kwajalein Atolls. Measured waveforms are presented.

***Project 6.6, Attenuation of Telemetry Frequencies by Nuclear Detonations***

**WT-1346**

The objective of this project was to report anomalous behavior of telemetry systems at very early times after detonations. The anomalies were noted for Blackfoot, Osage, and Inca.

**THERMAL RADIATION AND EFFECTS—PROGRAM 8**

***Project 8.1a, Basic Thermal Radiation Measurements from Ground Stations***

**WT-1338**

This project was to measure total thermal flux, irradiance vs time, and fireball diameter vs time at various ranges from Lacrosse, Cherokee, and Zuni GZs. Refined data and fireball photographs at various times after detonation are presented.

***Project 8.1b, Measurement of Irradiance as a Function of Time***

**WT-1347**

The project was to measure irradiance vs time for two high-yield detonations using bolometers with good time resolution. No data were acquired for Cherokee, but irradiance vs time data from Zuni are reported.

***Project 8.1c, Spectral Distribution of Irradiance with High Time Resolution***

**WT-1348**

The objective of this project was to measure spectral irradiance from an airburst (Cherokee) and a ground burst (Zuni). No data were acquired in Cherokee due to the large bombing error, and data acquisition was limited in Zuni due to cloud cover. Spectral irradiance is presented for the second thermal peak.

***Project 8.2, Thermal Effects on Cellulosic Materials***

**WT-1339**

Various materials were exposed to nuclear thermal radiation to assess their tendency to burn or char. Materials included paper, cloth, grass, and wood. Tests were performed for Cherokee, but misplacement of the bomb severely degraded this experiment. Some information on paper ignition is presented.

***Project 8.3, Evaluation of Self-Recording Thermal Radiation Instruments***

**WT-1340**

Three types of self-recording thermal indicators were to be tested but the Cherokee miss compromised the expected information. However, some unevaluated readings are presented.

***Project 8.4, Thermal Effects on Strength of Aircraft Structural Sandwich-Type Panels***

**WT-1341**

Panels of various materials and construction configurations, stressed and unstressed, were exposed to Cherokee, Zuni, Navajo, Tewa, and Apache. Temperature-time measurements were made and mechanical properties were measured after the tests to study the effects of nuclear thermal radiation on aircraft structural members. Effects and material degradation are described.

***Project 8.5, Airborne High-Resolution Spectral Analysis***

**WT-1342**

The objective of this project was to measure the spectrum of thermal radiation from nuclear bursts. Measurements were made for Lacrosse, Erie, Cherokee, Zuni, and Flathead. Many spectral plots are presented.

**SUPPORTING PHOTOGRAPHY—PROGRAM 9**

***Project 9.1a, Cloud Photography***

**WT-1343**

This project acquired motion pictures of the clouds formed by nuclear bursts. Numerous stations provided motion pictures of clouds from the Lacrosse, Cherokee, Zuni, Mohawk, Apache, and Flathead detonations. These films are available at DASIAC, Santa Barbara, California.



**SECTION 16**  
**PLUMBBOB**  
**Nevada Test Site**  
**1957**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield (KT)</u>	<u>Weapon Placement</u>
Boltzmann	May 28	Yucca Flat, Area 7	12	500-foot tower
Franklin	June 2	Yucca Flat, Area 3	0.14	300-foot tower
Lassen	June 5	Yucca Flat, Area 9	0.0005	Balloon (HOB, 500 feet)
Wilson	June 18	Yucca Flat, Area 9	10	Balloon (HOB, 500 feet)
Priscilla	June 24	Frenchman Lake	37	Balloon (HOB, 700 feet)
Hood	July 5	Yucca Flat, Area 9	74	Balloon (HOB, 1,500 feet)
Diablo	July 15	Yucca Flat, Area 2	17	500-foot tower
John	July 19	Yucca Flat, Area 10	2	Rocket (HOB, 20,000 feet)
Kepler	July 24	Yucca Flat, Area 4	10	500-foot tower
Owens	July 25	Yucca Flat, Area 9	9.7	Balloon (HOB, 500 feet)
Stokes	Aug 7	Yucca Flat, Area 7	19	Balloon (HOB, 1,500 feet)
Shasta	Aug 18	Yucca Flat, Area 2	17	500-foot tower
Doppler	Aug 23	Yucca Flat, Area 7	11	Balloon (HOB, 1,500 feet)
Franklin Prime	Aug 30	Yucca Flat, Area 7	4.7	Balloon (HOB, 750 feet)
Smoky	Aug 31	Yucca Flat, Area 2	44	700-foot tower
Galileo	Sept 2	Yucca Flat, Area 1	11	500-foot tower
Wheeler	Sept 6	Yucca Flat, Area 9	0.197	Balloon (HOB, 500 feet)
Laplace	Sept 8	Yucca Flat, Area 7	1	Balloon (HOB, 750 feet)
Fizeau	Sept 14	Yucca Flat, Area 3	11	500-foot tower
Newton	Sept 16	Yucca Flat, Area 7	12	Balloon (HOB, 1,500 feet)
Rainier	Sept 19	Rainier Mesa, Area 12	1.7	Tunnel (DOB, 790 feet)
Whitney	Sept 23	Yucca Flat, Area 2	19	500-foot tower
Charleston	Sept 28	Yucca Flat, Area 9	12	Balloon (HOB, 1,500 feet)
Morgan	Oct 7	Yucca Flat, Area 9	8	Balloon (HOB, 500 feet)

**BACKGROUND.**

Operation Plumbbob was a diverse nuclear test series performed at the Nevada Test Site (NTS). Aside from the AEC nuclear weapon development objectives, it contained a full-up air-to-air missile system test (John), the first fully contained underground nuclear test (Rainier), tactical operations exercises involving thousands of troops (Operation Desert Rock VII and VIII), nuclear safety tests with effectively no yield, and nuclear weapon effects experiments. It was also the first series in which many of the devices were suspended in the air by balloons to minimize fallout from radioactive soil. Weapon effects experiments were performed by the DoD,

the two AEC weapon development laboratories, and the Federal Civil Defense Administration (FCDA).

The Priscilla event had the greatest concentration of nuclear effects experiments. It was the last large-yield effects test at Frenchman Lake. It was the first test in which extensive high-pressure (over 50 psi) data were acquired. The device was suspended from a balloon over the Grable and MET GZ and was surrounded by a relatively small mass, resulting in higher neutron and gamma radiation free-field environments. Priscilla contained numerous structure loading and response experiments.

The DoD effects programs included:

- Program 1—Blast Measurements
- Program 2—Nuclear Radiation Studies
- Program 3—Effects on Structures
- Program 4—Biomedical Effects
- Program 5—Effects on Aircraft Structures
- Program 6—Electromagnetic Effects
- Program 8—Thermal Radiation Effects.

AEC and FCDA programs also provided significant effects information. Objectives and location of data are identified under appropriate subject areas. Most of the weapon test (WT) reports for Operation Plumbbob are now unclassified.

## OPERATION PLUMBBOB PROJECTS AND REPORTS

### Technical Summary of Military Effects, Programs 1-9

WT-1445

This document describes the goals and findings of each of the DoD effects programs. Implications are presented. Some data from WTs are provided. Extended summaries for each of the DoD projects are included.

### BLAST MEASUREMENTS—PROGRAM 1 AND RELATED EXPERIMENTS

#### *Project 1.1, Basic Airblast Phenomena*

WT-1401, ITR-1481

The objective of this project was to measure overpressure and dynamic pressure at various ranges from GZ for 14 Plumbbob events. These measurements enhanced the definition of precursor wave phenomena and the accuracy of scaling laws. A large number of pressure-time traces for various locations and plots of peak pressure vs distance and shock arrival time are presented.

#### *Project 1.3, Air-Blast Phenomena in the High-Pressure Region*

WT-1403

This project measured peak overpressure, pressure-time profiles, and dynamic pressures as a function of distance, particularly high-pressure regions close-in to the burst. Measurements were made during Priscilla. Shock arrival time, peak static and dynamic pressure, and pressure-time profiles near the detonation are reported.

***Project 1.4, Ground Acceleration, Stress, and Strain  
at High Incident Overpressures***

**WT-1404**

Measurements were made at ground ranges from 450 to 1,350 feet and at depths to 50 feet during Priscilla in order to measure ground stress, strain, and horizontal and vertical acceleration, particularly in the high-pressure region. Measured values are provided, along with ground motion measurements from earlier tests.

***Project 1.5, Ground Motion Studies at High Incident Overpressures***

**WT-1405**

This project measured vertical and radial accelerations and vertical displacements near GZ to depths from 0 to 200 feet for Priscilla. Measurements at GZ were lost, but numerous other data records are reported.

***Project 1.7, Loading on Simulated Buried Structures at  
High Incident Overpressures***

**WT-1406**

The objective of this project was to observe the response of drums with diaphragms of various thickness in the ends at different ranges and depths below ground level during Priscilla. Sixty-eight drums were buried at depths from 0 to 20 feet at three different ranges. Strain gauges on some of the diaphragms provided active diaphragm motion measurements. Diaphragm deformation and associated local pressures are presented.

***Project 1.8a, Effects of Rough and Sloping Terrain  
on Airblast Phenomena***

**WT-1407, ITR-1409**

The project measured characteristics of nuclear blast waves traveling over various types of terrain. Head pressure, dynamic pressure, and overpressure were measured along five blast lines on differing terrain during Smoky. Terrains and measured pressures at various distances along the terrain paths are reported, along with analyses and conclusions.

***Project 1.8b, Effects of Rough Terrain on Drag Sensitive Targets***

**WT-1408**

This project was to assess the effects of terrain on the response of jeeps to nuclear airblast. Fifty-one jeeps were exposed during Smoky along lines of flat, hilly, and rough terrains. Damage to jeeps at various exposure positions is described and photographs of vehicle damage presented.

***Project 1.9, Spectra of Ground Shocks Produced by Nuclear Detonations***

**WT-1487**

The objective of this project was to measure the spectral components of ground shock at various distances from GZ and for various gauge emplacements. Mechanical gauges operating in the 3- to 300-hertz range were placed at ground level, in a basement, and in concrete bases during Stokes, Smoky, Galileo, Whitney, and Charleston. Plots of maximum ground acceleration vs frequency, maximum displacement vs frequency, maximum velocity vs frequency and maximum acceleration vs overpressure for the various nuclear events are presented.

***Project 26.4a, Surface Motion from an Underground Detonation***

**WT-1528**

Surface and near-surface acceleration and strain were measured on Rainier. Waveforms of the recorded data as well as the information inferred by integration, that is, velocity and displacement, are presented.

***Project 26.4b, Subsurface Motion—Part 1***

**WT-1529**

Particle motion measurements were made on the surface and within the tunnel system. Measurements were primarily radial and curves of reduced data are presented.

***Project 26.4d, Surface Motions***

**WT-1530**

Seismic data were recorded at stations 1,200 to 45,000 feet from surface zero. In addition, teleseismic records from stations 100 to 300 miles are presented.

***Project 26.4e, Subsurface Accelerations and Strains***

**WT-1531**

Ground motion measurements were taken at the mouth of the main entrance tunnel during Rainier. Most data were lost but some were recorded and are presented.

***Project 26.4f, Photographic Analysis***

**WT-1532**

Motion picture cameras were set up to record surface motion from Rainier. One record was found suitable for analysis and this is presented in the WT report.

***Project 33.2, Secondary Missiles Generated by Nuclear Produced Blast Waves***

**WT-1468**

The objective of this project was to study the acceleration of potentially injurious debris from nuclear airblast. Missiles studied included glass, gravel and stones, nylon and wooden spheres, and fragments of steel. Catchers were devised to measure missile velocities and impact patterns. Experiments were performed for Priscilla, Smoky, and Galileo. Missile types, mass, and velocities for various test conditions are reported.

**NUCLEAR RADIATION STUDIES—PROGRAM 2**

***Project 2.1, Soil Activation by Neutrons***

**WT-1410**

Samples of three soil types were exposed during Franklin, Lassen, Wilson, Priscilla, and Owens. Neutron environments were measured at various soil depths, and induced gamma-ray activity was measured at similar depths. Maps of neutron flux and gamma-ray activity as a function of type of soil and position in soil are presented.

***Project 2.2, Neutron-Induced Activities in Soil Elements***

**WT-1411**

The objective of this project was to analyze the radioactivity induced into common elements in soil by neutron radiation from nuclear detonations. Elements such as Na, Al, Mn, and others were exposed at various depths below ground level for Wilson, Owens, and Laplace. Neutron energies and fluxes of the elements at various ground depths are reported.

***Project 2.3, Neutron Flux from Selected Nuclear Devices***

**WT-1412**

This project was tasked to measure neutron fluxes and spectra at various distances from the Franklin, Lassen, Wilson, Priscilla, Hood, Owens, John, Smoky, and Laplace detonations. Data tables and plots of neutron fluxes and energies are reported.

***Project 2.4, Neutron and Initial Gamma Shielding***

**WT-1413**

Assessed were gamma-ray and neutron shielding provided by various military vehicles, fortifications, and shelters. Military apparatus and structures were exposed to nuclear radiation at various ranges from Franklin, Lassen, Wilson, Priscilla, Hood, and Owens GZs. Radiation

environments were measured outside and inside the test vehicles and structures. Numerous data measurements are presented.

***Project 2.5, Initial Gamma Radiation Intensity and Neutron-Induced Gamma Radiation of NTS Soil***

**WT-1414**

The objectives of this project were to measure the prompt gamma radiation as a function of time and distance from nuclear bursts and the neutron-induced gamma radiation in NTS soil. Initial gamma intensities at ground stations and airborne stations were measured for Boltzmann, Franklin, Lassen, Wilson, Hood, John, and Owens. Neutron-induced gamma radiation measurements in soil were made after the Owens detonation. Gamma radiation data collected from ground, aircraft, and balloon stations are reported.

***Project 2.6, Evaluation of New Types of Radiac Instruments***

**WT-1415**

Although instrument development is the prime intent of this experiment, gamma and neutron dose measurements were taken at several ranges from Wilson, Priscilla, and Hood.

***Project 2.8, Evaluation of Military Radiac***

**WT-1417**

This experiment was concerned with development and modification of radiation detection instrumentation so that it would be more useful with biological studies involving phantoms. Therefore, the dose data developed and presented for Wilson, Priscilla, Hood, and Diablo are not directly interpretable in terms of the weapon-produced environment.

***Project 2.9, Nuclear Radiation Received by Air Crews Firing the MB-1 Rocket***

**WT-1418**

The objective of this project was to determine the amount of nuclear radiation aircrew members might receive while firing an MB-1 air-to-air nuclear rocket. Three F-89 aircraft delivered, or simulated delivery, of an air-to-air nuclear rocket and were at tactical flight positions at the time of detonation. Crewmembers were instrumented for gamma and neutron doses. Crew exposures and aircraft flight paths are reported.

***Project 2.10, Initial Neutron and Gamma Air-Earth Interface Measurements***

**WT-1419**

The objective of this project was to measure, near the ground and at various altitudes, neutron and gamma radiation from nuclear bursts, to determine the effect of the earth's surface on measured radiation environments. Neutron flux and dose, and gamma dose and dose rate measurements were made at heights from 0 to 950 feet at various ranges from Boltzmann, Lassen, Wilson, Hood, Diablo, Kepler, John and Owens. Tables of radiation measurements are reported, indicating radiation environments 30 percent higher at altitude than at ground level.

***Project 32.4, Fallout Studies and Assessment of Radiological Phenomena***

**ITR-1465**

The objective of this project was to study radioactive fallout in support of Project 32.3 (WT-1464). Measurements were made or attempted for Priscilla, Diablo, Owens, and Shasta. Measured radioactivity at various locations and aboveground heights at different times is presented.

***Project 36.4, Aerial Monitoring Operations Development***

**WT-1485**

The objectives of this project was to measure nuclear fallout radiation at ground level via surveys by foot, automobile, and aircraft at various altitudes, and to correlate aircraft radiation readings with ground survey readings to determine altitude correlation factors. Experiments were

performed during Shasta. Ratios of ground-to-air radiation readings are presented for various aircraft altitudes.

***Project 39.5, Radiation Dosimetry for Human Exposures***

**WT-1504**

This experiment was part of a larger effort called "Ichiban Dosimetry" to evaluate gamma and neutron exposures received by the survivors of the attacks upon Hiroshima and Nagasaki. This larger effort was meant to relate the data on medical effects being collected among these survivors to the quantity of exposure. This project made gamma and neutron dose measurements as functions of range and shielding for Wilson, Hood, Stokes, Doppler, Franklin Prime, and Fizeau. Measurements in houses built to provide the kind of shielding provided by typical Japanese houses were also made. Other dosimetry projects in Program 39 were: Project 39.1 (WT-1500), 39.1a (WT-1466), 39.1b (WT-1471), and 39.9 (WT-1509).

***Project 41.1a, Fireball Studies***

**WT-1517**

The objectives of this project were to measure, in or near the nuclear fireball, gamma radiation flux vs time, time-integrated neutron flux as a function of neutron energy, air pressure, radiant energy vs time, and gaseous electrical conductivity. Measurements were made for Boltzmann and Fizeau. Some limited data were collected and reported.

***Project 41.3, Effects of Altitude on Neutron Measurements***

**WT-1521**

The objective of this project was to measure neutron dose and spectrum at various altitudes and ranges from a nuclear device detonated several hundred feet above the ground. Detectors for different neutron bands were deployed on the ground and at altitudes up to about 1,400 feet during Wilson. Neutron doses for the various energy bands are reported for numerous locations.

**EFFECTS ON STRUCTURES AND SHELTERS—PROGRAM 3 AND RELATED AEC EXPERIMENTS**

***Project 3.1, Blast Loading and Response of Underground Concrete-Arch Protective Structures***

**WT-1420**

This project was to determine the response of buried concrete structures to high airblast loads from a nuclear explosion. Four instrumented concrete-arch structures were fielded at the 50-, 100-, and 200-psi stations of Priscilla. Measurements included air overpressure, earth pressures, deflections, accelerations, strains, and nuclear radiation. Numerous data records and descriptions of damage are presented. ITR-1426 discusses instrumentation for this project as well as for Projects 3.2, 3.3, and 3.6.

***Project 3.2, Evaluation of Buried Conduits as Personnel Shelters***

**WT-1421**

The objective of this project was to evaluate the viability of buried standard commercial steel and concrete conduit to serve as personnel shelters in nuclear bursts. Twelve large-diameter conduit sections, buried at depths of 5, 7.5, and 10 feet, were exposed at airblast overpressures between 60 and 150 psi during Priscilla. Instrumentation for pressure, acceleration, deflection, and radiation was employed. Measured data and response descriptions are presented.

***Project 3.3, Evaluation of Buried Corrugated-Steel Arch Structures and Associated Components***

**WT-1422**

The Navy evaluated an underground personnel shelter design as well as a generator shelter and an air-duct closure device. Three shelters covered with 5 feet of earth were exposed at the 60-

and 100-psi stations during Priscilla. Pressures, accelerations, deflections, and radiation environments were measured. Structure design and damage descriptions are presented.

***Project 3.4, Blast Effects on Existing Upshot-Knothole and Teapot Structures***

**WT-1423**

This project assessed the effects of the Priscilla shot on structures that were present because they had already been exposed in Encore, Grable, and MET. Structures included industrial buildings, housing elements, and underground structures. Some instrumentation was employed. Gauge records and descriptions of additional damage are presented.

***Project 3.5, Isolation of Structures from Ground Shock***

**WT-1424, WT-1424-1**

The project evaluated a concept for providing shock isolation to underground structures. Empty gin bottles were arranged on the exterior of concrete buried structures at the 100- and 300-psi stations of Priscilla. The glass bottles provided a frangible barrier, limiting shock loads to the structures. Acceleration records are presented.

***Project 3.6, Full-Scale Field Tests of Dome and Arch Structures***

**WT-1425, ITR-1448**

Ten concrete and aluminum dome structures and a blast closure door were exposed at the 35- and 70-psi stations of Priscilla. Pressure, acceleration, strain, and deflection were measured. Sensor readings, data traces, and photographs of damage are presented. The response of these structures is also the subject of Project 30.1 (ITR-1448).

***Project 30.2, Response of Dual-Purpose Reinforced-Concrete Mass Shelter***

**WT-1449**

This project was tasked to test the response of a large concrete structure to a nuclear airblast load. The structure would normally be a parking garage, but in time of emergency, it could serve as a nuclear blast shelter. The structure was exposed to Priscilla at the 35-psi test station. Peak overpressure, dynamic pressure, earth pressure, deflection, and radiation measurements were made. Numerous pressure and deflection data traces are presented.

***Project 30.3, Evaluation of FCDA Family Shelter, Mark 1, for Protection Against Nuclear Weapons***

**ITR-1450**

The project was to evaluate an underground family shelter in a nuclear test. Concrete shelters were exposed at the 30-, 48-, and 65-psi stations of Priscilla. Response is described, but no specific effects data are presented.

***Project 30.4, Response of Protective Vaults to Blast Loading***

**WT-1451**

The objective of this project was to determine if a vault, anchored in concrete and equipped with a standard steel vault door, could withstand high overpressure close-in to a nuclear burst. The vault was deployed at the 75-psi station of Priscilla. Free-field and vault surface pressures, door deflection, and film radiation and temperature measurements inside the vault were made and reported.

***Project 30.6, Test of French Underground Personnel Shelters***

**WT-1453, -1535**

Tested were French civil defense structures and structural elements at high airblast overpressures of Smoky. Five earth-covered structures were fielded at overpressures of 116 and 105 psi. Extensive environment and response instrumentation was deployed, but the sensor failure rate was high. Numerous pressure-time and displacement records are presented, along with

photographs of damage. WT-1535 presents additional photographs and pressure-time records from stations within the structures.

***Project 30.7, Test of German Underground Personnel Shelters*** **WT-1454, -1536**

German civil defense structures were tested for response to airblast loads during Smoky. Nine reinforced concrete underground shelters were fielded at pressures ranging from 170 to 7 psi. Instrumentation included air pressure and ground pressure gauges, strain gauges, accelerators, deflection gauges, and radiation dosimeters. Environment and structural response data are reported, and extensive photography of damage is presented. Additional information is presented in WT-1536.

***Project 31.4, Evaluation of Industrial Doors Subjected to Blast Loading*** **ITR-1459**

The objective of this project was to evaluate the performance of wooden and steel doors in a nuclear blast environment. Five doors were tested at 9 psi and five more at 17 psi during Smoky. Displacements were measured. Door damage and measured displacements are reported.

***Project 31.5, Test and Evaluation of Antiblast Valves for Protective Ventilating Systems*** **ITR-1460**

Closure valves for ventilation systems were tested in blast-resistant structures. Most of the valves were designed to be closed upon arrival of a nuclear blast wave and to reopen after passage of the wave. Eleven valves were tested during Priscilla at pressures ranging from 100 to 3 psi. Valve performances and closure times are reported.

***Project 32.1, Protection Against Fallout Radiation in a Simple Structure*** **WT-1462**

The objective was to assess the degree of protection provided by a simple structure in a nuclear fallout environment and to determine the safest location inside the structure. A metal "Butler" building was exposed to the fallout of Diablo, Shasta, and Fizeau. Radiation fields were measured outside and at many locations inside the building to determine the relative exposure or "protection factor" for each location. Measured dose rates and protection factors for various locations are presented.

***Project 32.3, Evaluation of Countermeasure Components and Operational Procedures*** **WT-1464**

The project was tasked to evaluate a navy bunker design for fallout protection, to assess the ability of a filterless air intake system to provide uncontaminated air, and to exercise posttest procedures for providing safe areas for outside operations. Personnel occupied the bunker during Diablo and Shasta and made numerous measurements of radiation inside and outside the bunker. While the report does not always make clear what the experiments are attempting to do, a significant amount of dose-rate data as a function of time and location is presented.

***Project 33.5, The Internal Environment of Underground Structures Subjected to Nuclear Blast; I. The Occurrence of Dust*** **ITR-1447**

The source and amount of dust from nuclear airblast was identified and measured in a total of 18 underground structures exposed to Priscilla, Smoky, and Galileo. Few data are presented, and results are ambiguous.



***Project 33.6, The Internal Environment of Underground Structures Subjected to Nuclear Blast, II. Effects on Mice Located in Heavy Concrete Shelters***

**WT-1507**

The objective was to place mice in bunkers exposed to nuclear environments to evaluate the habitability of the structures. Groups of 20 mice were placed in each of 12 bunkers tested during Smoky. The number of mice surviving over a 60-day period posttest is reported for each test station.

***Project 34.1, Effects of a Precursor Shock Wave on Blast Loading of a Structure***

**WT-1472**

This project was tasked to measure the characteristics of a non-ideal nuclear blast wave and to determine its effects on a test structure. A 6- by 6- by 20-foot concrete structure was exposed at a range of 2,000 feet from Priscilla GZ. Free-field pressure profiles were measured at heights of 3 and 10 feet. Pressures on the structure face were measured. Numerous pressure profiles at various locations on the structure are reported.

***Project 34.2, Comparison Test of Reinforcing Steels***

**WT-1473**

The objective of this project was to compare the performance of two different types of reinforcing steel embedded in concrete exposed to nuclear blast. Concrete slabs, either rail grade or intermediate grade with the two steel reinforcements, were exposed at identical pressure levels during Smoky. Slab deflections were measured, and slab properties, pressure measurements, and deflections are reported.

***Project 34.3, Test of Buried Structural-Plate Pipes Subjected to Blast Loading***

**WT-1474**

The project was to assess the potential of 20-foot-long, 7-foot-diameter steel pipe to serve as a scientific station close-in to nuclear bursts. Two segments, buried under 10 feet of soil, were exposed at 190 psi and 245 psi during Smoky. Transient and permanent pipe deflections are reported.

***Project 34.3a, Evaluation of Nuclear Blast Effects on AEC Test Site Facilities***

**WT-1455**

Facilities of interest include retaining walls, device-holding towers, and miscellaneous structures. The objective was to observe the response of AEC support facilities to nuclear blast and shock in order to add to the nuclear effects database and to improve the design of future support facilities. Pretest and posttest measurements were made to determine deflections and dislocations.

***Project 35.1, Penetration into Concrete of Gamma Radiation from Fallout***

**WT-1477**

Fallout radiation was measured on the ground, through air using aboveground sensors and through various thicknesses of concrete slabs, over a period of hours after detonation. Seven layers of concrete slab were stacked horizontally and flush with the ground surface in the exposure field, with radiation counters and film packs between each slab layer. Dose rate and total dose is reported for the aboveground sensors and beneath each succeeding layer of concrete. Measurements were taken hourly for 12 hours after detonation.

***Project 38.2, Effect of Fallout Contamination on Raw Agricultural Products***

**WT-1497**

The objective of this project was to expose agricultural products to radioactive fallout and assess the effectiveness of simple decontamination procedures. Fruits, vegetables, and grains were exposed to fallout and then washed or processed. Radioactivity levels of products before and after cleaning are reported.

***Project 41.c, Effects on Materials Exposed to a Nuclear Detonation***

**WT-1519**

A wide variety of materials were exposed to nuclear environments and changes resulting from such exposure were assessed. Hundreds of samples of metals, plastics, and wood were exposed from inside the fireball out to a range of 2,800 feet during Fizeau. Material response was determined by examination of recovered samples.

**BIOMEDICAL EFFECTS—PROGRAM 4**

***Project 37.1, Distribution, Characteristics, and Biotic Availability of Fallout, Operation Plumbbob***

**WT-1488**

This project characterized and quantified the near- and long range radioactive fallout from the Plumbbob events and tracked the radioactive materials through biological processes. Nuclear clouds, particle sizes, and fallout patterns over time are defined, and the radionuclides are identified. Animal and vegetation of the radionuclides is reported. Numerous data tables, analyses and discussions of implications are presented.

***Project 39.3, Thermal Radiation Measurements***

**ITR-1502**

Eight pigs were placed in a shelter exposed to Galileo in order to assess thermal radiation effects on biological specimens inside shelters. Descriptions of injuries to the pigs are provided.

***Project 39.6, Biological Effects of Nuclear Radiation on the Monkey***

**WT-1505**

Monkeys were exposed to neutron and gamma radiation from nuclear bursts and observed for effects on biological functions. The monkeys, protected from airblast, were exposed at various ranges of Wilson and Fizeau. Monkey mortality and cause of death are reported as a function of time and radiation dose.

***Project 39.6 (Supplement 1), Biological Effects of Nuclear Radiation on the Monkey (Macaca Mulatta: Two-Year Evaluation)***

**WT-1542**

The objective of this project was to report the medical history and behavior, over a two-year period, of the monkeys surviving exposure to neutron and gamma radiation of Wilson and Fizeau (WT-1505). Extensive medical tests were made and reported.

***Project 39.6a, Large-Animal Neutron-Gamma Irradiation Experiment***

**ITR-1476**

The objective of this project was to expose burros to various levels of neutron and gamma radiation from a nuclear burst in order to establish lethality levels. Eighty-eight burros, protected from the blast wave, were exposed at 11 different radiation levels. Burro mortality with time and radiation level is reported.

***Project 39.8, Depth-Dose Studies in Phantoms with Initial Bomb Gamma and Neutron Radiation***

**WT-1508**

Gamma radiation dose and neutron dose was measured as a function of depth in human-tissue-equivalent materials. A material that absorbs gamma rays like the human body and another material that primarily absorbs neutrons were instrumented at various depths with dosimeters and exposed to Franklin, Wilson, Charleston, and Morgan. Absorbed dose for gamma rays and neutrons, is reported as a function of depth.

***Project 4.1, Effects of Nuclear Detonations on a Large Biological Specimen (Swine)***

**WT-1428**

The objective of this project was to expose pigs to nuclear environments to assess potential nuclear effects on humans. Twelve hundred pigs were exposed at various ranges during Franklin, Wilson, and Priscilla. Injuries occurred from blast, neutron and gamma absorption, and thermal radiation. Detailed descriptions of effects as a function of dose and postirradiation time are presented.

***Project 4.2, Evaluation of Eye Protection Afforded by an Electromechanical Shutter***

**WT-1429**

The task was to evaluate a high-speed shutter for protection against flashblindness. Human subjects viewed Boltzmann, Wilson, Priscilla, Hood, and Diablo blasts through shuttered and unshuttered windows and were tested for visual activity immediately after the bursts. Thermal environments and spectra were measured. Optical recovery times from the various test conditions are reported.

***Project 33.1, Blast Biology—A Study of the Primary and Tertiary Effects of Blast in Open Underground Protective Shelters***

**WT-1467**

Dogs, pigs, rabbits, guinea pigs, and mice were exposed in underground shelters with open entrances in two nuclear tests in order to observe nuclear effects, mainly airblast, on animals. Damage to the animals under various conditions is described.

***Project 33.3, Tertiary Effects of Blast-Displacement***

**WT-1469**

The objective of this project was to determine the motion of mannequins and spheres exposed to nuclear airblast. Motion pictures were made of dummy movement and analyzed. Experiments were performed in two shots. Acceleration and velocity are calculated, translation distances are given, and postshot positions of dummies and spheres are shown.

***Project 33.4, Missile Studies With a Biological Target***

**WT-1470**

This project measured the effects on dogs of flying glass and rocks in a nuclear airblast. Fourteen dogs were placed behind windows and rock fields of Priscilla and Galileo. Biological effects are reported.

**EFFECTS ON AIRCRAFT STRUCTURES—PROGRAM 5**

***Program 5.1, In-Flight Structural Response of an HSS-1 Helicopter to a Nuclear Detonation***

**WT-1430**

An instrumented HSS-1 helicopter was flown in the vicinity of nuclear bursts to assess its response to overpressure and gust loads. The helicopter, instrumented with strain gauges, accelerators, pressure gauges, calorimeters, and temperature gauges, flew in the Boltzmann, Franklin, Wilson, Priscilla, Diablo, Kepler, Owens and Stokes events. Numerous data records and tables are presented.

***Project 5.2, Structural Response and Gas Dynamics of an Airship Exposed to a Nuclear Detonation***

**WT-1431**

Two instrumented airships were tested in the nuclear environments of Franklin and Stokes. The objective was to establish safe-escape distance criteria for Navy airships. Original plans were for participation in several nuclear tests, but each airship was badly damaged during its first

exposure. Most attempts at measurements failed, but film sequences of the airships during and after the detonations are presented.

***Project 5.3, In-Flight Structural Response of FJ-4 Aircraft to Nuclear Detonations***

**WT-1432**

An instrumented aircraft flew during Boltzmann, Hood, Diablo, Kepler, Shasta, Doppler, and Smoky to measure the thermal and airblast response of the FJ-4 aircraft to nuclear explosions. Instrumentation included strain gauges, thermocouples, calorimeters, radiometers, pressure transducers, film badges, and pitch-rate and attitude gyros. A considerable amount of environment and response data is presented, along with aircraft performance analyses.

***Project 5.4, In-Flight Structural Response of the Model A4D-1 Aircraft to a Nuclear Explosion***

**WT-1433**

The objective of this project was to measure the response of the A4D-1 aircraft to nuclear thermal and airblast loads. The instrumented aircraft flew during Boltzmann, Priscilla, Hood, Diablo, Shasta, Doppler, and Smoky. Measurements were made of nuclear environments and thermal and structural response of aircraft elements. A significant amount of response data is reported.

***Project 5.5, In-Flight Structural Response of an F-89D Aircraft to a Nuclear Detonation***

**WT-1434**

The objective of this project was to determine the structural response of the F-89D aircraft to the airblast and thermal effects of a nuclear detonation. The aircraft participated in 14 nuclear tests and was instrumented to measure the nuclear environments and the aircraft response to the environments. Tabular data compilations of the measurements are presented.

**SERVICE EQUIPMENT AND ELECTROMAGNETIC EFFECTS—PROGRAM 6**

***Project 2.7, Investigation of Effects of Nuclear Detonations on Electromagnetic Wave Propagation***

**WT-1416**

The most significant objective of this project was to study radiowave propagation in the vicinity of nuclear detonations. Radio transmissions at various frequencies were measured for paths over, through, and away from the fireballs of Boltzmann, Franklin, Lassen, Wilson, Priscilla, Hood, Diablo, Kepler and Owens. Transmitters, receivers, and equipment locations are described, and traces showing signal attenuation are presented. This experiment was by way of preparing instrumentation for telemetering data on the upcoming Hardtack shots.

***Project 6.1, Mine-Field Clearance by Nuclear Weapons***

**WT-1435**

Live and inert mines were buried 6 inches underground at overpressure stations from 5 to 60 psi of Priscilla to measure the response of pressure-activated mines to a nuclear blast. Pressure measurements were made at ground level and below ground level throughout the field. Response of mines as a function of airblast pressure is reported.

***Project 6.2, Measurement of the Magnetic Component of the Electromagnetic Field Near a Nuclear Detonation***

**WT-1436**

The task for this project was to measure magnetic fields in the vicinity of nuclear detonations in order to develop an understanding of EMP phenomenology. Measurements were made or

attempted at various ranges from Lassen, Wilson, Priscilla, Hood, Diablo, and Owen detonations. Data traces and reduced data are reported.

***Project 6.2a, Effect of Nuclear Radiation on Semiconductor Devices***

**WT-1489**

A total of 350 transistors and semiconductor diodes of the era were exposed and their posttest performance measured. Performance degradation as a function of neutron dose is presented for the devices.

***Project 6.3, Attenuation of Electromagnetic Radiation Through an Ionized Medium***

**WT-1437**

The objective of this project was to measure the attenuation of radio and radar transmissions through ionized clouds formed after nuclear detonations. Radio transmissions were made from an aircraft through ionized clouds to ground-based receivers. Radar transmissions, directed toward aircraft, were made from a ground-based radar through ionized clouds. Measurements were made for Franklin, Lassen, Wilson, and Priscilla. Radio and radar signal traces were reported, with little degradation occurring through the ionized clouds.

***Project 6.4, Accuracy and Reliability of a Short Baseline Narol System***

**ITR-1438**

Signal receiver networks were deployed in the western United States to detect and locate nuclear bursts by their electromagnetic signals. Lightning-generated signals and nuclear-explosion-generated signals were acquired and reported.

***Project 6.5, Effects of Nuclear Detonations on Nike Hercules***

**WT-1439**

The objective of this project was to determine the effects of nuclear explosions on components of the Nike-Hercules defense system. Guidance, fuzing, and propellant elements were exposed to Wilson, Owens, Morgan, Fizeau, Boltzmann, Franklin, Lassen, Hood, and Kepler. Tube and transistor electronics were tested. Electrical characteristics of components before and after exposure are reported.

***Project 16.2, Remote Electromagnetic and Bhangmeter Measurements on Operation Plumbbob***

**WT-1538**

The objective of this project was to measure electromagnetic pulse and light signals from nuclear bursts at ranges out to nearly 600 miles from the detonation points. Measurements were attempted in all Plumbbob tests. Data traces from the various test stations are presented.

**THERMAL RADIATION AND EFFECTS—PROGRAM 8 AND RELATED EXPERIMENTS**

***Projects 8.1 - 8.2, Thermal Protection of the Individual Soldier***

**WT-1440, WT-1441**

These projects evaluated clothing and creams as protection for soldiers in a nuclear thermal environment. A skin simulant was also evaluated. The materials were placed on pigs who were exposed at the 10- and 25-cal/cm<sup>2</sup> stations of Priscilla. Descriptions of the protective materials and the damage to the pigs are provided in the report.

***Project 8.3b, Instrumentation for Measuring Effects  
Phenomena Inside the Fireball***

**WT-1443**

Spheres and cylinders of various materials were hung from light-weight towers and guys so that they would be engulfed in the Priscilla and the Smoky fireballs. Some of these objects were instrumented to record pressure and most were recorded and photographed. Recession due to ablation was recorded and is reported for the various materials. Some pressure data is reported. This experiment is an extension of work by Project 5.4 in Teapot and Project 5.9 of Redwing.

***Project 34.4, Blast Effects on an Air-Cleaning System***

**WT-1475**

An air-cleaning system meant to simulate an AEC-type laboratory was set up in each of two test structures. These systems consisted of interior collection hoods, collection systems and high-efficiency filters intended to clean the exhaust air. These systems were exposed to a shock wave entering the exhaust side of the system and their performance was observed.

***Project 38.1, Effect of Fallout Contamination on Processed  
Foods, Containers, and Packaging***

**WT-1496**

Processed foods were exposed to radioactive fallout and the various packaging materials were assessed for their inclination to accumulate the fallout and also for their ability to be cleansed of the contamination. Packaging materials included cellophanes, foils, paper, cloth, and boxes. Activities measured before and after decontamination are reported for a number of packing materials.

***Project 38.1-II, Blast Effects on Glass Vacuum Containers***

**WT-1461**

Glass bottles in cases with and without vacuum seals and with and without a filling fluid were exposed in a slit trench at 1/2 and 1/4 mile from a burst. Data reported is a tabulation of which were broken and which had their seals intact.

**SECTION 17  
HARDTACK**

**Enewetak, Bikini Atolls and Johnston Island**

**1958**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield*</u>	<u>Weapon Placement</u>
Yucca	Apr 28	Between Enewetak and Bikini	---	Balloon (HOB, 86,000 feet)
Cactus	May 5	Runit Island, Enewetak	18 KT	Surface
Fir	May 11	Bravo site, Bikini	---	Barge
Butternut	May 11	Off Runit Island, Enewetak	---	Barge
Koa	May 12	Dridrilbwij, Enewetak	1.37 MT	Surface
Wahoo	May 16	Ocean south of Enewetak	---	Underwater (DOB, 500 feet)
Holly	May 20	Off Runit Island, Enewetak	---	Barge
Nutmeg	May 21	Zuni site, Bikini	---	Barge
Yellowwood	May 26	Off Enjebi Island, Enewetak	---	Barge
Magnolia	May 26	Off Runit Island, Enewetak	---	Barge
Tobacco	May 30	Off Enjebi Island, Enewetak	---	Barge
Sycamore	May 31	Bravo site, Bikini	---	Barge
Rose	June 2	Off Runit Island, Enewetak	---	Barge
Umbrella	June 8	Enewetak Lagoon	---	Underwater (DOB, 150 feet)
Maple	June 10	Off Lomilik Island, Bikini	---	Barge
Aspen	June 14	Bravo site, Bikini	---	Barge
Walnut	June 14	Off Enjebi Island, Enewetak	---	Barge
Linden	June 18	Off Runit Island, Enewetak	---	Barge
Redwood	June 27	Off Lomilik Island, Bikini	---	Barge
Elder	June 27	Off Enjebi Island, Enewetak	---	Barge
Oak	June 28	Over reef of Bokoluo Island, Enewetak	8.9 MT	Barge
Hickory	June 29	Zuni site, Bikini	---	Barge
Sequoia	July 1	Off Runit Island, Enewetak	---	Barge
Cedar	July 2	Bravo site, Bikini	---	Barge
Dogwood	July 5	Off Enjebi Island, Enewetak	---	Barge
Poplar	July 12	Bravo site, Bikini	---	Barge
Pisonia	July 17	Off Runit Island, Enewetak	---	Barge
Juniper	July 22	Zuni site, Bikini	---	Barge
Olive	July 22	Off Enjebi Island, Enewetak	---	Barge
Pine	July 26	Off Enjebi Island, Enewetak	---	Barge
Teak	Aug 1	Over Johnston Island	MT range	Rocket (HOB, 252,000 feet)
Quince	Aug 6	Runit Island, Enewetak Atoll	---	Surface
Orange	Aug 12	Over Johnston Island	MT range	Rocket (HOB, 141,000 feet)
Fig	Aug 18	Runit Island, Enewetak Atoll	---	Surface

\* Many of the yields for the Hardtack series were not announced.

## **BACKGROUND.**

Operation Hardtack was an extensive series of tests with several types of events. A second phase of Hardtack was held at NTS. This second phase is usually described as "Hardtack II." It is covered in Section 19.

Five of the events were designated as DoD weapon effects tests. Three of these, Teak, Orange, and Yucca, were high-altitude bursts, and two, Wahoo and Umbrella, were detonated underwater. Weapon effects experiments were also performed on many of the AEC weapon development tests.

The Teak and Orange tests were a two-event set. Impetus for these tests was derived from uncertainties in U.S. capability to discern Soviet high-altitude nuclear detonations. The initial objective of this set was to measure acoustic waves from high-altitude nuclear bursts with a network of ground stations. By calibrating this sensor network with high-altitude U.S. tests, it was envisioned that this system might be used to detect Soviet high-altitude bursts. The selected detonation altitudes were 250,000 feet for Teak, where the acoustic signals to the ground stations were predicted to be weak, and 120,000 feet for Orange, where the signals should be strong. Teak detonated 35,000 feet laterally from the planned burst point, and Orange detonated at 141,000 feet rather than 120,000 feet. These deviations affected data acquisition.

The Teak and Orange nuclear devices were delivered to the detonation points by Redstone missiles. This was the first time such a procedure had been employed. Three pods with instrumentation were also carried aloft by each missile. These pods were deployed to be at specific altitudes and ranges from the bursts at detonation time.

Original plans were for the Redstone missiles to be launched from Bikini Atoll with the burst to occur in that vicinity. However, late in test preparations, it was discovered that there would be a high likelihood that natives on surrounding islands could suffer retinal burns. Therefore, only months before the test date, operations had to be moved to Johnston Island. This change undoubtedly degraded the quality of the data for some experiments, particularly in the areas of optical and radar measurements.

One major finding from these tests was that measurement of acoustic waves was not required to detect high-altitude Soviet tests. Such tests were easily detectable by a wide variety of means.

The Yucca test was a high-altitude detonation in which the device was carried aloft by an untethered balloon launched from a ship. Burst altitude was 86,000 feet. Test objectives were to study blast, thermal, and nuclear radiation environments and effects. Instrumentation was carried on cables suspended from the device balloon.

The Wahoo device was detonated at a depth of 500 feet in deep water south of Enewetak. The Umbrella device was detonated at a depth of 150 feet in the shallow Enewetak Atoll lagoon.

Operation Hardtack had the greatest amount of DoD participation to date. The effects activities included:

- Program 1—Blast Measurements
- Program 2—Nuclear Radiation
- Program 3—Structures and Equipments
- Program 4—Biomedical Effects
- Program 5—Effects on Aircraft Structures



Program 6—Tests of Service Equipment and Materials  
Program 8—Thermal Radiation and Effects.

## OPERATION HARDTACK PROJECTS AND REPORTS

### Technical Summary of Military Effects Programs 1-9

ITR-1660

This document summarizes the DoD nuclear weapon effects activities in Operation Hardtack. Refined data from various projects are presented to support broad conclusions. Summaries of each of the DoD projects are included.

### Program 32, High Altitude Measurements (AEC/Sandia Corporation)

WT-1601

The fourfold objective of this program was to: (1) develop U.S. capability for detecting high-altitude nuclear explosions, (2) search for unexpected phenomena, (3) assess upper altitudes as nuclear weapon proving grounds, and (4) study high-altitude nuclear weapon effects relevant to U.S. warhead vulnerability, ballistic missile defense design, and the "sunlamp" effect. (The sunlamp effect was a concept for using high-yield, high-altitude nuclear bursts to flood large areas at bomber flight altitudes with levels of initial nuclear radiations.) Program 32 was carried out during Teak and Orange. Rockets were used to deliver test apparatus and instrumentation to the appropriate altitudes and positions and to place the radio frequency (rf) transmitters above and around the bursts to measure rf attenuation at two ground stations. Some data loss occurred because the bursts did not detonate at their planned locations, some of the test pods were not recovered, and some of the rf attenuation rockets fielded. Measurements made or attempted included (a) device x-ray output, (b) thermal radiation environment, (c) neutron flux, (d) gamma dose rate, (e) integrated gamma dose, (f) blast pressures, (g) rf attenuation, and (h) optical brightness and spectrum. A significant amount of data was collected and reported.

### Teak Phenomenology (Los Alamos Scientific Laboratory)

LAMS 2417

The results of theoretical studies and experimental observations from Teak are presented. These include neutron, gamma, and x-ray output, interaction of radiation with the atmosphere, hydrodynamic expansion of the fireball, yield/energy partitioning, upper atmospheric shock, and auroral phenomena. Raw data, reduced data, and analyses of results are provided.

## BLAST MEASUREMENTS—PROGRAM 1

### *Project 1.1, Underwater Pressures from Underwater Bursts*

WT-1606

The objective of this project was to measure the free-field water pressure from an underwater nuclear burst to determine safe-escape ranges for submarines and ships operating in the vicinity of nuclear detonations. Pressure-time and peak pressure measurements at depths as great as 2,000 feet were made at various ranges from the Wahoo and Umbrella detonations. Gauge locations, data traces, and reduced data are reported.

### *Project 1.2, Airblast Phenomena from Underwater Bursts*

WT-1607

The objective of this project was to measure the airblast resulting from a water pressure wave from an underwater nuclear burst. Pressure gauges were deployed at various altitudes and ranges of Wahoo and Umbrella. Low-level air pressure measurements are reported for several test stations.

***Project 1.3, Surface Phenomena from Underwater Bursts*** **WT-1608**

This project filmed the action of the water at the surface above underwater nuclear detonations. Plumes, spray domes, base surges, and shock wave "slicks" for Wahoo and Umbrella were photographically recorded from four ships plus aircraft. Photographs are presented and observed phenomena are reported.

***Project 1.4, Physical Characteristics of Craters from Near-Surface Nuclear Detonations*** **WT-1609**

The project was tasked to measure the crater characteristics (radius, depth, lip, and throwout) produced by near-surface nuclear bursts. The Koa, Cactus, and Fig craters were measured in detail, and some information was acquired from the Linden, Oak, Yellowwood, Butternut, and Holly craters. Crater profiles and photographs are presented.

***Project 1.5, Refraction of Shock from a Deep-Water Burst*** **WT-1610**

This project measured the pressure wave generated by an underwater nuclear burst. Measurements were made at various ranges and water depths of Wahoo. Most of the experiments failed, but some pressure and shock arrival time data are reported.

***Project 1.6, Water-Wave Measurements*** **WT-1611**

The objective of this project was to study wave generation from the Wahoo and Umbrella events and to see if flooding occurred on land. Photographs and descriptions of waves are presented.

***Project 1.7, Airblast Phenomena and Instrumentation of Structures*** **WT-1612**

The objective of this project was to measure overpressure-time, and dynamic pressure-time for many Hardtack events under a wide variety of conditions. Device yields ranged from fractions of a kiloton to megatons, detonated from surface level to 240,000 feet altitude. Blast lines for measuring the same shock wave at several horizontal ranges were employed on several events. Numerous blast data were collected and reported.

***Project 1.8, Ground Motion Produced by Nuclear Detonations*** **WT-1613**

Air pressure, relative displacement, and ground accelerations were measured at close range and at different depths for Cactus and Koa. A considerable amount of data and analysis is presented.

***Project 1.9, Loading on Buried Simulated Structures in High-Overpressure Regions*** **WT-1614**

Self-recording deformation gauges were buried at depths from 0 to 20 feet at approximately 250 psi overpressure for Cactus and Koa. The objective was to study the transmission of airblast-induced pressure through soil and the resultant loading on buried structures. Water-table depth was a consideration. Pressure-time data and analyses are presented.

***Project 1.11, Yield and Energy Partition of Underwater Bursts*** **WT-1616**

The objective of this project was to measure the shock arrival time close-in to the Wahoo and Umbrella underwater detonations in order to calculate pressures. Due to equipment failure, no information was collected for Wahoo. A small amount of shock-arrival data from Umbrella is presented.

***Project 1.12, Ground-Shock Spectra from Surface Bursts*** **WT-1617**

Mechanical reed gauges were used to measure spectral components of the ground shock of Cactus and Koa. The basic ground shock and the airblast-induced ground shock components were measured at predicted airblast overpressure ranges from 70 to 200 psi. Numerous shock spectrum measurements in the vertical and radial directions are presented.

***Project 1.13, Characteristics of Ocean and Bottom for Shots Wahoo and Umbrella, Including Umbrella Crater*** **WT-1618**

The objective of this project was to measure the ocean water and bottom characteristics prior to the underwater shots and to measure the crater after Umbrella. The ocean floor profiles before and after Umbrella are presented.

**NUCLEAR RADIATION AND EFFECTS—PROGRAM 2**

***Project 2.1, Shipboard Radiation from Underwater Bursts*** **WT-1619**

The objective of this project was to measure the gamma dose and dose rate versus time onboard and in the water around ships moored in the vicinity of the Wahoo and Umbrella underwater nuclear detonations. Extensive gamma-time maps at many locations are displayed.

***Project 2.2, Shipboard Contaminant Ingress from Underwater Bursts*** **WT-1620**

A destroyer moored in the vicinity of the Wahoo and Umbrella tests measured the radioactive contamination entering ventilated ship compartments after underwater nuclear explosions. Instrumentation included film badges and recording radiation detectors. Ingestion by live mice and guinea pigs of contamination was recorded. Gamma doses and dose rates at various locations in the ship are reported.

***Project 2.3, Characteristics of the Radioactive Cloud from Underwater Bursts*** **WT-1621**

The objective of this project was to characterize the airborne radioactive material within a radius of 30,000 feet from Wahoo and Umbrella. Gamma doses were measured and fallout samples were collected on ships and floats. Extensive gamma dose and dose rate maps are presented.

***Project 2.4, Neutron Flux from Large Yield Bursts*** **WT-1622**

The objective of this project was to measure neutron flux at various ranges from the two nuclear detonations, Yellowwood and Walnut. The neutron spectrum was also measured using a variety of absorber materials. Tables of flux measurements are presented.

***Project 2.4a, Neutron Flux Measurements*** **WT-1679**

This project measured the neutron and gamma-ray environments around and above low-yield nuclear detonations. Measurements were made at altitude by balloon-borne sensors during Fig. Many data points are reported.

***Project 2.6, Neutron Flux from Very-High-Altitude Bursts*** **WT-1623**

Instruments for measuring neutron and gamma radiation fields were deployed from six missile pods during Teak and Orange to measure the neutron and gamma radiation environments at high altitudes from high-altitude nuclear detonations. Data acquired from three of the six pods are presented. Telemetry signals were also monitored for blackout effects.

***Project 2.8, Fallout Measurements by Aircraft and Rockets***

**WT-1625**

The objective was to measure the activity and content of nuclear clouds using aircraft and rockets for sample collection. The rocket collections failed, but B-57 and WB-50 aircraft collected radioactive debris for Koa, Walnut, and Oak. Particle sizes, activities, and radionuclides are reported.

***Project 2.9, Gamma Dose from Very-Low-Yield Bursts***

**WT-1677**

In order to measure gamma dose at tactically significant ranges from low-yield devices, film badges were deployed at different ranges, directions, and altitudes for Quince and Fig. Some badges were exposed for short times and then shielded so that they measured only the early-time gamma dose. Measured gamma dose as a function of direction and distance from the bursts, and at altitudes up to 1,200 feet are reported.

***Project 2.10, Residual Radiation from a Very-Low-Yield Burst***

**WT-1678**

The objective of this project was to measure the radiation near the crater and lip of low-yield bursts shortly after detonation. Nevada Test Site (NTS) soil was substituted for coral in the projected crater areas of Quince and Fig. Radiation was measured at various distances, directions, and times after detonation. Dose rates as a function of position and time, alpha-particle levels, and contamination chemistry are reported.

***Project 2.12a, Neutron Flux from Very-Low-Yield Bursts***

**WT-1679**

The objective of this project was to measure the neutron environment in terms of dose, flux, and spectrum at various distances from low-yield nuclear detonations. Measurements were made for Fig and Quince. Data plots characterizing the neutron fields are presented.

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

**WT-1602**

The objective was to track the fallout pattern from a low-yield burst to develop a fallout model for tactical battlefield conditions. NTS soil was placed in the vicinity of the Fig explosion area, and fallout collection trays and radiation monitors were distributed over land and water stations. Considerable loss of instrumentation occurred, but some fallout activity and plutonium measurements are presented.

***Project 2.14b, Dimensions of Nuclear Cloud from a Very-Low-Yield Bursts***

**WT-1603**

The objective of this project was to determine nuclear cloud dimensions as a function of time to support radioactive fallout analysis and model development. The Fig cloud was photographically recorded. Cloud dimensions at various times are reported.

**STRUCTURES AND EQUIPMENT—PROGRAM 3**

***Project 3.2, Response of Earth-Confined Flexible Arch Structures in High Overpressure Regions***

**WT-1626**

This project was tasked with assessing the response of buried steel arched buildings to long- and short-duration high-pressure blast waves. One buried structure was tested for Cactus and three for Koa. Displacement gauge traces and photographs of structure damage are presented.

***Project 3.3, Shock Loading in Ships from Underwater Bursts  
and Response of Shipboard Equipment***

**WT-1627**

Several instrumented ships, a submarine, and a simulated submarine were tested during Wahoo and Umbrella. The objective was to assess onboard equipment damage and ship and submarine lethality from underwater nuclear bursts. Instrumentation included shock pressure and spectrum and vessel acceleration. Motion pictures were taken of internal vessel component motion. Traces of shock spectra and structure displacement with time at various locations are presented. Descriptions of damage and operational implications are included in the report.

***Project 3.4, Loading and Response of Surface-Ship  
Hull Structures from Underwater Bursts***

**WT-1628**

The objective of this project was to measure, at various locations on ships' hulls, the forces acting upon the hulls due to underwater nuclear bursts and the subsequent motion of the hulls at these locations. Instrumented destroyers and a barge were exposed to Wahoo and Umbrella. Pressure-time traces and hull displacement-time measurements are presented.

***Project 3.5, Loading and Response of Submarine  
Hulls from Underwater Bursts***

**WT-1629**

The project objective was to determine the lethal pressure-loading level for a submerged submarine exposed to an underwater nuclear burst. An instrumented submarine and a simulated submarine submerged at shallow depths were exposed to Wahoo and Umbrella. Strain, pressure, and displacement gauges were employed. High-speed motion-picture photography was used to observe hull and vessel internal component movement. Gauge traces and measured deformations are reported.

***Project 3.6, Behavior of Deep Reinforced-Concrete Slabs  
in High Overpressure Regions***

**WT-1630**

The objective was to determine the response of reinforced concrete slabs in various configurations to high pressures close-in to a nuclear burst. The slabs were deployed at ground level at two stations of Koa. Measured pressures, descriptions of damage to the concrete, and extensive theoretical analyses are presented.

***Project 3.7, Damage to Existing EPG Structures***

**WT-1631**

The objective of this project was to inspect structures that had been tested in previous events and to report damage that occurred from subsequent nuclear explosions. Facilities inspected were on islands of the Enewetak Atoll. This was a low-cost data acquisition, since no new structures were installed, and the only instrumentation installed was self-recording. Numerous photographs of structures, before and after the later detonations, are presented.

***Project 3.8, Assessment of Ship Damage and Preparation of Targets***

**WT-1632**

The purpose of this project was to inspect naval vessels before and after exposure to the Wahoo and Umbrella events and report resultant damage. Comments on the vessels' operational capabilities after exposure and photographs of explosion-induced damage are presented.

## **BIOMEDICAL EFFECTS—PROGRAM 4**

### ***Project 4.1, Effects on Eyes from Exposure to Very-High-Altitude Bursts*** **WT-1633**

A study of chorioretinal burn damage from the flash from Teak and Orange was performed using rabbits as test specimens. Exposure distances ranged from 50 to 350 nmi at test stations on the ground and behind plexiglas canopies in aircraft. Physical eye damage as a function of exposure conditions is illustrated.

## **EFFECTS ON AIRCRAFT STRUCTURES—PROGRAM 5**

### ***Project 5.1, In-Flight Structural Response of a B-52 Aircraft to Side Loading from a Nuclear Detonation*** **WT-1634**

The objective of this project was to expose a B-52 aircraft in flight to nuclear thermal and airblast loads and measure system response. A B-52 bomber was flown at various orientations to the bursts of Redwood, Walnut, Dogwood, Elder, Cedar, Maple, Koa, Oak, and Fir. Thermal, airblast, and nuclear radiation environments were measured, as well as structural response. Numerous tables of environment and response data are presented.

### ***Project 5.2, In-Flight Structural Response of A4D-1 Aircraft to Nuclear Detonations*** **WT-1635**

Two instrumented A4D-1 aircraft were flown during Cactus, Butternut, Koa, Yellowwood, Magnolia, Tobacco, Rose, and Walnut with the objective of measuring the response of in-flight A4D-1 aircraft to nuclear environments. Extensive data on nuclear environments and response of aircraft structural elements are reported.

### ***Project 5.3, In-Flight Structural Response of FJ-4 Aircraft to Nuclear Detonations*** **WT-1636**

Two instrumented FJ-4 aircraft flew during Cactus, Butternut, Koa, Yellowwood, Magnolia, Tobacco, Rose, and Walnut to assess the response of the aircraft to nuclear environments. Extensive data on measured thermal, blast, and nuclear radiation environments and aircraft structure response are reported.

## **SERVICE EQUIPMENT AND MATERIALS—PROGRAM 6 AND RELATED EXPERIMENTS**

### ***Project 6.3, Effects of Nuclear Radiation on Electronic Fuze Components and Materials*** **WT-1637**

The purpose of this project was to measure effects of nuclear radiation on electronic systems and components. A fuzing system and various electronic components were exposed to the neutron and gamma radiation environments of Nutmeg, Maple, Hickory, and Juniper. Electrical characteristics before and after exposure are reported, and some active measurements during exposure are presented, along with nuclear environmental data.

### ***Project 6.3a, Effects of Nuclear Radiation on Semiconductor Devices*** **WT-1742**

The objective of this project was to study the effects of nuclear radiation on a variety of transistors. Transistor performance was measured before and after exposure to Nutmeg, Yellowwood, Maple, and Hickory. Changes in performance parameters are reported.

***Project 6.4, Wave Form of Electromagnetic Pulse from Nuclear Detonations*** **WT-1638**

Measurements were made of the characteristics of the electromagnetic pulse from various nuclear detonations. Instrumentation was deployed at stations from 100 to 500 miles from Yucca, Cactus, Fir, Butternut, Koa, Holly, and Nutmeg detonations. Data traces and analyses are presented.

***Project 6.5, Radar Determination of Fireball Phenomena*** **WT-1639**

This project investigated the nature of radar returns from nuclear fireballs and attempted to ascertain the GZ location, height of burst, and yield from such returns. Measurements were made during Yucca, Cactus, Fir, Butternut, Koa, Yahoo, Holly, and Teak. Photographs of scope traces with radar returns are presented, along with discussions of conditions under which the radar measurements were acquired.

***Project 6.6, X-Band Radar Determination of Nuclear-Cloud Parameters*** **WT-1640**

Weather radars, at ranges as great as 400 miles, were employed for Yucca, Cactus, Fir, Butternut, Koa, Wahoo, Holly, Yellowwood, Magnolia, Teak, and Orange to assess the feasibility of using a weather radar to characterize nuclear clouds. Radar performance in the various tests is described.

***Project 6.7, Naval-Mine-Field Clearance by Underwater Bursts*** **WT-1641**

The objective was to assess the feasibility of using nuclear detonations to clear naval mine fields. Various types of mines were instrumented and deployed in the vicinity of the Umbrella nuclear burst. Mine damage and response at various ranges from the detonation are reported.

***Project 6.8, Feasibility of Wide-Area Clearance of Naval Influence Mines by Nuclear Weapons*** **WT-1642**

The task was to determine if naval mines employing pressure, magnetic, or acoustic activators could be detonated by nuclear environments. Measurements of pressure, magnetic field, and acoustic signals were made for Umbrella, Wahoo, Yellowwood, Tobacco, and Sycamore. Measured signals and discussions of consequences to mines are presented.

***Project 6.9, Effects of Nuclear Detonations on the Ionosphere*** **ITR-1643**

This project was designed to probe the ionosphere for disturbance due to nuclear detonations. Vertical probes were made from two islands in the Pacific for Yucca, Fir, Butternut, and Koa. Due to extensive equipment failure, very few data were collected, but some measurements and observations are presented.

***Project 6.10, Ionization Produced by High Altitude Bursts*** **WT-1644**

The objective of this project was to study the radio and radar blackout phenomena associated with high-altitude nuclear bursts. Two instruments, one ground-based and the other aircraft-based, made continuous measurements of the ionosphere before, during, and after the Teak and Orange detonations at a variety of transmission frequencies. Also, various radio signal frequencies from Hawaii were monitored at Johnston Island. Radio signals from different locations in the Pacific were monitored in Hawaii. Magnetic field strength was measured from an aircraft platform. Photographic coverage of the sky in the vicinity of the bursts was provided. Extensive photographic and radiofrequency measurement data are presented, along with ionograms and observations of the expansion of the fission debris cloud.

***Project 6.11, HF and VHF Attenuation and Reflection Phenomena***

**WT-1645**

Observations were made of the variations in reflection or absorption of radar signals due to high-altitude nuclear bursts. Five radars in the 10- to 1,000-MHz range were deployed on ships in the vicinity of Teak and Orange. Reflected radar signals are described. Additionally, satellite transmissions were monitored for signal degradation.

***Project 6.12, Effects of High Altitude Bursts on Pulsed Electromagnetic Transmissions***

**WT-1646**

The purpose of this project was to place transmitters above the nuclear-burst ionized region and measure the transmitted signals at ground stations. Rockets were used to place the transmitters above the ionized region. Six rockets were launched 5 minutes apart for both Teak and Orange. Each rocket carried an L-band (450 MHz) and an S-band (2,900 MHz) transmitter. Receivers were deployed on Johnston Island, Hawaii, and two destroyers. Due to mechanical failure and operator errors, no data were recorded for Teak. Five L-band records were acquired for Orange. Tables showing signal strength as a function of time at various receiver stations are presented.

***Project 6.13, Study of Very-High-Altitude Bursts with Airborne UHF Radar***

**WT-1659**

This project was to assess UHF radar operations in the presence of an ionization cloud produced by very-high-altitude nuclear detonations. Two Navy aircraft were employed, one equipped with a 425-MHz radar and the other with a 675-MHz radar. Data on radar returns from the ionized region is reported from burst time until approximately one hour after detonation as a function of aircraft position.

***Effects of High Altitude Nuclear Detonations on High Frequency Communications (U.S. Army Signal Radio Propagation Agency, Ft. Monmouth, NJ)***

**AFSWP 1104**

The objective of this effort was to assemble all available information on the radio communication outages that occurred in connection with the Teak and Orange nuclear tests. The radio stations affected, period of effects, operating frequencies, and geometry relative to the test are presented.

***Some Effects of High Altitude Nuclear Detonations on the Ionosphere During Project Newsreel, Operations HARDTACK (U.S. Army Signal Radio Propagation Agency, Ft. Monmouth, NJ)***

**Project 678**

The objective of this project was to measure effects in the ionosphere due to the Teak and Orange nuclear tests. Probes of the ionosphere were made from numerous ground stations in the Pacific and from a C-54 aircraft. Types and periods of disturbances are reported. Ionogram records are presented.

**THERMAL RADIATION AND EFFECTS—PROGRAM 8 AND RELATED EXPERIMENTS**

***Project 8.1, Effects on Materials by Thermal Radiation from Nuclear Detonations***

**WT-1647**

The stated objective of this project was to evaluate a laboratory simulation that assessed thermal effects on human skin from nuclear detonations. The important activity was to measure the thermal radiation environments from ground, ship, and airborne stations during Yellowwood, Walnut, Teak, and Orange. Range vs calorie levels from a few hundredths to a few calories per square centimeter are reported.



***Project 8.2, Thermal Radiation from High-Altitude Bursts***

**WT-1648**

The purpose of this project was to determine the spectrum and amplitude of the thermal pulse from high-altitude nuclear explosions. Two RB-36 aircraft patrolling between 30,000 and 40,000 feet altitude performed the data collection for Teak, Orange, and Yucca. Spectral irradiance, as a function of time, for four wave bands between 0.3 and 3.6 microns is reported.

***Project 8.3, Growth of Fireball Radii at Very High Altitudes***

**WT-1649**

The objective was to optically measure fireball growth as a function of time for the Yucca, Teak, and Orange high-altitude nuclear events. Filming was done from two RB-36 aircraft at altitudes between 30,000 and 37,000 feet, from Johnston Island, and from *USS Boxer*. Streak, Fastax, 35-mm and 70-mm cameras were employed. Fireball dimensions vs time are reported and photographic sources are referenced. The majority of the film sources used for this project are available at DASIAC, Santa Barbara, California.

***Project 8.4, Early-Time Spectra of Very-High-Altitude Nuclear Detonations***

**WT-1650**

Time-resolved spectral measurements of device thermal output between 2,100 and 6,000 angstroms were made from RB-36 aircraft for the Teak, Orange, and Yucca high-altitude events. The aircraft patrolled at altitudes between 30,000 and 37,000 feet. Raw and refined data, with analyses, are presented.

***Project 8.5, Narrow-Band Infrared Spectral Irradiance of High-Altitude Bursts***

**WT-1651-1, -2**

This project was tasked to measure the infrared spectral irradiance from high-altitude nuclear bursts for the first 300 msec after the detonation, and total irradiance for minutes after detonation. An infrared rapid-scan monochrometer and an infrared mapping device were installed on an aircraft to make measurements during Cactus, Teak, Orange, and Koa. Spectral irradiance vs time and thermal source maps are presented.

***Project 8.6, Vulnerability of Missile Structures to Nuclear Detonations***

**WT-1652**

The objective of this project was to study the effects of nuclear thermal radiation and x rays on missile structure materials. Samples were exposed inside the fireball of the Cactus burst. Samples in pods carried aloft by Redstone missiles were exposed to x rays from the Teak and Orange detonations. Few quantitative data were collected, but descriptions of sample damage, including photomicrographs are presented.

***Project 8.7/2.12d, Thermal Radiation from Very-Low-Yield Bursts***

**WT-1676**

Calorimeters were placed at ranges up to 900 feet from Fig GZ. Tabulations of total thermal energy are presented for two stations in discrete time increments up to six seconds after shot.

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

**WT-1690**

This project was designed to measure thermal radiation as a function of time and also the integrated thermal output of the Teak and Orange nuclear detonations. Bolometer instruments were deployed on Johnston Island. The presentation of results is ambiguous.

***Very Long Range Light Measurements***

**EG&G B-1866**

Intensity and spectral measurements of light from Yucca, Teak, and Orange were made on the islands of Guam, Wake, Parry, Johnston, and Maui. Measurements and photographic data are presented.

**SECTION 18**  
**ARGUS**  
**South Atlantic**  
**1958**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield (KT)</u>	<u>Weapon Placement</u>
Argus I	Aug 27	S38.5° W11.5°	1-2	Rocket (HOB, ~300 miles)
Argus II	Aug 30	S49.5° W8.2°	1-2	Rocket (HOB, ~300 miles)
Argus III	Sept 6	S48.5° W9.7°	1-2	Rocket (HOB, ~300 miles)

**BACKGROUND.**

Argus was an unusual operation. It was completed less than 6 months after Presidential approval, and it was accomplished in complete secrecy. Nuclear-tipped missiles were fired from ships for the first time. These launches occurred in the South Atlantic, with the nuclear detonations occurring at very high altitudes.

Basically, Operation Argus was a scientific experiment with significant military implications. The Argus hypothesis was that negatively charged particles from a high-altitude nuclear burst could become trapped in the earth's magnetic field and provide a shield against intercontinental ballistic missiles. It was also hypothesized that this electron layer might disrupt communications and damage satellites.

Physicist Nicholas Christofilos proposed that a nuclear detonation occurring above the earth's atmosphere, but within the earth's magnetic field, would produce beta particles (high-energy electrons) that would spiral around magnetic field lines, moving generally northward or southward. When the electrons reached conjugate points, they would reflect and spiral in the opposite direction. A large number of such electrons, with slightly different energies, would gradually form a toroidal band around the earth. If the electron density in this band was great enough, it could damage the electronics of traversing systems, such as missiles or satellites.

To assess this concept, nuclear devices were detonated at appropriate altitudes and locations with regard to the earth's magnetic field lines and changes in the electron densities at high altitudes were measured. The three Argus shots were designed to detonate at about 300 miles altitude at about 45° latitude in the South Atlantic. Satellite and rocket-borne instruments were used to measure electron densities and energies as a function of position in space and time. Electron energy density at conjugate points was monitored by radars.

It was found that the proposed phenomena did occur and there was an increase in electron density in a band around the earth. However, the increase did not appear to be great enough to provide the basis for a ballistic missile defense system.

There were practically no traditional nuclear weapon effects data collected during Argus. However, unique nuclear weapon phenomenology was probed and the theory behind the phenomenon was delineated. There were three measurement programs on Argus. The first was based on the newly launched Explorer IV satellite and its report WT-1668 reports the counting rates from the satellite's radiation detectors before and after the Argus events. The second program was one that used rockets carrying radiation detectors in order to detect the newly

created radiation belt. This program, Project Jason, is reported in **WT-1669**. A surface and airplane-based program called Project Midas took measurements in the ionosphere that would indicate the existence of a belt of charged particles above it. This program is reported in **WT-1670**. Measurements of electron density at various locations and times are reported in **WT-1665**, the Task Force Commanders report.

**SECTION 19**  
**HARDTACK II**  
**Nevada Test Site**  
**1958**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield (KT)</u>	<u>Weapon Placement</u>
Eddy	Sept 19	Yucca Flat, Area 7	0.083	Balloon (HOB, 500 feet)
Mora	Sept 29	Yucca Flat, Area 7	2	Balloon (HOB, 1,500 feet)
Tamalpais	Oct 8	Rainier Mesa, Area 12	0.072	Tunnel (DOB, 330 feet)
Quay	Oct 10	Yucca Flat, Area 7	0.079	100-foot tower
Lea	Oct 13	Yucca Flat, Area 7	1.4	Balloon (HOB, 1,500 feet)
Neptune*	Oct 14	Rainier Mesa, Area 12	0.115	Underground cratering (DOB, 98 feet)
Hamilton	Oct 15	Frenchman Lake	0.0012	50-foot tower
Logan	Oct 16	Rainier Mesa, Area 12	5	Tunnel (DOB, 932 feet)
Dona Ana	Oct 16	Yucca Flat, Area 7	0.037	Balloon (HOB, 450 feet)
Vesta*	Oct 17	Yucca Flat, Area 9	0.024	Surface
Rio Arriba	Oct 18	Yucca Flat, Area 3	0.090	75-foot tower
Socorro	Oct 22	Yucca Flat, Area 7	6	Balloon (HOB, 1,450 feet)
Wrangell	Oct 22	Frenchman Lake	0.115	Balloon (HOB, 1,500 feet)
Rushmore	Oct 22	Yucca Flat, Area 9	0.188	Balloon (HOB, 500 feet)
Sanford	Oct 26	Frenchman Lake	4.9	Balloon (HOB, 1,500 feet)
De Baca	Oct 26	Yucca Flat, Area 7	2.2	Balloon (HOB, 1,500 feet)
Evans	Oct 29	Rainier Mesa, Area 12	0.055	Tunnel (DOB, 848 feet)
Humboldt	Oct 29	Yucca Flat, Area 3	0.0078	25-foot tower
Mazama	Oct 29	Yucca Flat, Area 9	0	50-foot tower
Santa Fe	Oct 30	Yucca Flat, Area 7	1.3	Balloon (HOB, 1,500 feet)
Blanca	Oct 30	Rainier Mesa, Area 12	22	Tunnel (DOB, 835 feet)

**BACKGROUND.**

Operation Hardtack II was a highly accelerated test series approved by the President just 2 months before the start of the 1958 nuclear test moratorium that the major powers had previously agreed upon. Hardtack II included 37 tests — 18 safety tests and 19 development tests. Fifteen of the development tests were in the atmosphere and four were performed underground. All of the tests were of comparatively low yield. Although the most significant nuclear effects information from this series resulted from underground events. These effects are not covered in this guide. X-ray effects phenomenology was addressed in the Logan event, and its exclusion is not purely arbitrary. The output energy of a nuclear explosion is mainly in the form of x-rays which are quickly converted to thermal and blast energy in the presence of air. The interest in actually

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\* Safety experiments.

intercepting incoming ballistic missiles before these objects reentered the earth's atmosphere was beginning to grow at this time and an obvious killing mechanism was x-rays. Therefore interest in x-ray effects grew at this time and was the motivation for a great deal of contained underground nuclear testing from 1958 to the present. Logan may be viewed as a starting point in this process and its x-ray experiments belong to a description of those more recent experiments, not the atmospheric test experiments. The ground shock experiments conducted on Logan are however included in this guide.

A relatively small amount of atmospheric nuclear effects data was collected in Hardtack II, due to insufficient time in which to prepare effects experiments. The two events that had been designated for DoD effects experiments (Hamilton and Humboldt) had much lower yields than predicted. One technical area that did receive attention was the measurement of the nuclear environments from low-yield devices, since these are the environments to be considered for the delivery of low-yield air-to-air nuclear weapons.

The results of two safety tests are included here because some effects experiments were fielded and reported for these events.

## **OPERATION HARDTACK II PROJECTS AND REPORTS**

### **GROUND SHOCK MEASUREMENTS**

#### ***Project 26 Strong Motion Measurements***

**ITR-1711**

Surface and subsurface measurements were made on six underground tests, Tamalpais, Neptune, Logan, Evans, and Blanca in the Rainier Mesa area of NTS.

#### ***Project 26.1 Earth Motion Measurements***

**WT-1702, -1715, -1740**

Vertical acceleration and velocity were measured in boreholes and horizontal and vertical acceleration and horizontal strain on the surface for Evans and Blanca.

As part of this project, post shot measurements of seismic noise possibly indicating chimney formation or other shot associated phenomena were attempted. Measurements of post shot changes in elevation were also attempted. The purpose of these were the development of instruments and techniques for detecting underground explosions.

#### ***Projects 26.2 and 26.10 Surface and Subsurface Strong Motion Measurements***

**ITR-1703**

This project measured radial acceleration on a vertical radius in two boreholes above Evans. Vertical and horizontal radial accelerations were measured on the mesa surface on Tamalpais, Evans, and Blanca.

#### ***Project 26.3 Ground Motion Measurements***

**ITR-1704**

On Evans this project measured radial accelerations and strain in the earth media surrounding the shot. Some gage development measurements were made on Tamalpais.

#### ***Project 26.4 Surface Motions***

**WT-1741**

This project measured surface acceleration and transient displacement on Tamalpais, Logan, Evans, and Blanca at stations from 2,000 feet to 3,800 km from the test site.

***Project 26.5 Earth Motions***

**ITR-1706**

High speed and regular speed motion picture records were made of the surface motions at the tunnel portals for shots Neptune and Blanca. Motion pictures of the mesa surface above the tests were also made using lighted towers as reference points.

***Project 26.7 Structural Response and Permanent Displacement***

**WT-1708**

Measurement of permanent displacement were made by noting changes in surveyed bench marks on the mesa surface. Dynamic measurements were made by recording the output of strain gages attached to steel pipes forming cross cavity beams in alcoves. Dynamic measurements were made on Evans. Surface measurements were made on Evans, Tamalpais, Neptune, Logan, and Blanca.

The project also made measurement of the response of several of the Plumbbob structures in the Frenchman Lake to HE loading.

***Project 26.8 Medium Studies***

**ITR-1709**

Time histories of stress in the floor of the excavation leading to the shot chamber of shot Tamalpais were made. These were at ranges from 100 to 425 feet from the shot. Two measurements of radial displacement at a distance of 300 feet from the shot were also made.

***Project 26.9 Close-in TOA Measurements***

**WT-1710**

The velocity of the shock front was measured by two systems. The first method used the time intervals required to crush pressure switches at accurately determined radial distances in the underground medium. The second used a Doppler system which measured the rate at which the shock front crushed a rigid coaxial cable at known distances. The purpose of these measurements was device yield estimation. The project made measurements on Tamalpais, Logan, Evans and Blanca.

***Project 26.13 Effects on Tunnel Support***

**ITR-1714**

This project collected static measurements from surveying methods and still photography on rock breakage and tunnel lining response in mining drifts near the Tamalpais, Evans, Logan, and Blanca shots. Data is in the form of still pictures. Attempts at dynamic measurements such as fly rock motion picture photography were not successful.

**NUCLEAR RADIATION MEASUREMENTS**

***Project 2.4a, Neutron Flux Measurements***

**WT-1679**

This project measured the neutron and gamma-ray environments around and above low-yield nuclear detonations. Measurements were made at altitude by balloon-borne sensors during Humboldt and Hamilton. Many data points are reported.

***Project 2.12a, Neutron Flux from Very-Low-Yield Bursts***

**WT-1679**

The objective of this project was to measure the neutron environment in terms of dose, flux, and spectrum at various distances from low-yield nuclear detonations. Measurements were made for Hamilton and Humboldt. Data plots characterizing the neutron fields are presented.

***Project 2.12b, Gamma Dose from Very-Low-Yield Bursts***

**WT-1677**

The objective was to measure gamma dose at different ranges from low-yield nuclear detonations. Measurements were made in all directions, at ranges up to 800 yards, for Hamilton and Humboldt. Measurements were also made in military vehicles and foxholes. Gamma doses as a function of position and time are reported.

***Project 2.12c, Soil Activation***

**WT-1680**

This project made measurements of spectrally resolved gamma radiation after Hamilton with the intent of identifying the emissions from activated species. Unfortunately, the soil had become contaminated with fission products whose radiations masked the activated species. Some sampling of soil cores was done and generalizations about depth of activation are put forward. Plots of total dose rate for several times are presented and decay rates are analyzed.

***Project 2.13, Gamma Radiation and Induced Activity from Very-Low-Yield Bursts***

**WT-1681**

The project objective was to measure gamma dose and dose rate and neutron dose in the vicinity of a low-yield detonation. Sensors were deployed around the Hamilton tower. The unexpected low yield degraded data acquisition. Gamma rate as a function of time and distance and neutron and gamma doses as a function of distance are reported.

**BIOMEDICAL EXPERIMENTS**

***Project 4.2, Effects of Very-Low-Yield Bursts on Biological Specimens (Swine and Mice)***

**WT-1663**

This experiment exposed animals to high radiation doses to investigate dosage for immediate lethality. Pigs and mice were placed in foxholes and military vehicles and exposed at levels of many thousands of rads during Hamilton and Humboldt. Some animals were given anti-radiation pills. Measured doses and animal responses are reported.

***Project 4.3, Effect of Light from Very-Low-Yield Nuclear Detonations on Vision (Dazzle) of Combat Personnel***

**WT-1664**

The objective of this project was to determine the impact of nuclear flash on combat soldiers' ability to perform their functions. Twenty-five soldiers were placed within viewing range, but facing away from Hamilton GZ. After the burst, the troops were given vision tests. The ability of each individual to recognize targets shortly after the detonation is reported.

**ELECTROMAGNETIC MEASUREMENTS**

***Project 6.15, Electromagnetic Pulses from Low-Yield Bursts***

**WT-1662**

The project was tasked to acquire electromagnetic pulse waveforms from low-yield detonations to establish a relationship between waveforms and yield. Attempts were made to record electromagnetic signals from the 15 atmospheric and 4 underground nuclear tests at a range of about 100 miles. Traces were acquired and reported for three events.

## THERMAL MEASUREMENTS

***Project 8.7/2.12d, Thermal Radiation from Very-Low-Yield Bursts*** **WT-1676**

Radiant exposures for Hamilton were recorded at ranges up to 700 feet from surface zero. The project report questions the accuracy of several of the ranges because of the low range being measured.

***Project 8.8, Thermal Radiation from Low-Yield Nuclear Bursts*** **WT-1675**

Thermal pulse ( $W/cm^2$ ) in four bandpasses from 2 to 10 microns were recorded for 10 of the test shots and tabulations of the instrument outputs are presented. Also presented are early-time photographs of the fireballs as an aid in interpreting the tabulations. Curves of thermal pulse vs time inferred from the tabulations are given.

***Project 10.1, Fireball Yields*** **WT-1743**

Tabulations of fireball size vs time for yield estimation derived from high-speed motion pictures are presented for the 12 LASL devices tested in Hardtack II.

## STRUCTURAL RESPONSE

***Project 34.1, Physical Damage Survey of AEC Test Structures*** **WT-1701**

The objective of this project was to assess nuclear blast and thermal damage to a concrete structure near a burst, and to frame houses at low-overpressure ranges from bursts. Damage to the concrete bunker at the base of the Quay shot tower was assessed and reported. Damage to frame houses exposed to Mora, Lea, and Socorro is described. Posttest photographs of damaged structures are presented. Also provided is a table of thermal and blast damage to structures from previous operations.

***Project 34.2, Radiation Shielding and Response Studies of AEC Test Structures*** **WT-1723**

The study objectives were to measure the radiation doses and the accelerations in four small, buried concrete structures exposed to nuclear detonations. The structures had served as instrumentation shelters in previous tests. Measurements were made during Mora, Lea, Socorro, Vesta, Rushmore, and Quay. Radiation dose as a function of position inside the bunkers is presented. Some free-field overpressure measurements and acceleration measurements inside the bunkers are reported.

***Project 39, Attenuation of Weapons Radiation:  
Application to Japanese Houses*** **WT-1725**

Seven Japanese-style houses were exposed to nuclear radiation at various ranges from Mora, Lea, and Socorro GZ. Free-field energy-dependent radiation doses are reported, along with radiation doses measured inside the houses.

***Project 70.4, Effect of Nuclear Weapons on OCDM Family Fallout Shelter*** **ITR-1718**

The objective was to evaluate the ability of an underground concrete shelter to provide families with nuclear blast and radiation protection. During Vesta, three identical shelters were exposed at nominal 20-, 10-, and 5-psi ranges, respectively. Radiation fallout profiles and pressures outside and inside the shelters are reported.



**SECTION 20**  
**NOUGAT, STORAX, AND DOMINIC**  
**1961-1962**

Date	TEST OPERATIONS				Plowshare Series	OTHER U.S. NUCLEAR TESTS
	Dominic					
	Weapon Development Airdrops	Sun Beam (Dominic II)	Fishbowl	Other Dominic		
<b>1961</b>						
15 Sept	----- First Operation Nougat Shot ----->					Antler
10 Dec					Gnome	:
<b>1962</b>						Hard Hat
15 Feb						Danny Boy
5 Mar						:
25 Apr	Adobe*					:
6 May	.			Frigate Bird		:
11 May	.			Swordfish		:
28 June	.					Marshmallow
30 June	----- Last Operation Nougat Shot ----->					Sacramento
6 July	----- First Operation Storax Shot ----->				Sedan	.
7 July	.	Little Feller II				.
9 July	.	:	Starfish			.
11 July	Pamlico	Small Boy				.
2 Oct	Androscoggin**					.
20 Oct	:		Checkmate†			.
30 Oct	Housatonic		:			.
4 Nov			Tightrope‡			.
<b>1963</b>						.
25 June	----- Last Operation Storax Shot ----->					Kennebec

**Notes:**

- \* Weapon development airdrops commencing 25 April 1962 (Adobe) and continuing through 11 July 1962 (Pamlico) were conducted at Christmas Island.
- \*\* Weapon development airdrops commencing 2 October 1962 (Androscoggin) and continuing through 30 October 1962 (Housatonic) were conducted near Johnson Island.
- † Second or Fall Phase of Fishbowl begins over Johnston Island.
- ‡ Last U.S. atmospheric test.

After the USSR broke the moratorium on testing in the summer of 1961, the United States resumed nuclear testing with Antler, a 2.6-KT underground shot at NTS on 15 September and followed with Shrew, another low-yield NTS underground test, the following day. These

underground weapon development shots were followed by seven more before the end of calendar year 1961. By the end of the federal government's 1962 fiscal year on 30 June, 32 more had been conducted. Interspersed with these were several DoD-sponsored UGTs, a UGT devoted to the study of the peaceful uses of atomic energy as part of the Plowshare program, 22 weapon development airdrop tests off Christmas Island, an underwater test, and a proof test of the Polaris system. All of these nuclear tests were part of Operation Nougat.

The use of the word "operation" here is obviously quite different than its use followed in the usage of the weapon test literature before the 1959-1961 moratorium. Operations up to that point had denoted a series of tests conducted by a test organization or joint task group over a limited span in time and over a limited geographic region, but now another definition was added: all tests occurring during a given government fiscal year — Operation Nougat for tests during fiscal 1962 and Operation Storax for tests during fiscal 1963.

Whatever virtues such a nomenclature has for accounting purposes, these new-style operations are not very useful for organizing the material in this guide and this will be the last reference to Nougat and Storax. They have been introduced only as they are used to a small degree in the literature of the period and the reader should be familiar with them.

Fortunately, the word operation continued to be used in the older sense in addition to the fiscal-year sense, and this provides a way to present the information in this guide. Unfortunately, the word operation was also used in an overlapping sense with the result that some test shots may be legitimately described as being a part of several named operations, whereas a few are not part of any operation within the operative old-style meaning used here.

The organization adopted for the information is shown in the table above and is described in the subsequent paragraphs.

Almost all U.S. atmospheric nuclear weapon testing after the end of the test moratorium, both weapon development and DoD effects shots, was conducted as part of Operation Dominic. Operation Dominic is a loosely used designation and includes within its definition other operations such as Operation Fishbowl and Operation Sunbeam. The only nuclear detonations that freely vented to the atmosphere that were not part of Dominic were the Danny Boy shot discussed in Section 22 and the large cratering shot Sedan at NTS on 6 July 1962, one of the Plowshare series discussed in Section 23.

Dominic included a proof test of the Polaris system. The submarine *USS Ethan Allen* fired a Polaris armed with a nuclear warhead, which then flew into the restricted area near Christmas Island and detonated at low altitude. This was designated as the Frigate Bird shot and no effects data was developed.

Swordfish, the underwater detonation in the Pacific 500 miles west of San Diego, was also part of Dominic. Swordfish is the subject of Section 24.

Dominic included a series of 24 weapon-development airdrops off Christmas Island from 25 April through 11 July and a series of 4 weapon development airdrops during October off Johnston Island. These shots were instrumented almost exclusively for weapon diagnostics but some effects data were collected; they are considered in Section 25.

Dominic also included a series of five tests based on Johnston Island in which rockets were used to lift nuclear devices to high altitudes where they were detonated. This series is referred to as Operation Fishbowl and was the subject of many DoD effects experiments. Fishbowl is discussed in Section 26.

Finally Dominic included a series of four atmospheric effects shots at NTS, usually called Operation Sunbeam, conducted in July 1962. This also became known as Dominic II perhaps in parallel with the Hardtack II NTS operations in 1958. Sunbeam is the subject of Section 27.

There was one DoD sponsored shot executed during this period that is not considered in this guide and that is Marshmallow (28 June 1962). This was a completely contained underground explosion. This was an x-ray effects test like Logan of Hardtack II and its experiments descriptions belong to the history of a more recent era.

**SECTION 21  
HARD HAT  
Nevada Test Site  
1962**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Hard Hat	Feb 13	Area 15	5.7 KT	Tunnel

**BACKGROUND.**

Although Hard Haat was a fully contained underground test, it is included because of the weapons effects objective (see comment on page 1-1). Hard Hat was designed to study ground shock effects on underground structures, and was the successor to Lollipop, a shot planned during the moratorium period. It was not part of a larger operation of the kind used to organize information in this report, although it was part of Operation Nougat discussed in Section 20. Some tunnel liner test sections had been made during this period for testing in Lollipop which were then used in Hard Hat. Previous tunnel testing in Hardtack II was done in volcanic tuff. The Hard Hat site was a granite material which is referred to as Climax Stock.

**HARD HAT PROJECTS AND REPORTS**

***Project 3.1, Tunnel and Tunnel Liners***

**WT-1801**

This experiment examined 43 test sections of tunnel in granite in drifts that were from 244 to 457 feet from the shot point. Thirty of these test sections were lined and backpacked with shock isolation material either volcanic cinders or rigid polyurethane foam. The remaining 13 test sections were either lined without the shock isolation material or were unlined. The liner types ranged from rigid, reinforced concrete, through wide flange rings with lagging to flexible corrugated tunnel liner plate.

This project focused on post shot survey of the sections. Data collected is in the form of photographs and cross section diagrams showing the changes in the sections. The project report however covers some of the other projects data as well as a great deal of information on the overall conduct and results of the tests and therefore may serve as a single volume summary.

***Project 3.2, Electronic Measurements***

**POR-1802**

This project made measurements of transient particle velocity and displacement, relative displacement, and liner and rock strain on 24 of the 43 tunnel liner sections described above. Just less than half of the instrument channels returned data because of EMP, recorder failure, and cable breaks. Traces of much of the data is presented without much interpretation in the project report.

***Project 3.3, Free Field Ground Motion***

**WT-1803**

Ground motion was observed at six stations between 256 and 784 feet range along a horizontal radius from the shot point. Accelerometers were oriented to respond to radial motion with velocity and displacement gages as backup at most stations. At the two most remote stations

accelerations and velocities in the radial, vertical, and tangential were recorded. Traces and reduced data are presented.

***Project 3.6, Static Stress Determinations***

**WT-1804**

Rock cores were taken in the area of the test sections, both before and after the test. Their stress properties were tested and results are presented.

***Project 3.11, Fly Rock Photography***

**POIR-1805**

Motion picture cameras were installed in the three test drifts to record deformation and to determine fly-rock trajectories and velocities. One of the three sets of cameras were not recovered and the film from the other two were fogged.

***Project 3.12, Displacement Spectrum***

**POR-1806**

Twenty one reed gages were installed to record radial and vertical shock spectrum measurements. Thirteen were in the test sections tunnel liners and seven in the unlined access tunnel. One was set up at a radial distance of 1,340 feet from shot point.

Reed gages are arrays of masses on springs or reeds and are designed so that their natural frequencies cover the range from 3 to 300 hertz at 10 discrete frequencies. The masses scribe a polished metal plate.

Fifteen gages were recovered of the 21 installed and 12 gave usable frequency displacement data which is presented in tabular form.

**SECTION 22  
DANNY BOY  
Nevada Test Site  
1962**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Danny Boy	March 5	Buckboard Mesa, Area 18	0.43 KT	Cratering (DOB, 110 feet)

**BACKGROUND.**

Danny Boy was the first U.S. atmospheric nuclear test since late 1958. Danny Boy was a DoD cratering test. The primary objective was to establish relationships between crater dimensions, nuclear yield, and depth of burial of the nuclear device in basalt medium. Since a number of high-explosive (HE) cratering tests had been performed in basalt, a goal was to compare characteristics of an HE-generated crater with that from a nuclear burst. The Danny Boy device was detonated 110 feet below the earth's surface. The resulting crater was about 60 feet deep and 200 feet in diameter.

The characterization of the base surge and mapping of the radioactive fallout from Danny Boy received considerable attention. These results could be important factors both in the use of tactical cratering weapons and also in the use of nuclear devices in the Plowshare program for peaceful construction programs.

Other effects projects performed during Danny Boy included ground shock studies and airblast effects from a buried nuclear device.

**DANNY BOY PROJECTS AND REPORTS**

***Project 26.2, Preliminary Summary Report of a Nuclear Cratering Experiment***

**POIR-1833**

The preliminary report summarized the goals and results of Danny Boy. Results reported here are also presented in other reports. Crater profile, radiation contours, and photographs of the detonation and crater are provided.

***Project 1.1a, Long Range Air-Blast Measurements and Interpretations***

**POR-1809**

The objective of this project was to perform measurements of low-amplitude airblast at distances out to 240 km from the Danny Boy detonation. Similar pressure measurements were made from HE detonations. Equipment and communications failures degraded the experiment. A limited number of pressure data traces are presented.

***Project 1.1b, Close-In Air Blast from a Nuclear Detonation in Basalt***

**POR-1810**

This project was to measure airblast overpressure close to the Danny Boy detonation. The airblast could be the product of the gases escaping from the detonation cavity or the ground shock causing a shock in the air. Pressure-time gauges were installed at ranges from 200 to 8,500

feet from surface zero. Pressure-time instrument readings, shock arrival times, and analyses of measurements are reported.

***Project 1.2, Earth-Motion Measurements***

**POR-1811**

Measurements included horizontal and vertical ground acceleration, particle velocity, and shock velocity in the vicinity of the Danny Boy detonation at ranges from 10 to 2,000 feet from surface zero. Most of the gauges were buried about 1 foot in the ground. Measured accelerations and velocities are presented in tabular and data trace form.

***Project 1.3, Surface Phenomena Photography***

**POR-1812**

Cameras were used to record the movement of the earth over the Danny Boy detonation. Both high-speed and low-speed cameras were used for data collection. Both earth surface and ejecta movement versus time are reported.

***Project 1.4, Seismic Effects from a Nuclear Cratering Experiment in Basalt***

**WT-1813**

The objective of this project was to measure earth acceleration and displacement and the velocity of the shock wave at ranges of 0.760 to 340 km from the Danny Boy surface zero. Seismographs, accelerometers, displacement gauges, and geophones were deployed at 12 stations. Tables of gauge readings are presented.

***Project 1.5, Throwout Study of an Underground Nuclear Detonation***

**POR-1814**

The study investigated throwout from a nuclear cratering shot by comparing the positions of marked ground objects before and after the detonation. Objects such as metal spheres, cubes, rods, plates, and pieces of wood were color coded and numbered and installed at surface and subsurface specific locations in the predicted Danny Boy crater area. A large number of the items were located after the shot, and their new positions were carefully noted. The displacement of each test item found is described in detail.

***Project 1.6, Mass Distribution Measurements of Crater Ejecta and Dust***

**POR-1815**

The project was tasked to measure and characterize the ejecta from a cratering event at locations beyond the crater lip. Four- by four-foot tarpaulins were deployed in a circular pattern at ranges from 200 to 7,000 feet for collection of throwout material. From a total of 158 collector stations, 27 samples were recovered, weighed, and assessed for particle size. Sample sizes, weights, and locations relative to GZ are reported.

***Project 1.9, Crater Studies***

**ITR-1816**

The Danny Boy crater dimensions are compared to pretest predictions. The crater and lip profiles are presented.

***Project 21.1, Distribution of the Radioactivity from a Nuclear Cratering Experiment***

**WT-1817**

The objective of this project was to characterize and quantify the airborne radioactive debris in Danny Boy. Cloud samples were collected by aircraft; fallout samples were collected from plates on the ground at 2,500 to 25,000 feet from surface zero. The radionuclides and activities for the different samples are reported and a fallout map is presented.

***Project 2.4, Some Radiological Observations and Characteristics of Fallout Debris from a Nuclear Cratering Experiment, Shot Danny Boy***

**POR-1818**

This project was to characterize the fallout from Danny Boy in terms of activity, fallout mass, aerial distribution, and particle size, and to measure the cloud activity using aircraft at great distances from the detonation point. Large sample trays were placed on the ground out to 7,600 meters from surface zero. Activity as a function of distance from the burst is reported. Measured particle sizes were both greater and smaller than 44 microns. Data tables and isodose contours are presented.

***Project 2.5, On-Site Fallout from a Partially Contained Nuclear Burst in a Hard Medium***

**POR-1819**

The objective of this project was to measure gamma rate and total dose near surface zero for Danny Boy. Gamma dose rates were measured by aerial and ground surveys in the vicinity of the lip as early as H+50 minutes and as late as D+9 days. Numerous tables of gamma rate information and dose rate contours are presented.

***Project 26.4, Results of the Sandia Seismic Net***

**WT-1821**

The seismic signals from Danny Boy were measured at various locations and compared to high-explosive test signals. Characteristics of the measured seismic waves are reported.

***Project 1.10, Permanent Angular Displacement of Cylindrical Models Buried in Basalt Near an Explosion Crater***

**ITR-1824**

The project objective was to measure the permanent tilt of cylinders buried at various ground locations in the vicinity of Danny Boy. Cylinders were buried to depths of 37 meters at ranges out to 150 meters from surface zero. ITR-1824 contains no data because cylinder recovery had not occurred when the document was written.

***Geology of the U18a Site, Buckboard Mesa, Nevada Test Site***

**WT-1828**

The objective of this project, performed by the U.S. Geological Survey, was to characterize the soil and geology in the area where the Danny Boy cratering test was to occur. Physical and chemical characteristics of the soil and the area geology are presented.

***Post-Shot Geologic Report***

**ITR-1829**

Apparent crater dimensions and thickness variation of crater ejecta are derived from photographs and presented.

***Off-Site Report***

**WT-1830**

This report by the U.S. Public Health Service describes the radioactivity from nuclear fallout measured outside the Nevada Test Site after Danny Boy. Ground and aerial dose-rate monitors were employed, and collector trays were used for acquiring radioactive debris samples. Activities at distant points from the burst are reported.

***Weather and Surface Radiation Prediction Activities***

**WT-1831**

On- and off-site fallout data were collected and summarized in a series of plots. Derived lifetime doses for stations as far as 60 miles away are presented as predicted and as inferred from the data.



***On-Site Rad-Safe Report***

**WT-1832**

A radiation safety group was responsible for monitoring the radioactivity at the Danny Boy site after the test. Measured activity readings at various times and locations and isodose contour maps are presented.

***The Definition of True Crater Dimensions by Post-Shot Drilling***

**WT-1834**

The objective of this project was to determine the true crater profile by drilling into the crater area and examining the core samples. The resultant true crater profile is reported.

**SECTION 23**  
**SEDAN**  
**Nevada Test Site**  
**1962**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Sedan	July 6	Area 10	104 KT	Cratering (DOB, 635 feet)

**BACKGROUND.**

Sedan was one of the Plowshare series nuclear detonations, the only one of that series that freely vented to the atmosphere during the period covered in this guide.

Plowshare was a program meant to study the possible peaceful uses of nuclear detonations. One of the proposed uses of such detonations was excavation and Sedan was a test whose depth of burial was calculated to be near that which would optimize excavation efficiency. There were several experiments on this test that were of interest to DoD and these are discussed below. Plowshare experiments use the PNE series as their reporting medium and the PNE report numbers are cited with the experiments.

**SEDAN EXPERIMENTS**

*The Sedan Event*

**PNE-242 F**

Summarizes cratering, fallout, airblast, ground shock, ejecta, and surface motion information derived from the test without heavy reference to the instrumentation records.

**AIRBLAST EXPERIMENTS**

*Long Range Blast*

**PNE-202F**

Microbarograph recordings were made at 8 stations in California and Nevada at ranges from 100 to 230 miles from NTS. Wave forms are presented.

*Close-in Airblast*

**PNE-211F**

A single blast line was set up with BRL self recording gages at ranges from 1,000 to 3,970 feet from surface zero and very low pressure gages from 5,290 to 15,500 feet. All the self recording gages were either destroyed or their recordings were compromised. The surviving measurements are presented and discussed.

**GROUND MOTION**

*Seismic Effects*

**PNE-213F**

Strong motion seismic data was collected at 11 stations from 1 to 27 km from surface zero. Mobile station seismic data was collected from 6 sites ranging from 150 to 1,700 km from surface zero. Additional particle velocity data was collected at three stations from 150 to 285 km range. Tables of peak values and times of first arrival are presented.

## **CRATER AND EJECTA**

### ***Crater Dimensions***

**PNE-230**

Dimensions were derived for crater as well as area of base surge from aerial photographs. A somewhat finer scale contour map of the crater is presented in the summary report (PNE-242) above.

### ***Mass Distribution and Throwout***

**PNE-217**

A series of sampling stations in circular arrays at from just under 2 to 8 predicted crater radii. Each circle or ring consisted of 24 sample collectors. Additional information was provided by stakes showing pre- and post-shot surface. Derived and presented are areal density contours of cratered material and crater lip height. Distribution of discrete missiles ejected was also mapped.

**SECTION 24**  
**DOMINIC-SWORDFISH**  
**Pacific Ocean**  
**1962**

<u>Shot name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Swordfish	May 11	N29° W126°	Low	Underwater

**BACKGROUND.**

Swordfish had two major objectives. The first was to perform the first operational firing test of the U.S. Navy Anti-Submarine Rocket (ASROC) missile-launched nuclear depth charge. The second was to acquire tactical information on safe delivery and escape distance when employing the ASROC. The ASROC was scheduled for wide deployment; therefore, this test was considered extremely vital.

The Navy sought answers to a number of questions in its nuclear weapon effects activities:

1. What is the minimum range for a destroyer to operate from the ASROC detonation and continue to maintain full capability for attack?
2. What is the minimum range for a destroyer after sustaining damages to operate from the ASROC detonation and have war fighting capability?
3. What is the safe delivery range for submarines employing the ASROC?
4. What are the effects of an underwater explosion regarding the Navy's capability to acquire and track enemy vessels?
5. How is the Navy's ability to operate affected by radioactive debris from an underwater nuclear explosion?

Navy effects projects also addressed such issues as comparisons of ship damage resulting from a nuclear charge as opposed to high-explosive charges, detection of underwater nuclear explosions at great distances, and general hydrodynamic phenomena resulting from an underwater nuclear explosion.

The Swordfish test was performed at approximately the same location as Operation Wigwam. Four destroyers and one submarine were in the target area at the time of detonation. Other ships and aircraft were in the general vicinity.

**SWORDFISH PROJECTS AND REPORTS**

**Scientific Directors Summary Report**

**POR-2007**

This report summarizes the operational implications of the Swordfish test, including ship operations in contaminated areas. Some photographic data are presented.

***Project 1.1, Underwater Pressures***

**POR-2000**

The objective of this project was to map the water-pressure field in the vicinity of the Swordfish detonation in order to determine weapon yield and to investigate underwater explosion

phenomenology. Dynamic pressures were measured at depths from 20 to 2,000 feet and ranges from 3,100 to 20,000 feet. Extensive peak pressure and shock-arrival-time data are reported for both direct and reflected shock waves.

***Project 1.2, Surface Phenomena***

**POR-2001**

The objective of this project was to record and report visible water surface phenomena caused by an underwater nuclear explosion. Extensive photographic coverage was provided from three ships and four aircraft. Slick, spray dome, base surge, and plumes are described in detail. Photographs of visible effects are presented.

***Project 1.3a, Effects of Underwater Nuclear Explosions on Sonar Systems at Close Ranges***

**POR-2002**

The project was to assess the effect of the underwater detonation of an ASROC nuclear weapon on active and passive sonar systems. Targets were observed with sonar from various ships before, during, and after detonation. Sonar performance is described.

***Project 1.3b, Effects of an Underwater Nuclear Explosion on Hydroacoustic Systems***

**WT-2003**

Assessment was made of the effects of an underwater nuclear explosion on long-range underwater tracking systems. Some sensor systems were saturated with signals for tens of minutes after detonation. Descriptions of effects on various acquisition and tracking systems are provided.

***Project 2.1, Radiological Effects from an Underwater Nuclear Explosion***

**POR-2004**

An array of eight collector stations was positioned from more than a mile upwind to almost nearly three miles downwind of surface zero. The objective was to measure the extent of radioactive contamination from an underwater nuclear burst. Measured activity as a function of time for free air and at various locations on ships is reported.

***Project 3.1, Shock Motions of Ships and Equipment***

**POR-2005**

The objective of this project was to measure ships' hull and equipment motion in response to an underwater nuclear detonation. Velocity meters and motion picture photography were the primary sources of data. Damage to ships' equipment is described. Velocity and displacement records are presented.

***Project 9.1, Ship Damage Assessment and Technical Support of Test Elements***

**POR-2006**

Surveys were to be made of damage to all ships in the vicinity of Swordfish and assessment made of each ship's operational capability. Detailed listings of damage to ships and equipment are provided, and judgments regarding capabilities to accomplish missions are presented.

**SECTION 25**  
**DOMINIC-AIRDROPS**  
**1962**

<u>Shot Name</u>	<u>Date</u>	<u>Yield Range</u>
<b>High Airbursts South of Christmas Island</b>		
Adobe	Apr 25	20 to 1,000 KT
Aztec	Apr 27	20 to 1,000 KT
Arkansas	May 2	Less than 20 KT
Questa	May 4	20 to 1,000 KT
Yukon	May 8	20 to 1,000 KT
Mesilla	May 9	20 to 1,000 KT
Muskegon	May 11	20 to 1,000 KT
Encino	May 12	20 to 1,000 KT
Swanee	May 14	20 to 1,000 KT
Chetco	May 19	20 to 1,000 KT
Tanana	May 25	Less than 20 KT
Nambe	May 27	20 to 1,000 KT
Alria	Jun 8	20 to 1,000 KT
Truckee	Jun 9	20 to 1,000 KT
Yeso	Jun 10	Less than 20 KT
Harlem	Jun 12	20 to 1,000 KT
Rinconada	Jun 15	20 to 1,000 KT
Dulce	Jun 17	20 to 1,000 KT
Petit	Jun 19	Less than 20 KT
Otowi	Jun 22	20 to 1,000 KT
Bighorn	Jun 27	Megaton range
Bluestone	Jun 30	Less than 20 KT
Sunset	Jul 10	20 to 1,000 KT
Pamlico	Jul 11	Less than 20 KT

**High Airbursts in the Johnston Island Danger Area**

Androscoggin	Oct 2	20 to 1,000 KT
Bumping	Oct 6	Less than 20 KT
Chama	Oct 18	Less than 20 KT
Calamity	Oct 27	20 to 1,000 KT
Housatonic	Oct 30	Megaton range

## **BACKGROUND.**

Many new weapon design concepts had been developed during the 1958-1961 test moratorium and Dominic provided an opportunity to test them. The weapons were loaded onto B-52s based in Hawaii and then flown to Christmas Island or the Johnston Island area where the weapons were dropped. Weapon diagnostic instrumentation was primarily airborne with a few photo stations on Christmas Island. There were a few DoD effects experiments, some ground based and some on airplanes.

## **AIRDROP PROJECTS AND REPORTS**

***Project 1.1, Blast Measurements at Various Distances  
from High-Altitude and Low-Altitude Nuclear Detonations*** **POR-2010**

Pressure measurements at ground level were attempted on Androscoggin, Bumping, Calamity, Chama, and Housatonic. Numerous ground measurements of overpressure-time and shock arrival time are reported.

***Project 1.2, Shock Photography*** **POR-2011**

High-speed motion picture films were analyzed for shots Bighorn, Housatonic, and Rinconada. Discussions of fireball and shock were derived and are presented.

***Blast Predictions at Christmas Island*** **WT-2057**

Blast pressures from all the Christmas Island shots were measured at several stations at ranges up to 40 miles from surface zero. Tabulations of blast parameters and sketches of the waveforms are given for each test.

***Water Wave Measurements*** **WT-2058**

Surface water waves were measured at several sites on Christmas Island and at remote sites such as Maldin, Samoa, Oahu, and Johnston. Tabulations of crest height, period, and number of crests are presented. Some selected original oscillograph records are also reproduced.

***Project 4.1, Production of Chorioretinal Burns*** **POR-2014**

Total irradiance vs time and irradiance in selected wave bands were measured from airplanes at various ranges from surface zero. These measurements were to aid interpreting the results of eye burns on rabbits and monkeys who observed the detonations from the same airplanes. Data were taken on eight of the Christmas Island airdrop tests and two of the Johnston Island airdrops. The project also participated in Fishbowl.

***Project 6.8, Riometer Measurements*** **POR-2027**

Relative ionospheric opacity measurements at 30 MHz were made at Christmas Island and effects were observed. Reproductions of the chart records for seven events are presented.

***Project 7.1, Electromagnetic Signal, Underwater Measurements*** **POIR-2033**

Two ships off Oahu with antennas both above and underwater observed EMP generated by the Christmas Island airdrops and Starfish. Qualitative data is presented.

***Project 7.3, Microwave Attenuation***

**POR-2043**

Ground-based microwave radars on Christmas Island tracked beacon-bearing airplanes as they flew paths that could be obscured by the rising fireballs of a number of the airdrops. On some events, reflector arrays dropped by an airplane were also tracked. Presented data are plots of one-way (beacon tracks) and two-way (both reflector and skin track) attenuation. Also presented is the geometry of the propagation paths.

***Project 7.5, Thermal Radiation from an Air Burst Nuclear Weapon***

**ASD-TDR-62-283**

B-57s were instrumented with calorimeters, radiometers, accelerometers, and overpressure instruments as close to the airdrop events as safe. Tabulations and plots of the thermal data for the ten shots covered are presented.

***Project Stemwinder***

**WT-2060**

B-57 samplers flew through the clouds and stems at early times when this would not interface with their basic weapon diagnostic sampling. The purpose of the early penetrations was to map the contours of radioactivity within the stems and clouds. Data presented are only complete for Bluestone at one altitude and Bighorn at two. Cloud tops and bases for all tests are tabulated.



**SECTION 26  
FISHBOWL  
Pacific Ocean  
1962**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Starfish	July 9	Johnston Island	1.4 MT	Missile (HOB, 400 km)
Checkmate	Oct 20	Johnston Island	Low	Missile (HOB, tens of km)
Bluegill	Oct 26	Johnston Island	High	Missile (HOB, tens of km)
Kingfish	Nov 1	Johnston Island	High	Missile (HOB, tens of km)
Tightrope	Nov 4	Johnston Island	Low	Missile (HOB, tens of km)

**BACKGROUND.**

In 1961 the Soviets performed a series of tests related to the development of an anti-ballistic missile (ABM) system. The United States hurriedly organized a high-altitude test series, Operation Fishbowl, for ABM nuclear warhead development and for assessing nuclear weapon effects on missile reentry vehicles.

Operation Fishbowl originally consisted of three events, scheduled for late spring of 1962, using Thor missiles to deliver warheads and effects-experiment pods to high altitudes. Failures of four Thor missiles dramatically affected the plan and schedule. Two more nuclear events, which did not employ Thor missiles, were eventually added to the series. Operation Fishbowl was finally completed in November 1962.

The Starfish, Bluegill, and Kingfish events were deployed by Thor missiles, which also carried pods for instrumentation and experiments. The Checkmate and Tightrope missiles were not Thors, and no experimentation pods were carried aloft. Small rockets were used to deploy instruments in the vicinity of all five detonations.

**OPERATION FISHBOWL PROJECTS AND REPORTS**

**Operation Fishbowl Projected  
Measurements Summary**

**DASA Data Center SR-001**

This document lists and describes the instruments employed in each project of the FISHBOWL series.

***Project 1.1, Blast Measurements at Various Distances  
from High-Altitude and Low-Altitude Nuclear Detonations***

**POR-2010**

The objective of this project was to measure the free-field airblast and the resulting accelerations experienced by a body close-in to high-altitude nuclear detonations. In addition, pressures were to be measured at ground level in the vicinity of high-altitude nuclear bursts. Instrumented pods were supposed to make near-in free-air airblast and structural response measurements in the Starfish, Bluegill, and Kingfish events, but all pod experiments failed to provide useful data.

Pressure measurements at ground level were attempted on all Fishbowl events. Numerous ground measurements of overpressure-time and shock arrival time are reported.

***Project 2.1, External Neutron Flux Measurements***

**POR-2012**

This project was to measure the neutron environment at various distances from the Bluegill, Kingfish, and Starfish detonations. Pods carried aloft by the missiles delivering the nuclear devices bore neutron activation materials that were recovered after the tests. Measured activities and conversions to neutron flux vs range are reported.

***Project 2.2, Gamma Radiation Measurements***

**POR-2013**

Passive gamma dosimeters were carried aloft by missile pods and were recovered after the tests to measure gamma dose at various distances from Starfish, Bluegill, and Kingfish. Dose vs distance plots for the various types of dosimeters are presented.

***Project 4.1, Production of Chorioretinal Burns***

**POR-2014**

Total irradiance vs time and irradiance in selected wave bands were measured from airplanes at various ranges from surface zero. These measurements were to aid interpreting the results of eye burns on rabbits and monkeys who observed the detonations from the same airplanes. Data were taken on eight of the Christmas Island airdrop tests and two of the Johnston airdrops. The project also participated in Fishbowl.

***Project 6.1, Fireball Attenuation and Refraction***

**POR-2015**

This project investigated effects of a nuclear fireball on radar transmissions. Rockets carried L-, C-, and X-band CW transmitters to high altitudes above the Bluegill, Kingfish, and Tightrape detonations. Receivers were placed on four ships and on Johnston Island. Transmissions through and near the fireballs were monitored. Signal-strength data for a variety of conditions and transmitter/receiver geometries are presented.

***Project 6.2, Gamma Ray Scanning of Debris Cloud***

**POR-2017**

The project was designed to measure the radioactive cloud extent at various times after detonation. Rockets with radiation sensors and telemetry systems flew through the Starfish, Bluegill, and Kingfish nuclear detonation clouds. Gamma, beta, and light sensors were employed. Most of the data is presented in the form of counts per second at particular times and locations.

***Project 6.3, D-Region Physical Chemistry***

**POR-2018**

Rockets carrying radiation sensors and telemetry systems were fired into the debris region of Starfish, Kingfish, and Bluegill. Determinations were made of the radiation environments from high-altitude nuclear bursts in order to assess the effects of those environments on the D-region. Goals, procedures, measurements made, results, and conclusions are extremely obscure.

***Project 6.4, E- and F-Region Physical Chemistry***

**POR-2019**

The objective of this project was to measure the nuclear environments and resultant electron density at high altitudes during Starfish and Kingfish. Rockets carrying sensors, telemetry systems, and transmitting beacons were launched to the debris regions. There was considerable equipment failure. Beacon transmissions and some limited measurements are presented.

***Project 6.5a, Ionospheric Soundings and Magnetic Measurements***

**POR-2020**

The purpose of this project was to measure some nuclear-detonation-induced effects on the ionosphere and communications. Observations were made from ground level in all the Fishbowl events plus some Soviet tests. Measurements included ionospheric probes, HF signal strength, pressure waves, optical emissions, and EMP signals. Numerous data traces and observations are presented.

***Project 6.5b, Ionospheric Measurements in Southern Conjugate Area***

**POR-2021**

The project was tasked to study the nuclear debris trapping by the earth's magnetic field and the migration of such radiation to the southern conjugate area. Nuclear radiation, optical radiation, and radiofrequency transmissions were measured from various ground and airborne balloon locations in all the Fishbowl events. Measurements and technical assessments are presented.

***Project 6.5c, Vertical Ionospheric Sounding Measurements***

**POR-2022**

The project objective was to assess the effects of the Fishbowl detonations on the ionosphere. Ionograms were made from several Pacific islands from shortly before the detonations until several hours afterwards. Selected ionograms are presented along with interpretations of data.

***Project 6.5d, Effects of Nuclear Radiation on the Ionosphere***

**POR-2023**

The objective was to observe the effects of high-altitude nuclear bursts on the ionosphere and employ unusual HF transmission techniques to avoid signal perturbations. Ionosonde measurements were made in the Fishbowl events, and the results of the transmissions are described. Application of the "pinwheel" technique enhanced communications through a high-altitude nuclear debris region.

***Project 6.5e, Magnetic Measurements***

**POR-2024**

Magnetometers and earth current instruments were employed at two Pacific islands and several stations on the U.S. mainland. Fluctuations in the earth's magnetic field caused by the Fishbowl detonations were measured. Measured signal forms and times of arrival are reported.

***Project 6.6, Long-Term Observations by Resonance Scattering Techniques***

**POR-2025**

Observations of specific types of nuclear debris were made after Bluegill, Starfish, Checkmate, and Kingfish using optical techniques. The debris was tracked from 10 sites over extended time periods. Density of debris and observation conditions are reported.

***Project 6.7, Debris Expansion Experiment***

**POR-2026**

The objective of this project was to measure the interaction of Starfish and Checkmate nuclear debris with the earth's magnetic field. Rockets delivered sensors to high altitudes to measure gamma, beta, and neutron radiation environments and the magnetic field. Data was telemetered to ground stations. Telemetry signal strength was monitored. Data measurements and scientific analyses are presented.

***Project 6.8, Riometer Measurements***

**POR-2027**

The project measured changes in the ionosphere from high-altitude nuclear detonations and investigated the effect of these changes on HF and VHF transmissions. Riometers were deployed

on islands and ships throughout the Pacific to measure cosmic noise changes during and after each of the Fishbowl events. Riometer traces and interpretations are presented.

***Project 6.9, Radar Clutter Measurements***

**POR-2028**

The objective was to assess the effect of high-altitude nuclear detonations on radar operations. A wide variety of ground-, sea-, and air-based radars were operated during all of the Fishbowl detonations. An extensive amount of radar operations and response information is presented, including rare late-time range-intensity photos, along with analyses and observations.

***Project 6.10, Large-Scale Ionization Effects from High-Altitude Nuclear Detonations***

**POR-2029**

The task was to measure the effects of a nuclear detonation on the ionosphere and investigate nuclear blackout of radio and radar. Observations of auroral effects, gamma-ray measurements, HF and VHF propagation experiments, and low-frequency studies of the D-region were performed for all Fishbowl events. Measurements were made from ground-based and airplane platforms. Considerable data and analysis are presented.

***Project 6.11, HF Communications Experiment***

**POR-2030**

The experiment was designed to measure the effects of high-altitude nuclear detonations on HF communications. Ionograms were made from 12 sites throughout the Pacific, and HF signal strength for numerous frequencies and propagation paths. Ionograms and transmission records are presented.

***Project 6.13, RF Measurements and Optical Measurements***

**POR-2032**

Assessed were the effects of high-altitude nuclear detonations on radiofrequency and optical tracking systems. Shipborne radiofrequency and optical systems tracked rockets flown in the vicinity of the Fishbowl detonations. Very detailed descriptions of tracker response are reported.

***Project 7.1, Electromagnetic Signal, Underwater Measurements***

**POIR-2033**

Two ships off Oahu with antennas both above and underwater observed EMP generated by the Christmas Island airdrops and Starfish. Qualitative sort of data are presented.

***Project 7.2a, Synchrotron Radiation***

**POR-2034**

The objective of this project was to measure synchrotron radiation at Palmyra Island during the Fishbowl detonations. Data traces and observations are presented in a highly technical fashion.

***Project 7.2b, Microwave Radiometric Measurements***

**POR-2059**

Microwave radiometers at 925 MHz, 3,000 MHz, and 34,450 MHz were sited on Johnston Island with antennas viewing the fireballs of the five detonations. Data presented are excess antenna temperatures as a function of time for the three bands.

***Project 7.4, UHF, HF, LF, and VLF Measurements During Fishbowl***

**POR-2044**

Communication links from various locations and at various wavelengths were monitored during Starfish, Checkmate, and Bluegill. Effects of high-altitude nuclear explosions on radio communications at certain wavebands were measured. Outages and periods of disruption are reported.

***Project 8A.1, High-Altitude Nuclear Detonation  
Optical-Infrared Effects***

**POR-2035**

The project addressed the auroral and airglow effects from high-altitude nuclear detonations and the implications to weapon systems employing optical sensors. Auroral and airglow effects were characterized from ground and air platforms during the Fishbowl events. Measurements were made and reported in a large number of spectral bands.

***Project 8A.2, Optical Phenomenology of High-Altitude  
Nuclear Detonations***

**POR-2036**

This project was tasked to make temporal, spatial, and spectral measurements of optical phenomena during the Fishbowl events. Ground-based and airplane-based photographic and spectrographic measurements were made. Detailed descriptions of results and observations are presented. A film catalog and most of the films from this project are at DASIAC, Santa Barbara, CA.

***Project 8A.3, Close-In Thermal and X-ray Vulnerability  
Measurements—Shots Bluegill and Kingfish***

**POR-2037**

The project objective was to investigate thermomechanical loading of structures from exposure to nuclear thermal and x-ray environments. Pods with sensors and material samples were deployed at high altitudes by the missiles that carried the Bluegill and Kingfish devices aloft. Measurements of environments and material response to shock loading were made. Most of the test specimens and sensors were recovered and a significant amount of response data is reported.

***Project 8B, Nuclear Weapon X-Ray Effects as Measured  
by Passive Instruments***

**POR-2038**

The objective was to measure x-ray environment and spectrum and to measure impulse for various materials. Samples and sensors were exposed in pods at high altitudes for Starfish and Kingfish. X-ray impulse data for metals, plastics, and reentry vehicle materials in the Starfish event are reported.

***Project 9.1a, Atmospheric Properties***

**POR-2040**

The project objective was to characterize the atmosphere in the vicinity of each zero point before and after nuclear detonations. Rockets deployed atmospheric measuring devices aloft before and after Checkmate, Bluegill, Kingfish, and Tighrope. Changes in atmospheric conditions are reported.

***Program 32, High Altitude Measurements***

**WT-2046**

Emphasis in Sandias' experimental program was on diagnostic measurements from rocket-borne instrumentation. Measurements of interest to weapons effects were blackbody temperature and irradiance, isotropic x-ray yield, neutron spectra, and delayed gamma and beta radiation from rockets launched from Johnston Island and Kauai. Rocket experiments were on the Starfish, Checkmate, and Kingfish events only. Ground-based measurements included photographic measurements at Johnston Island and on Maui; microbarographic measurements at Johnston Island, Kauai, and Oahu; and EMP measurements at Kauai. Attenuation of telemetry signals in the 200 to 250 MHz range from instrumentation rockets to ground stations was also recorded for the purpose of studying effects on radars and communications.

**SECTION 27**  
**SUNBEAM**  
**Nevada Test Site**  
**1962**

<u>Shot Name</u>	<u>Date</u>	<u>Location</u>	<u>Yield</u>	<u>Weapon Placement</u>
Little Feller II	July 7	Buckboard Mesa, Area 18	Low Yield	Suspended (HOB, 3 feet)
Johnie Boy	July 11	Buckboard Mesa, Area 18	0.5 KT	Shallow-buried (DOB, 2 feet)
Small Boy	July 14	Frenchman Lake	Low Yield	10-foot tower
Little Feller I	July 17	Buckboard Mesa, Area 18	Low Yield	Rocket (HOB, 3 feet)

**BACKGROUND.**

Operation Sunbeam is also referred to as Operation Dominic II. It was a series of four low-yield events sponsored by the DoD.

Little Feller I and II used the Davy Crockett tactical weapon warhead as sources. In Little Feller I, the warhead was launched by soldiers to simulate an operational firing, and detonated close to the earth's surface. Military maneuvers (called Ivy Flats) were performed in the vicinity of Little Feller I to provide about 1,000 soldiers with experience in tactical nuclear weapon operations. In Little Feller II, the device was suspended from a cable between posts slightly above the ground. These two events also supported a number of nuclear weapon effects projects. An effects project participating in the two events was typically reported in a single Project Officer's Report (POR). Therefore, these two tests are treated as a unit.

Johnie Boy was a low-yield cratering event. The device was buried about 2 feet below ground level. A number of nuclear weapon effects experiments were fielded.

Originally, Small Boy was the only event in Operation Sunbeam. The other events were added only a few months before the scheduled Small Boy detonation. Small Boy was a weapon effects test, with particular emphasis on electromagnetic pulse (EMP) phenomenology and effects.

The nuclear operations of the 1950s tended to have projects that participated in several nuclear tests, and test results for that project were reported for the entire operation in a single document. In Operation Sunbeam, most projects participated in only one or two events. Therefore, many reports were written for activities in one nuclear event, and the documents were organized under the title of the event rather than Operation Sunbeam. Projects and reports were generally grouped under Little Feller I and II, Johnie Boy, and Small Boy. Therefore, descriptions of projects and resultant data will be presented in this report using the event groupings. A few exceptions will be noted for projects participating in three or four of the tests.

## LITTLE FELLER I AND II

These tests were primarily geared toward assessing the operations and effects of the Davy Crockett tactical nuclear weapon. This system was designed for use at relatively close range by Army ground forces. Effects activities were designed to provide information on enemy target destruction and on keepout ranges to avoid damage to friendly forces and equipment. A larger number of effects projects were fielded on Little Feller II than Little Feller I because the Little Feller II device was detonated from a fixed point rather than being fired from a rocket. Also, the extensive troop activities in Little Feller I could degrade effects data acquisition or recovery. Below are summarized the project reports for Little Feller I and II.

### LITTLE FELLER I AND II PROJECTS AND REPORTS

***Project 1.1, Airblast Phenomena from Small Yield Devices*** **POR-2260**

The objective of this project was to measure airblast overpressure-time and dynamic pressure in the vicinity of a Davy Crockett tactical nuclear weapon. Pressure gauges were installed at ground level and suspended in the air by balloons. Pressures at various ranges from the Little Feller I and II detonations are reported.

***Project 1.3, Blast Effects on Simple Objects and Military Vehicles*** **POR-2261**

The primary objective was to study the airblast drag forces from low-yield nuclear detonations. Rigidly mounted cubes and spheres, tanks, and covered trucks were exposed during Little Feller II. Radiation dose measuring devices were installed in the tanks. Motion picture records were acquired. Damage to the test hardware is described, and radiation doses at various locations in the military equipment are reported.

***Project 1.5, Debris Throwout*** **POR-2262**

This project was to determine if debris thrown out by low-yield tactical nuclear weapons posed a serious problem to personnel in the area. Various types of marked debris were placed at various distances from the Little Feller II GZ and then located after the detonation to determine displacement. Debris type and amount of displacement are reported.

***Project 1.9, Crater Size and Shape*** **POR-2263**

Buried vertical columns of colored soil were employed for Little Feller II to help in posttest assessment of crater characteristics. Crater sizes and configurations are reported.

***Project 2.3, Neutron Flux Measurements*** **POR-2264**

The project was to measure the neutron flux and spectrum at various ranges and heights above ground level for Little Feller I and II. Numerous plots of neutron doses and spectra as a function of location are presented.

***Project 2.4, Integrated Gamma Dose Measurements*** **POR-2265**

Measurements of the gamma radiation doses were made at various ranges from Little Feller I and II. A variety of passive gamma dose measuring devices were employed. Measured gamma doses at numerous locations in the four tests are reported.

***Project 2.8, Radiological Surveys***

**POR-2266**

The project was tasked to map the radioactive fields around the Little Feller I and II detonation points and to measure the rates of decay of the activities. Measurements of dose rates were made in the vicinities of the crater areas immediately after the detonations and at later times. Significant amounts of gamma dose rate data for many locations are reported.

***Project 2.16, Residual Radiation in the Crater and Crater-Lip Area of Low-Yield Nuclear Devices***

**POR-2267**

The objective of this project was to measure some residual radiation characteristics around the crater of Little Feller II. Gamma-ray energy and activity as a function of soil depth were measured shortly after the shots. Gamma intensities at various locations and depths are reported for Little Feller II.

***Project 2.17, Transient Radiation Effects Measurements — Guidance Systems Circuits and Piece Parts***

**POR-2268**

Performed during Little Feller II, this project was to assess the transient radiation effects on various transistors, diodes, and electronic circuits. The parts and circuits were also tested in laboratory flash x-ray machines. Posttest properties of parts and circuits were measured and reported. Knowledge of electronics operations and theory is required to fully understand POR-2268.

***Project 2.20, Transient Radiation Dose Rate***

**POR-2269**

The objective of this project was to measure the radiation emitted by the nuclear cloud immediately after detonation. Gamma dose and dose rate measurements were made in foxholes and at ground level at various ranges from Little Feller II. Plots of dose rate vs time are presented for numerous locations.

***Project 4.1, Tissue Dosimetry***

**POR-2270**

The project objective was to test the radiation absorption of a material that was designed to react to radiation in a manner similar to that of the human body. Neutron and gamma radiation measurements were made in open air, inside exposed sheep, and in the synthetic human flesh material. Radiation measurements in the different media at various ranges from Little Feller I and II are reported.

***Project 6.6, Electromagnetic Measurements***

**POR-2271**

Straight cables and loops were fielded for Little Feller I and II to accommodate the investigation of electromagnetic pulse (EMP) phenomenology and effects. Measurements of generated currents and fields were attempted. Data traces and analyses are presented.

***Project 7.16, Airborne E-Field Radiation Measurements of Electromagnetic Pulse Phenomena***

**POR-2272**

The objective of this project was to measure the vertical component of the nuclear-burst-induced E-field of Little Feller I. A whip antenna on an aircraft served as the sensor. No signal was recorded.



***Project 7.17, Radiological Water Decontamination Study***

**POR-2273**

Soil samples from Little Feller I and II were dissolved in water. Activity was measured to assess the solubility of radioactive soil in water and to evaluate various water filtration techniques. The water was then filtered and activity of the water was measured again. Solubility and filter effectiveness are reported.

***Project 8.1, High Time Resolution of the First Thermal Pulse***

**POR-2274**

This study was to characterize the first thermal pulse from Little Feller I in terms of direct and indirect total energy, spectral components, and time of delivery. Photographic techniques and filters were employed. Reduced data are reported.

***Project 8.2, Fallout Hazard Determination by Fireball Spectroscopy***

**POR-2275**

The project was to determine the fallout that would occur from a nuclear detonation by spectroscopic analysis of the materials in the fireball. Spectroscopes were deployed to view the fireballs in Little Feller I and II. Several spectrum sequences for the Little Feller I fireball are presented.

**JOHNIE BOY**

Planned in May 1962, Johnie Boy was fired in July 1962. The major objective of the test was to investigate cratering from a low-yield nuclear burst. There was little opportunity to prepare effects experiments other than those required for analysis of cratering.

The Johnie Boy device had a 0.5-KT yield. It was buried about 2 feet below the earth's surface. The throwout and fallout was of particular interest because this test produced conditions approximating those of a tactical nuclear battlefield.

**JOHNIE BOY PROJECTS AND REPORTS**

***Project 1.1, Free-Air and Free-Field Blast Phenomena  
from a Small Yield Device***

**POR-2280**

The objective of this project was to obtain measurements of overpressure vs time and dynamic pressure vs time at the earth's surface as well as measurements from balloons of free-field overpressure vs time. The balloon measurements were cancelled. Thirty pressure gauges were deployed at ground level ranges from 40 to 4,900 meters from GZ. Peak overpressure, shock arrival time, positive pulse time, and dynamic pressure vs range are reported.

***Project 1.2, Earth Motion Measurements***

**POR-2281**

Measurements of shock arrival time vs distance, ground accelerations, particle velocity, and earth displacement are provided in this report characterizing the ground motion in the vicinity of Johnie Boy. Thirty-two vertical and horizontal acceleration and velocity gauges were installed at ranges from 150 to 500 feet from GZ at depths from 1 to 10 feet.

***Project 1.5, Mass Distribution Measurements***

**POR-2282**

One hundred and eighty-six metal collector trays were arranged in seven concentric rings ranging from 50 to 600 meters from GZ to characterize the debris thrown from the crater in terms of projectile size and mass vs distance. Thickness of the lip formed by the ejecta at different

directions from GZ is reported, along with ejecta particle size distribution and quantity at many locations.

***Project 1.9, Crater Measurements***

**POR-2284**

The objective of this project was to determine the dimensions of the Johnie Boy crater. Fourteen vertical columns of colored sand were installed in the predicted crater area. The colored sand columns were 6 to 8 inches in diameter and 10 to 50 feet deep. Aerial photography and posttest excavation and analysis of sand columns were employed for crater and lip measurements. Dimensions of apparent and true craters are reported.

***Project 1.11, Soils Survey***

**POR-2285**

Soil samples were extracted from locations ranging from 1.5 to 150 meters from GZ to characterize the soil in the vicinity of the Johnie Boy event prior to the test. Detailed descriptions of soil properties are provided.

***Project 1.12, Measurement of Permanent Ground Displacement and Rotation***

**POR-2286**

Concrete cones were poured in place about 3 feet deep and flush with the top of the ground to enable measurement of the horizontal displacement of the ground at various ranges from GZ. Pretest and posttest measurements of "monument" location were made. Some "monuments" had prisms for determining precisely the amount of tilt that occurred due to ground shock. Measurements of displacement and tilt as a function of distance from GZ are reported.

***Project 1.13, Measurement of Permanent Ground Movements with Depth***

**POR-2287**

The objective was to measure the earth's displacement from ground shock as a function of depth in the ground. Six holes, each 75 feet deep, were drilled between 150 and 210 feet from GZ and plastic pipe installed. Pretest and posttest measurements of pipe alignment were made. Vertical and horizontal displacement and tilt of the pipes at various ranges are reported.

***Project 2.3, Neutron Flux Measurements***

**POR-2264**

The project was to measure the neutron flux and spectrum at various ranges and heights above ground level for Johnie Boy. Numerous plots of neutron doses and spectra as a function of location are presented.

***Project 2.4, Integrated Gamma Dose Measurements***

**POR-2265**

Measurements of the gamma radiation doses were made at various ranges from Johnie Boy. A variety of passive gamma dose measuring devices were employed. Measured gamma doses at numerous locations in the four tests are reported.

***Project 2.8, Radiological Surveys***

**POR-2266**

The project was tasked to map the radioactive fields around the Johnie Boy detonation point, and to measure the rates of decay of the activities. Measurements of dose rates were made in the vicinities of the crater areas immediately after the detonations and at later times. Significant amounts of gamma dose rate data for many locations are reported.

***Project 2.9, Fallout Sampling and Analysis; Radiation Dose Rate and Dose History at 16 Locations***

**POR-2289**

To characterize the fallout in the vicinity of Johnie Boy, measurements of gamma intensity and samples of fallout material were obtained. Fallout mass per unit area at various locations is reported along with fallout particle size distribution and activity levels. Radiochemical analyses of samples were performed.

***Project 2.13, Radioisotope Fractionation and Particle Size Characteristics of a Low-Yield Surface Nuclear Detonation***

**POR-2291**

The project collected and characterized airborne samples of the Johnie Boy cloud. Samples acquired using collectors on aircraft penetrating the nuclear cloud were characterized in terms of activity, particle size, and radiochemical composition. Comparisons were made with similar samples collected on the ground. Extensive data on particle characteristics are reported.

***Project 2.16, Residual Radiation in the Crater and Crater-Lip Area of Low-Yield Nuclear Devices***

**POR-2267**

The objective of this project was to measure some residual radiation characteristics around the crater of Johnie Boy. Gamma-ray energy and activity as a function of soil depth were measured shortly after the shots.

***Project 2.20, Transient Radiation Dose Rate***

**POR-2269**

The objective of this project was to measure the radiation emitted by the nuclear cloud immediately after detonation. Gamma dose and dose rate measurements were made in foxholes and at ground level at various ranges from Johnie Boy GZ. Plots of dose rate vs time are presented for numerous locations.

***Project 6.6, Electromagnetic Measurements***

**POR-2271**

Straight cables and loops were fielded for Johnie Boy to accommodate the investigation of electromagnetic pulse (EMP) phenomenology and effects. Measurements of generated currents and fields were attempted. Data traces and analyses are presented. There is another Project 6.6 on Johnie Boy that is reported in POR 2292. The subject of that Project 6.6 was gamma measurements, but it failed to measure anything.

***Project 7.17, Radiological Water Decontamination Study***

**POR-2273**

Soil samples from Johnie Boy were dissolved in water. Activity was measured to assess the solubility of radioactive soil in water and to evaluate various water filtration techniques. The water was then filtered and activity of the water was measured again. Solubility and filter effectiveness are reported.

**SMALL BOY**

The purpose of this test was to study nuclear weapon effects, with primary emphasis on electromagnetic pulse (EMP). The existence of EMP accompanying a nuclear explosion was recognized even before the Trinity test (1945). In the early days of testing, EMP was considered only a minor aggravation that perturbed electrical circuits employed in nuclear tests. Subsequently, with the development of hardened silos and launch-control facilities that could

survive the overpressure of close-in nuclear bursts, it was recognized the EMP from nuclear detonations might destroy the electrical systems necessary for a retaliatory missile launch. Very little was known about the near-field EMP environment or effects. The Small Boy test was devised primarily to provide definition of EMP phenomenology and effects. Specific experiments were to measure the radiation environment that generated the EMP, magnetic and electric fields near the bursts, earth and atmospheric electrical conductivity, and EMP effects on various components. Project reports are summarized below.

Small Boy also had experiments involving airblast, ground shock, initial radiation effects on military hardware, and radioactive fallout. Experiments to measure very high overpressures near the burst were fielded. Blast response of structures was assessed.

The Small Boy event occurred only 10 months after the Soviets broke the nuclear test moratorium, providing little time for experiment preparation. This undoubtedly contributed to the low data return for the test. Much of the near-field instrumentation was negated by EMP or thermal effects, although subsequent high-altitude nuclear tests did provide information on high-altitude EMP. The military hardware exposures did provide survivability peg points. Far-field EMP effects were measured.

## **SMALL BOY PROJECTS AND REPORTS**

### **AIRBLAST—PROGRAM 1**

#### ***Project 1.1, Airblast Measurements***

**POR-2200**

The objective of this project was to measure overpressure and dynamic pressure at overpressures up to 10,000 psi. Many pressure gauge and data recorder failures occurred because of EMP, thermal radiation, and shock. The sensor nearest to the burst to survive was at a ground range of 155 feet, registering an overpressure of 1,640 psi. Instruments beyond about 300 feet from the burst (below 200 psi overpressure) performed reasonably well. Measurements were acquired down to a few hundredths of 1 psi. There were some indications that a precursor shock existed between 380 and 680 feet ground range.

#### ***Project 1.2, Close-in Earth Motion***

**POR-2201**

This project was to measure airblast-induced ground motions as a function of lateral range from the burst, depth in the ground, and time. Fifty-four instruments for measuring acceleration, shock velocity, displacement, strain, and earth pressure were fielded at depths from 5 to 250 feet and ranges from 0 to 2,250 feet. Ten gauges failed due to EMP. Some very-close-in measurements are reported.

#### ***Project 1.3, Underground Stress Measurements***

**POR-2202**

Stress measurements in soil loaded by the nuclear airblast were attempted at ranges of 190 and 300 feet from GZ. No usable stress data were obtained. Time of arrival for the compression portion of the ground shock was measured, but details of the waveform could not be determined. Permanent ground deformation measurements in the vertical and horizontal planes were made near the burst.

#### ***Project 1.4, Shock Photography***

**POR-2203**

The project was tasked with obtaining high-speed film coverage of the detonation to attain a position-time record of the shock wave. Using the resultant shock velocity, peak overpressures

could be calculated. Usable footage was acquired from three motion-picture cameras at two different locations with speeds of 1,200, 2,500, and 2,700 frames/sec. Fireball growth was measured. These films are available at DASIAC, Santa Barbara, CA.

***Project 1.5, Blast Effects in the High Pressure Region***

**POR-2204**

The objective of this project was to measure airblast overpressures in the 10- to 5,000-psi regime and dynamic pressures at ranges corresponding to 30 to 600 psi peak overpressures. This encompassed the precursor region. Nine of fourteen gauges provided data, but only one gauge within a range of 290 feet survived.

***Project 1.6, Airblast Induced Ground Motion Studies***

**POR-2205**

Measurements were made of ground motion induced by airblast. Accelerometers, particle velocity gauges, and displacement gauges were installed at depths from 0 to 400 feet and at ground ranges from 0 to 300 feet. Data were acquired from 35 of 39 instrumentation channels.

***Project 1.7, Shock Spectrum Measurements***

**POR-2206**

The objective of this project was to measure the spectral components of the airblast-induced ground shock at various locations near the burst. Each instrument contained 10 frequency bands between 3 and 300 Hz. Two "reed" instruments were installed at each test point to measure the spectral components, one in the horizontal plane, and the other in the vertical plane. Test points were at the surface and 10 feet deep at ground ranges of 185, 200, 245, and 290 feet. Data were acquired from all 16 gauges.

***Project 1.8, Soils Survey***

**POR-2207**

The purpose of this effort was to characterize the soil (water content, density, etc.) in the vicinity of the nuclear test. This information could be used in the investigation of EMP phenomenology and ground shock.

***Project 1.9, Crater Measurements***

**POR-2208**

The project was to provide a complete description of the Small Boy apparent and true craters and the earth deformation around the crater. Pretest and posttest aerial and ground surveys were made. Colored columns of sand, in boreholes drilled at various depths and distances from GZ, were used as markers or indicators for earth deformation assessments.

**PROGRAM 2—NUCLEAR RADIATION**

***Project 2.1, Gamma Dose Rate Measurements***

**POR-2209**

The assignment for this project was to measure, over the first 10 seconds, time-resolved nuclear radiations near the burst. Gamma rate measurements were made at 191, 488, and 1,220 meters. Time-resolved neutron flux data were obtained at 191 meters.

***Project 2.2, Neutron Dose Rates***

**POR-2210**

The two objectives for this project were to measure the fast neutron radiation intensity as a function of time and distance from the burst, and to measure the fast neutron energy spectrum. The intensity measurements were successful, but the attempt at spectral measurement failed.

***Project 2.3, Neutron Flux Measurements***

**POR-2264**

The project was to measure the neutron flux and spectrum at various ranges and heights above ground level for Small Boy. Numerous plots of neutron doses and spectra as a function of location are presented.

***Project 2.4, Integrated Gamma Dose Measurements***

**POR-2265**

Measurements of the gamma radiation doses were made at various ranges from Small Boy. A variety of passive gamma dose measuring devices were employed. Measured gamma doses at numerous locations in the four tests are reported.

***Project 2.7, Off-site Meteorology-Winds Aloft***

**POR-2213**

Extensive measurements of wind conditions in the region of the nuclear test were made to assist in radioactive fallout mapping. Wind conditions from 0 to 30,000 feet altitude at ground ranges from 20 to 250 miles downwind are reported.

***Project 2.8, Radiological Surveys***

**POR-2266**

The project was tasked to map the radioactive fields around the Small Boy detonation points and to measure the rates of decay of the activities. Measurements of dose rates were made in the vicinities of the crater areas immediately after the detonations and at later times. Significant amounts of gamma dose rate data for many locations are reported.

***Project 2.9, Fallout Collection and Gross Sample Analysis***

**POR-2215**

The purpose was to map the radioactive fallout from Small Boy as a function of time to characterize the fallout material. There were a total of 350 collection points, some constantly manned and others tended by mobile field teams. This was considered the most complete, detailed, and successful mapping to date. Numerous radiation contour maps are presented.

***Project 2.10, Physicochemical and Radiochemical Analysis***

**POR-2216**

In this project, the laboratory analyses of the radioactive fallout samples collected for Project 2.9 (POR-2215) were performed. Sample characteristics and activities are reported. Methods of analysis are described.

***Project 2.11, Ionization Rate Measurements***

**POR-2217**

The objective of this project was to measure gamma dose rate vs time at 3 feet above the ground in the Small Boy radioactive fallout sector. A total of 140 gamma intensity vs time recorders were employed at ranges from 1 mile to about 20 miles from GZ. Extensive amounts of data were collected and reported.

***Project 2.12, Evaluation of a Rocket-Mounted Collector***

**POR-2218**

The project task was to develop and evaluate a rocket-mounted debris collector for taking samples from the nuclear fireball, stem, and cloud shortly after detonation. Five rockets carrying radiation sampling instruments were fired through the Small Boy cloud about one minute after detonation. Three rockets were never found, one was found badly damaged about 4 months after the test, and the fifth rocket collected no data.

***Project 2.13, Evaluation of a New Fallout Collector***

**POR-2219**

The objective of this project was to evaluate a new fallout collector capable of surviving overpressure up to 5 psi. The collector operated well mechanically but did not receive enough fallout to provide adequate evaluation of sampling efficiency.

***Project 2.14, Shielding Effectiveness of Compartmented Structures in a Fallout Field***

**POR-2220**

This project measured the shielding effectiveness of cubical steel boxes with varying wall thicknesses in a fallout field. The boxes were stacked as 3- by 3- by 3-foot cubes to produce 27 individual compartments per stack, with radiation monitors installed inside selected compartments, as well as in open air outside the stacks of boxes. The gamma spectrum hardened as the radiation penetrated deeper into the cubes. Gamma doses at various locations are reported.

***Project 2.15, Shielding Effectiveness of Enclosure Shields in a Fallout Field***

**POR-2221**

Tasked to determine the shielding effectiveness of steel spherical and cubical compartments of various dimensions, containers were exposed in the fallout field and gamma radiation was measured inside and outside the compartments. Doses and transmission factors (ratio of inside dose to outside dose) are reported.

**PROGRAM 3—EFFECTS ON STRUCTURES**

***Project 3.1, Response of Buried Arch and Dome Models***

**POR-2222**

The project was to assess the response of shallow-buried arch-shaped and dome-shaped structures to nuclear airblast loading. Models were buried from 0- to 6-inch depths at projected overpressure stations from 35 to 250 psi. A few inches of earth cover dramatically increased model survivability. Overpressure-time traces and observations on structure response are reported.

***Project 3.2, Dynamic Bearing Capacity of Soils, Response of Impulsively Loaded Footings on Frenchman Flat Silt Field Test***

**POR-2223**

The objective of this project was to measure the response of soil under square footings and wall-type footings supporting shallow-buried subterranean structures exposed to impulsive nuclear blast loads. The load vs time delivered to the footings was measured as well as total footing displacement. Tests were performed at the 30- and 150-psi airblast overpressure stations.

***Project 3.3, Behavior of Buried Model Arch Structures***

**POR-2224**

This project was to determine the effect of an airblast on buried arch structures. Six arched structures, 5 to 11 feet in length and buried at depths of 6 to 14 inches, were tested at overpressure stations from 4 to 16 psi. Soil pressure, air pressure, ground displacement, and some structural response measurements are reported.

***Project 3.4, Structures Instrumentation***

**POR-2225**

The purpose of this project was to describe the airblast and structural instrumentation and the data recording systems employed by Ballistic Research Laboratories (BRL) for Small Boy. Numerous data records are presented.

## **PROGRAM 6—ELECTROMAGNETIC EFFECTS**

### ***Project 6.1, Electric Field Measurement***

**POR-2226**

The objective of this project was to measure the mutually perpendicular components of the electric field produced by a nuclear explosion. While not expressly stated in the POR, it appears that little usable data was acquired from this project, due in large part to instrumentation limitations. Scope data traces and analyses are presented.

### ***Project 6.2, Magnetic Loop Measurements***

**POR-2227**

Magnetic field components resulting from a nuclear burst were to be measured in an attempt to clarify the mechanisms of EMP generation. Vital early-time (less than 10  $\mu$ sec) data were lost, due in large part to EMP effects on the instrumentation, but some later-time data were recorded and presented.

### ***Project 6.3, Inherent Magnetic Field Measurement***

**POR-2228**

The objective was to take measurements of a nuclear-explosion-induced magnetic field. Instrumentation was fielded at ranges of 190, 490, 1,220, and 3,000 meters. Two off-the-shelf sensors were used, with limited success. Lack of instrument dynamic range and EMP effects on instrumentation were detrimental. Some data traces and much discussion of interpretation are presented.

### ***Project 6.4, Initial Gamma Flux Measurements***

**POR-2229**

This project was to measure the gamma dose rate at three different locations and for four time periods covering the total time period from nanoseconds to 100 seconds. A limited amount of data was collected and reported.

### ***Project 6.5, EMP Current Transients***

**POR-2230**

Measurements were made of the nuclear-induced EMP currents in buried communications cables. Some electric and magnetic field measurements were made. Secondary experiments to study responses of an equipment shelter, hardened antenna elements, magnetic memory components, and thermal detectors were performed on a noninterference basis. Data return was high. Cable current magnitudes, waveforms, and core-to-sheath potentials are reported.

### ***Project 6.6, Cable Loop Measurements***

**POR-2231**

The project was tasked to measure EMP effects on standard and modified Minuteman cable loops. Extensive amounts of data were collected and presented in the POR with interpretations. Traces of measured currents and voltages with time are provided.

### ***Project 6.7, Soil Conductivity Measurements***

**POR-2232**

The objective of this project was to determine the electrical conductivity of the alluvium in the Frenchman Flat area. This conductivity was one factor in the interpretation of EMP phenomenology data. Preshot and postshot measurements are reported.

### ***Project 6.8, Earth's Static Field Measurements***

**POR-2233**

Measurements of the earth's static electric field were made shortly before, and for extensive periods after, the Small Boy detonation. The measurements were taken at ground level and from



balloons near the test site. The input was used for interpretation of EMP phenomenology. Measured electrostatic fields at various locations are presented, and reasons for electric field changes after the test are discussed.

***Project 6.9, Correlation of Present and Previous Electric Field Measurements*** **POR-2234**

The project measured the EMP-induced electric field signal at a significant distance from the Small Boy GZ and compared this signal with those from other detonations. The Small Boy waveform is presented and compared with those of other tests.

***Project 6.11, Air Conductivity Measurements*** **POR-2235**

The objective was to measure the air conductivity near the Small Boy GZ for a period of time immediately after the detonation. The measurement was made at 0.5 km from the Small Boy GZ. Air conductivity as a function of time as determined by different techniques is reported.

***Project 6.13, Troposcatter Test Installation*** **POR-2237**

The project operated troposcatter radio equipment during the detonation, using the troposphere above GZ as the scatter area, to search for anomalies related to the nuclear detonation. Other than a brief signal enhancement, no anomalies occurred.

**PROGRAM 7—TESTS OF SERVICE EQUIPMENT**

***Project 7.1, Pragmatic Instrumental Measurements*** **POR-2238, -2239**

Measurements were made to assess EMP effects (POR-2238) and transient radiation effects (POR-2239) on selected Minuteman, Atlas, and Titan missile system components. Test hardware included power cables, logic circuits, computer memory elements, antennas, communication cables, and guidance components. Posttest descriptions of test hardware are presented, along with some electric field data traces.

***Project 7.2, Experimental Confirmation of Theoretical Development on Radiological Armor*** **POR-2240**

Radiation shielding capability of a radiological armor concept for use in tanks was evaluated for this project. The shield was designed to provide protection from direct gamma rays, neutrons, and secondary gammas resulting from neutron interactions. Four M48 tanks and one "pod" were exposed at ranges from 700 to 2,100 feet from the burst. Environments outside and inside the structures were measured and reported.

***Project 7.5, Response of Electric Power Systems to Electromagnetic Effects of Nuclear Detonations*** **POR-2241**

The objective of this project was to assess the response of an army field electrical power system to EMP. Little data or analysis is provided for this project because although the system was operating and instrumented prior to exposure, it was shut down by EMP and prompt radiation.

***Project 7.6, Test Evaluation of Aerial Radiac Survey Systems*** **POR-2242, -2243**

Evaluated was the feasibility of using gamma radiation measurements from an aircraft at 200 to 1,000 feet altitude to determine radioactivity levels on the ground. This would have application in planning tactical troop movement. Helicopters and drone aircraft flew over the fallout area and made radiation measurements from 2 to 47 hours after detonation. These were converted to

ground-level radiation intensities. Isodose contours from air and ground measurements are reported.

***Project 7.8, Arming and Fuzing Component Test***

**POR-2244**

The objective of this project was to assess initial nuclear radiation effects on arming and fuzing components. The chamber containing the test components was 625 feet from GZ. Instrumentation was essentially go or no-go, depending on whether a firing signal was produced to initiate an explosive switch. No EMP effects were detected.

***Project 7.8.1, NOL Magnetic Detection Equipment Test***

**POR-2245**

Navy magnetic detection equipment was used to monitor the EMP signal. The detector was 5.3 miles from GZ. No EMP signal was recorded, possibly because the data recorder was inadequate.

***Project 7.9, Ships Superstructure Response***

**POR-2246**

The task was to proof-test Navy antenna, deckhouse, and smokestack response to nuclear blast loads. The structures were instrumented. Test levels ranged from 7 to 15 psi. Extensive photographic information is presented as well as strain and displacement measurements.

***Project 7.10, Thermal Radiation Pulse Analysis***

**POR-2247**

This project investigated the spectral characteristics of the initial thermal pulse. Additionally, thermal masks for head protection were exposed. Temporal and spectral thermal radiation measurements are reported. A large amount of refined data is presented.

***Project 7.12, Nuclear Effects on Television Camera Installations***

**POR-2248**

The objective of this project was to test hardened security video cameras exposed to nuclear airblast and radiation effects. Television cameras were placed at 50- and 20-psi stations, as well as at a manned station at 8,000 feet from GZ. The latter station recorded the entire test on film. Extensive damage to various mechanical and electronic elements was reported.

***Project 7.13, F-100F/GAM 83 B Simulation***

**POR-2249**

The objectives were to assess response of an in-flight aircraft to a real nuclear environment, and assess possible visual impairment to the pilot and rear-seat observer due to the nuclear flash. The aircraft was instrumented to measure radiation environment and structural loads. Neither the aircraft nor the crew sustained damage. Data records are presented.

***Project 7.14, Bomb Alarm Detector Test***

**POR-2250**

The project tested a system designed to sense a nuclear detonation and transmit a signal into the national nuclear alert communications complex. Sensors, which operate on the nuclear thermal pulse, were deployed from 0.5 to 12 miles from GZ. The sensors responded and the alert signal went out. EMP did not degrade operation. Oscilloscope records of outputs of sensors and other electronics are presented.

***Project 7.15, Nuclear Radiation Effects on B-52/GAM-77 Weapon System***

**POR-2251**

Two B-52s, each with two GAM-77 weapon systems, flew over the test point at detonation time. The objective was to expose the B-52/GAM-77 to a nuclear environment to assess the effects on the missile guidance. Effects to the missiles were determined by pretest and posttest bench tests.

Some changes were noted in missile electronic responses, but it was concluded that these were not the result of the nuclear environment. Crewmembers received as much as 2 rem radiation.

***Project 7.16, Airborne E-Field Radiation Measurements of  
Electromagnetic Pulse Phenomena***

**POR-2272**

The objective of this project was to measure the vertical component of the nuclear-burst-induced E-field of Small Boy. A whip antenna on an aircraft served as the sensor. No signal was recorded.

***Project 7.17, Radiological Water Decontamination Study***

**POR-2273**

Soil samples from Small Boy were dissolved in water. Activity was measured to assess the solubility of radioactive soil in water and to evaluate various water filtration techniques. The water was then filtered and activity of the water was measured again. Solubility and filter effectiveness are reported.

***Blast Loading Vulnerability***

**POR-2303**

The objective of this project was to investigate the response of reentry vehicles to airblast loads from low-altitude interceptors. Conical and sphere cone shapes, representative of reentry vehicles, were exposed to the blast wave. Pressures on the bodies and body responses were measured. Some free-field environments were measured. Considerable airblast environment and response data is reported.

***Air Force Arming and Fuzing Components***

**DASIAC 14966**

The objective of this experiment was to assess nuclear initial radiation effects on Air Force MK3 and MK6 A&F components and systems. Test articles were exposed at two different stations. Definitive data on system response in the armed and unarmed state is reported. Also reported is the exposure response of an ultrahard electronics concept—Thermionic Integrated Micro Module (TIMM).

***Operation SUNBEAM: Small Boy Data Review***

**DNA 4137T**

The Small Boy EMP-related data was reviewed several years after the event in light of later understanding of phenomenology and effects. The most refined form of EMP data is presented with extensive analysis.

## APPENDIX A

### GLOSSARY OF ACRONYMS AND INITIALISMS

A-3D-1	jet attack plane	C-54	military version of DC-4 air transport
A-4D-1	jet attack plane		
AA	Anti-aircraft	CEX	Civil Effects Series reports
ABM	Anti Ballistic Missile	CW	Carrier wave
AEC	Atomic Energy Commission	DASA	Defense Atomic Support Agency
AFSWP	Armed Forces Special Weapons Project	DASIAC	DoD Information and Analysis Center
Al	Aluminum	DNA	Defense Nuclear Agency
AM	Amplitude Modulation	DOB	Depth of burst
ASD	AF Aeronautical Systems Div.	DOD	Department of Defense
ASROC	Anti-Submarine Rocket	DOE	Department of Energy
B-17	propeller driven bomber	DSM	Director of Ship Material
B-29	propeller driven bomber	EMP	Electromagnetic Pulse
B-36	propeller driven bomber	ESS	Effects Sub Surface
B-47	jet bomber	F-101A	jet fighter
B-52	jet bomber	F-80	jet fighter
B-57	jet bomber	F-84	jet fighter
B-66	jet bomber	F-89	jet fighter
BRL	Army Ballistics Research Laboratory	FCDA	Federal Civil Defense Agency
BuAer	Navy Bureau of Aeronautics	FJ-4	jet fighter
BuDock	Navy Bureau of Yards and Docks	FM	Frequency Modulation
BuMed	Navy Bureau of Medicine	GAM77	Ground to air missile
BuOrd	Navy Bureau of Ordnance	GAM83B	Ground to air missile
BuShips	Navy Bureau of Ships	GZ	Ground (on surface) explosion point
C-band	4,000 – 8,000 MHz	HA	High Altitude

<b>HE</b>	<b>High Explosive</b>	<b>POL</b>	<b>Petroleum Oil Lubricants</b>
<b>HF</b>	<b>High Frequency</b>	<b>POR</b>	<b>Project Officers Report</b>
<b>HOB</b>	<b>Height-of-Burst</b>	<b>PPI</b>	<b>Plan Position Indicate</b>
<b>HSS-1</b>	<b>helicopter</b>	<b>RB-36</b>	<b>Recon version B-36</b>
<b>Hz</b>	<b>Hertz</b>	<b>rf</b>	<b>radio frequency</b>
<b>IBDA</b>	<b>Indirect Bomb Damage Assessment</b>	<b>SAC</b>	<b>Strategic Air Command</b>
<b>ITR</b>	<b>Interim Test Report</b>	<b>SOFAR</b>	<b>underwater detection system</b>
<b>Ku-band</b>	<b>12.5 to 188 GHz</b>	<b>SQUAW</b>	<b>model submarine</b>
<b>L-band</b>	<b>1,000 – 2,000 MHz</b>	<b>SS</b>	<b>Sandstone Series</b>
<b>LA</b>	<b>LASL Report Series</b>	<b>T-33</b>	<b>Travis version of F-80</b>
<b>LAMS</b>	<b>LASL Report Series</b>	<b>TAC</b>	<b>Tactical Air Command</b>
<b>LANL</b>	<b>Los Alamos National Laboratory</b>	<b>TIMM</b>	<b>Thermionic Integrated Micro Module</b>
<b>LASL</b>	<b>Los Alamos Scientific Laboratory</b>	<b>TN</b>	<b>Thermonuclear</b>
<b>LF</b>	<b>Low Frequency</b>	<b>TOA</b>	<b>Time of Arrival</b>
<b>LP</b>	<b>Liquid petroleum</b>	<b>UHF</b>	<b>Ultra-High Frequency</b>
<b>LVT</b>	<b>Landing Vehicle Tank</b>	<b>USPHS</b>	<b>US Public Health Service</b>
<b>MET</b>	<b>Military Effects Test</b>	<b>VHF</b>	<b>Very High Frequency</b>
<b>MHz</b>	<b>megahertz</b>	<b>VLF</b>	<b>Very Low Frequency</b>
<b>Mn</b>	<b>Magnesium</b>	<b>VUF</b>	<b>Vela Uniform report series</b>
<b>Na</b>	<b>Sodium</b>	<b>WT</b>	<b>Weapon Test report series</b>
<b>NTS</b>	<b>Nevada Test Site</b>	<b>X-band</b>	<b>8,000 – 12,500 MHz</b>
<b>OCDM</b>	<b>Office of Civil Defense Management</b>	<b>XB-47</b>	<b>early version of B-47</b>
<b>P-2V</b>	<b>propeller driven patrol plane</b>	<b>XRD</b>	<b>Crossroads report series</b>
<b>PNE</b>	<b>Plowshare report series</b>		
<b>POIR</b>	<b>Project Officer Interim Report</b>		

**APPENDIX B**  
**ALPHABETICAL LISTING OF NUCLEAR EVENTS\***

<b>Event Name</b>	<b>Operation Name</b>	<b>Date</b>	<b>Location</b>	<b>Weapon Placement</b>	<b>Section No.</b>
Able	Buster-Jangle	10/22/51	Nevada Test Site	Tower	8
Able	Crossroads	07/01/46	Bikini Lagoon	Airdrop	4
Able	Ranger	01/17/51	Nevada Test Site	Airburst	6
Able	Tumbler-Snapper	04/01/52	Nevada Test Site	Airdrop	9
Adobe	Dominic	04/25/62	Christmas Island	Airdrop	25
Alma	Dominic	06/08/62	Christmas Island	Airdrop	25
Androscoggin	Dominic	10/02/62	Johnston Island	Airdrop	27
Annie	Upshot-Knothole	03/17/53	Nevada Test Site	Tower	11
Apache	Redwing	07/09/56	Enewetak Atoll	Barge	15
Apple 1	Teapot	03/29/55	Nevada Test Site	Tower	13
Apple 2	Teapot	05/05/55	Nevada Test Site	Towe	13
Argus I	Argus	08/27/58	South Atlantic	Rocket	18
Argus II	Argus	08/30/58	South Atlantic	Rocket	18
Argus III	Argus	09/06/58	South Atlantic	Rocket	18
Aspen	Hardtack	06/14/58	Bikini Atoll	Barge	17
Arkansas	Dominic	05/02/62	Christmas Island	Airdrop	25
Aztec	Dominic	04/27/62	Christmas Island	Airdrop	25
Badger	Upshot-Knothole	04/18/53	Nevada Test Site	Tower	11
Baker	Buster-Jangle	10/28/51	Nevada Test Site	Airdrop	8
Baker	Crossroads	07/25/46	Bikini Lagoon	Underwater	4
Baker	Ranger	01/20/51	Nevada Test Site	Airburst	6
Baker	Tumbler-Snapper	04/15/52	Nevada Test Site	Airdrop	9
Baker-2	Ranger	02/02/51	Nevada Test Site	Airburst	6
Bee	Teapot	03/22/55	Nevada Test Site	Tower	13
Bighorn	Dominic	06/27/62	Christmas Island	Airdrop	25
Blackfoot	Redwing	06/12/56	Enewetak Atoll	Tower	15
Blanca	Hardtack II	10/30/58	Nevada Test Site	Tunnel	19
Bluestone	Dominic	06/30/62	Christmas Island	Airdrop	25
Bluegill	Fishbowl	10/26/62	Johnston Island	Missile	26
Boltzmann	Plumbbob	05/28/57	Nevada Test Site	Tower	16
Bravo	Castle	02/18/54	Bikini Atoll	Surface	12

\*Additional details of the nuclear events can be found in the section given in the last column.

<u>Event Name</u>	<u>Operation Name</u>	<u>Date</u>	<u>Location</u>	<u>Weapon Placement</u>	<u>Section No.</u>
Bumping	Dominic	10/06/62	Johnston Island	Airdrop	27
Butternut	Hardtack	05/11/58	Enewetak Atoll	Barge	17
Cactus	Hardtack	05/05/58	Enewetak Atoll	Surface	17
Calamity	Dominic	10/27/62	Johnston Island	Airdrop	27
Cedar	Hardtack	07/02/58	Bikini Atoll	Barge	17
Chama	Dominic	10/18/62	Johnston Island	Airdrop	27
Charleston	Plumbbob	09/28/57	Nevada Test Site	Balloon	16
Charlie	Buster-Jangle	10/30/51	Nevada Test Site	Airdrop	8
Charlie	Tumbler-Snapper	04/22/52	Nevada Test Site	Airdrop	9
Checkmate	Fishbowl	10/20/62	Johnston Island	Missile	26
Cherokee	Redwing	05/21/55	Bikini Atoll	Airdrop	15
Chetco	Dominic	05/19/62	Christmas Island	Airdrop	25
Climax	Upshot-Knothole	06/04/53	Nevada Test Site	Airdrop	11
Dakota	Redwing	06/26/56	Bikini Atoll	Barge	15
Danny Boy	Danny Boy	03/05/62	Nevada Test Site	Subsurface	22
De Baca	Hardtack II	10/26/58	Nevada Test Site	Balloon	19
Diablo	Plumbbob	07/15/57	Nevada Test Site	Tower	16
Dixie	Upshot-Knothole	04/06/53	Nevada Test Site	Airdrop	11
Dog	Buster-Jangle	11/01/51	Nevada Test Site	Airdrop	8
Dog	Greenhouse	04/08/51	Enewetak Atoll	Tower	7
Dog	Tumbler-Snapper	05/01/52	Nevada Test Site	Airdrop	9
Dogwood	Hardtack	07/05/58	Enewetak Atoll	Barge	17
Dona Ana	Hardtack II	10/16/58	Nevada Test Site	Balloon	19
Doppler	Plumbbob	08/23/57	Nevada Test Site	Balloon	16
Dulce	Dominic	06/17/62	Christmas Island	Airdrop	25
Easy	Buster-Jangle	11/05/51	Nevada Test Site	Airdrop	8
Easy	Buster-Jangle	11/05/51	Nevada Test Site	Airdrop	8
Easy	Greenhouse	04/21/51	Enewetak Atoll	Tower	7
Easy	Ranger	02/01/51	Nevada Test Site	Airburst	6
Easy	Tumbler-Snapper	05/07/52	Nevada Test Site	Tower	9
Eddy	Hardtack II	09/19/58	Nevada Test Site	Balloon	19
Elder	Hardtack	06/27/58	Enewetak Atoll	Barge	17
Encino	Dominic	05/12/62	Christmas Island	Airdrop	25
Encore	Upshot-Knothole	05/08/53	Nevada Test Site	Airdrop	11
Erie	Redwing	05/31/56	Enewetak Atoll	Tower	15
ESS	Teapot	03/23/55	Nevada Test Site	Subsurface	13
Evans	Hardtack II	10/29/58	Nevada Test Site	Tunnel	19
Flathead	Redwing	06/12/56	Bikini Atoll	Barge	5

<u>Event Name</u>	<u>Operation Name</u>	<u>Date</u>	<u>Location</u>	<u>Weapon Placement</u>	<u>Section No.</u>
Fig	Hardtack	08/18/58	Enewetak Atoll	Surface	17
Fir	Hardtack	05/11/58	Bikini Atoll	Barge	17
Fizeau	Plumbbob	09/14/57	Nevada Test Site	Tower	16
Fox	Ranger	02/06/51	Nevada Test Site	Airburst	6
Fox	Tumbler-Snapper	05/25/52	Nevada Test Site	Tower	9
Franklin	Plumbbob	06/02/57	Nevada Test Site	Tower	16
Franklin Prime	Plumbbob	08/30/57	Nevada Test Site	Balloon	16
Galileo	Plumbbob	09/02/57	Nevada Test Site	Tower	16
George	Greenhouse	05/09/51	Enewetak Atoll	Tower	7
George	Tumbler-Snapper	06/01/52	Nevada Test Site	Tower	9
Grable	Upshot-Knothole	05/25/53	Nevada Test Site	Gun-launched	11
HA	Teapot	04/06/55	Nevada Test Site	Airdrop	13
Hamilton	Hardtack II	10/15/58	Nevada Test Site	Tower	19
Hard Hat	Hard Hat	02/13/62	Nevada Test Site	Tunnel	21
Harlem	Dominic	06/12/62	Christmas Island	Airdrop	25
Harry	Upshot-Knothole	05/19/53	Nevada Test Site	Tower	11
Hickory	Hardtack	06/29/58	Bikini Atoll	Barg	17
Hiroshima		08/96/45	Japan	Airdrop	3
Holly	Hardtack	05/20/58	Enewetak Atoll	Barge	17
Hood	Plumbbob	07/05/57	Nevada Test Site	Balloon	16
Hornet	Teapot	03/12/55	Nevada Test Site	Tower	13
Housatonic	Dominic	10/30/62	Johnston Island	Airdrop	25
How	Tumbler-Snapper	06/05/52	Nevada Test Site	Tower	9
Humboldt	Hardtack II	10/29/58	Nevada Test Site	Tower	19
Huron	Redwing	07/22/56	Enewetak Atoll	Barge	15
nca	Redwing	06/22/56	Enewetak Atoll	Tower	15
Item	Greenhouse	05/25/51	Enewetak Atoll	Tower	7
John	Plumbbob	07/19/57	Nevada Test Site	Rocket	16
Johnie Boy	Sunbeam	07/11/62	Nevada Test Site	Shallow-buried	27
Juniper	Hardtack	07/22/58	Bikini Atoll	Barge	17
Kepler	Plumbbob	07/24/57	Nevada Test Site	Tower	16
Kickapoo	Redwing	06/25/56	Enewetak Atoll	Tower	15
King	Ivy	1/15/52	Enewetak Atoll	Airdrop	10
Kingfish	Fishbowl	11/91/62	Johnston Island	Missile	26
Koa	Hardtack	05/12/58	Enewetak Atoll	Surface	17
Koon	Castle	04/06/54	Bikini Atoll	Surface	12
Lacrosse	Redwing	05/05/56	Enewetak Atoll	Surface	15
Laplace	Plumbbob	09/08/57	Nevada Test Site	Balloon	16



<u>Event Name</u>	<u>Operation Name</u>	<u>Date</u>	<u>Location</u>	<u>Weapon Placement</u>	<u>Section No.</u>
Lassen	Plumbbob	06/05/57	Nevada Test Site	Balloon	16
Lea	Hardtack II	10/13/58	Nevada Test Site	Balloon	19
Linden	Hardtack	06/18/58	Enewetak Atoll	Barge	17
Little Feller I	Sunbeam	07/17/62	Nevada Test Site	Rocket	27
Little Feller II	Sunbeam	07/07/62	Nevada Test Site	Suspended	27
Logan	Hardtack II	10/16/58	Nevada Test Site	Tunnel	19
Magnolia	Hardtack	05/26/58	Enewetak Atoll	Barge	17
Maple	Hardtack	06/10/58	Bikini Atoll	Barge	17
Mazama	Hardtack II	10/29/58	Nevada Test Site	Tower	19
Mesilla	Dominic	05/09/62	Christmas Island	Airdrop	25
MET	Teapot	04/15/55	Nevada Test Site	Tower	13
Mike	Ivy	10/31/52	Enewetak Atoll	Surface	10
Mohawk	Redwing	07/03/56	Enewetak Atoll	Tower	15
Mora	Hardtack II	09/29/58	Nevada Test Site	Balloon	19
Morgan	Plumbbob	10/07/57	Nevada Test Site	Balloon	16
Moth	Teapot	02/22/55	Nevada Test Site	Tower	13
Muskegon	Dominic	05/11/62	Christmas Island	Airdrop	25
Nagasaki		08/09/45	Japan	Airdrop	3
Nambe	Dominic	05/27/62	Christmas Island	Airdrop	25
Nancy	Upshot-Knothole	03/24/53	Nevada Test Site	Tower	11
Navajo	Redwing	07/11/56	Bikini Atoll	Barge	15
Nectar	Castle	05/13/54	Enewetak Atoll	Barge	12
Neptune	Hardtack II	10/14/58	Nevada Test Site	Underground	19
Newton	Plumbbob	09/16/57	Nevada Test Site	Balloon	16
Nutmeg	Hardtack	05/21/58	Bikini Atoll	Barge	17
Oak	Hardtack	06/28/58	Enewetak Atoll	Barge	17
Olive	Hardtack	07/22/58	Enewetak Atoll	Barge	17
Orange	Hardtack	08/12/58	Johnston Island	Rocket	17
Osage	Redwing	06/16/56	Enewetak Atoll	Airdrop	15
Otowi	Dominic	06/22/62	Christmas Island	Airdrop	25
Owens	Plumbbob	07/25/57	Nevada Test Site	Balloon	16
Pamlico	Dominic	07/11/62	Christmas Island	Airdrop	25
Petit	Dominic	06/19/62	Christmas Island	Airdrop	25
Pine	Hardtack	07/26/58	Enewetak Atoll	Barge	17
Pisonia	Hardtack	07/17/58	Enewetak Atoll	Barge	17
Poplar	Hardtack	07/12/58	Bikini Island	Barge	17
Post	Teapot	04/09/55	Nevada Test Site	Tower	13
Priscilla	Plumbbob	06/24/57	Nevada Test Site	Balloon	16

<u>Event Name</u>	<u>Operation Name</u>	<u>Date</u>	<u>Location</u>	<u>Weapon Placement</u>	<u>Section No.</u>
Quay	Hardtack II	10/10/58	Nevada Test Site	Tower	19
Questa	Dominic	05/04/62	Christmas Island	Airdrop	25
Quince	Hardtack	08/06/58	Enewetak Atoll	Surface	17
Rainier	Plumbbob	09/19/57	Nevada Test Site	Tunnel	16
Ray	Upshot-Knothole	04/11/53	Nevada Test Site	Tower	11
Redwood	Hardtack	06/27/58	Bikini Atoll	Barge	17
Rinconada	Dominic	05/15/62	Christmas Island	Airdrop	25
Rio Arriba	Hardtack II	10/18/58	Nevada Test Site	Tower	19
Romeo	Castle	03/26/54	Bikini Atoll	Barge	12
Rose	Hardtack	06/02/58	Enewetak Atoll	Barge	17
Rushmore	Hardtack II	10/22/58	Nevada Test Site	Balloon	19
Ruth	Upshot-Knothole	03/31/53	Nevada Test Site	Tower	11
Sanford	Hardtack II	10/26/58	Nevada Test Site	Balloon	19
Santa Fe	Hardtack II	10/30/58	Nevada Test Site	Balloon	19
Sedan	Sedan	07/06/62	Nevada Test Site	Subsurface	23
Seminole	Redwing	06/06/56	Enewetak Atoll	Surface	15
Sequoia	Hardtack	07/01/58	Enewetak Atoll	Barge	17
Shasta	Plumbbob	08/18/57	Nevada Test Site	Tower	16
Simon	Upshot-Knothole	04/25/53	Nevada Test Site	Tower	11
Small Boy	Sunbeam	07/14/62	Nevada Test Site	Tower	27
Smoky	Plumbbob	08/31/57	Nevada Test Site	Tower	16
Starfish	Fishbowl	07/09/62	Johnston Island	Missile	26
Socorro	Hardtack II	10/22/58	Nevada Test Site	Balloon	19
Stokes	Plumbbob	08/07/57	Nevada Test Site	Balloon	16
Sugar	Buster-Jangle	11/19/51	Nevada Test Site	Surface	8
Sunset	Dominic	07/10/62	Christmas Island	Airdrop	25
Swanee	Dominic	05/14/62	Christmas Island	Airdrop	25
Swordfish	Dominic-Swordfish	05/11/62	Pacific Ocean	Submerged	24
Sycamore	Hardtack	05/31/58	Bikini Atoll	Barge	17
Tamalpais	Hardtack II	10/08/58	Nevada Test Site	Tunnel	19
Tanana	Dominic	05/25/62	Christmas Island	Airdrop	25
Teak	Hardtack	08/01/58	Johnston Island	Rocket	17
Tesla	Teapot	03/01/55	Nevada Test Site	Tower	13
Tewa	Redwing	07/26/56	Bikini Atoll	Barge	15
Tightrope	Fishbowl	11/04/62	Johnston Island	Missile	26
Tobacco	Hardtack	05/30/58	Enewetak Atoll	Barge	17
Trinity		07/16/45	Alamogordo, NM	Tower	2
Truckee	Dominic	06/09/62	Christmas Island	Airdrop	25

<u>Event Name</u>	<u>Operation Name</u>	<u>Date</u>	<u>Location</u>	<u>Weapon Placement</u>	<u>Section No.</u>
Turk	Tumbler-Snapper	03/07/55	Nevada Test Site	Tower	13
Umbrella	Hardtack	06/08/58	Enewetak Atoll	Submerged	17
Uncle	Buster-Jangle	11/29/51	Nevada Test Site	Subsurface	8
Union	Castle	04/25/54	Bikini Atoll	Barge	12
Vesta	Hardtack II	10/17/58	Nevada Test Site	Surface	19
Wahoo	Hardtack	05/16/58	Enewetak Atoll	Submerged	17
Walnut	Hardtack	06/14/58	Enewetak Atoll	Barge	17
Wasp	Teapot	02/18/55	Nevada Test Site	Airdrop	13
Wasp Prime	Teapot	03/29/55	Nevada Test Site	Airdrop	13
Wheeler	Plumbbob	09/06/57	Nevada Test Site	Balloon	16
Whitney	Plumbbob	09/23/57	Nevada Test Site	Tower	16
Wilson	Plumbbob	06/18/57	Nevada Test Site	Balloon	16
Wigwam	Wigwam	03/14/55	Open Pacific	Submerged	14
Wrangell	Hardtack II	10/22/58	Nevada Test Site	Balloon	19
X-Ray	Sandstone	04/15/48	Enewetak Atoll	Tower	5
Yankee	Castle	05/04/54	Bikini Atoll	Barge	12
Yellowwood	Hardtack	05/26/58	Enewetak Atoll	Barge	17
Yeso	Dominic	06/10/62	Christmas Island	Airdrop	25
Yoke	Sandstone	05/01/48	Enewetak Atoll	Tower	5
Yucca	Hardtack	04/28/58	Between Enewetak and Bikini islands	Balloon	17
Yukon	Dominic	05/08/62	Christmas Island	Airdrop	25
Yuma	Redwing	05/28/56	Enewetak Atoll	Tower	15
Zebra	Sandstone	05/15/48	Enewetak Atoll	Tower	5
Zucchini	Teapot	05/15/55	Nevada Test Site	Tower	13
Zuni	Redwing	05/28/56	Bikini Atoll	Surface	15

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25 February 2015

To: DTIC-OQ

Subject: Distribution Review

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Report Number: DASIAC SR-92-007

  
Byron L. Ristvet, RD-CXT  
DTRA Deputy STI Manager