REPORT BY THE COMMANDER, JOINT TASK FORCE THREE

1 AUG 1951

ON

COMPLETION OF OPERATION GREENHOUSE

412068

R

Reference: JCS 1998 Series

THE PROBLEM

1. To present a summary report on Operation GREENHOUSE to the Joint Chiefs of Staff in compliance with paragraph 8, Appendix to Enclosure "F" of JCS 1998/13, and to the Atomic Energy Commission pursuant to the delegation of authority contained in a letter from the Chairman, Atomic Energy Commission to the Commander, Joint Task Force THREE, dated 13 February 1951.

DISCUSSION

2. See Enclosure.

CONCLUSIONS

3. The mission of Joint Task Force THREE, as delineated in the JCS 1998 Series, was carried out successfully.

[redacted]

6. The close agreement between predicted and measured weapon performance is proof of the reliability of Los Alamos Laboratory's predictions. Greater dependence should be put on laboratory predictions in future considerations of weapon performance in the interest of more rapid progress and economy.

7. Military effects programs will yield much data useful to the design of tactics, structures and equipment. However, due to the complexity of analyzing data, additional time will be required before this data will be available.

8. The assignment of the task force commander as representative of the Atomic Energy Commission as well as of the Joint Chiefs of Staff while overseas facilitated operations by establishing a single authority. The principle of functional task groups proved sound. In combined Armed Forces-Atomic Energy Commission operations of this type, commanders in all echelons should again be chosen from either the Atomic Energy Commission or the Armed Forces, based solely on adaptability and qualification.

9. Further improvement in management of joint military activities can be made by a more complete adherence to the management fund or single appropriation principle, standardization of definition of "normal" and "above normal" costs, and by developing a uniform system of cross financing between Services.

10. Full scale test operations such as GREENHOUSE are excellent opportunities for training military personnel in the practical aspects of radioactivity. Instances of adverse psychological reactions at ENIWETOK, when conservative exposure dosages were exceeded and were detected by highly sensitive survey meters, indicates the need for the Services to stress in their training programs the practical aspects of radiation as well as to furnish troops a less sensitive survey meter. To assist in training personnel in the presence of higher level radiation such as will exist in atomic war, higher level exposure standards should be adopted where feasible on future test operations.

11. Adequate arrangements have been made for the completion of residual tasks of Joint Task Force THREE.

RECOMMENDATIONS

12. That the Joint Chiefs of Staff and the Atomic Energy Commission approve the above conclusions.

13. That a copy of this report be transmitted to the Research and Development Board by the Joint Chiefs of Staff.

14. That, subject to the comments of the Atomic Energy Commission, Joint Task Force THREE be inactivated by the Joint Chiefs of Staff as of 30 September 1951.

ENCLOSURE

DISCUSSION

INTRODUCTION

1. Joint Task Force THREE (JTF-3), commanded by Lieutenant General Elwood R. Quesada, United States Air Force, was activated 1 November 1949, at WASHINGTON, D.C. The command post of the Commander was opened at PARRY ISLAND, ENIWETOK ATOLL, on 3 March 1951 and was closed 27 May 1951 (East Longitude Dates). [redacted] In conjunction with these detonation, eight (8) experimental programs were conducted. This report describes the weapons, devices and experimental programs, giving as many conclusions as possible which can be drawn from the incomplete analysis of data. This report also covers the operational and fiscal aspects of JTF-3.

WEAPONS AND DEVICES

2. [redacted] DoE 6.1(a)

[redacted]

[redacted]

DoE 6.1(a)

[redacted]

[redacted]

[redacted]

[redacted] DOE 6.(a)

[redacted]

582

[redacted]

EXPERIMENTAL PROGRAMS

6. Eight (8) experimental programs were conducted as set forth in the JCS 1998 Series. Minor additions and alterations to programs were made under authority granted the Commander, Joint Task Force THREE (CJTF-3). Much of the experimental data has not been analyzed or evaluated. The conclusions presented herein are those that can be drawn at the present time.

7. PROGRAM 1.0 - LOS ALAMOS EXPERIMENTS

The objectives of this program were threefold: to measure the performance of each of the weapons and devices described above; to increase basic knowledge in phenomenology such as blast, thermal and nuclear radiation; and to develop methods of measuring weapon performance by simple, remote means.

a. WEAPON PERFORMANCE

Three (3) diagnostic measurements were made for each weapon and device; transit time (time from firing signal to first nuclear reaction), alpha (rate of rise of the nuclear reaction) and yield. Transit time measurements on all detonations agreed very closely to predicted values which indicated that each high explosive system reacted as expected. Alpha measurements on each of the first three detonations agreed very closely with predicted values. [redacted]

b. PHENOMENOLOGY

The characteristics of the blast wave were studied in detail. These data, as they are compiled, will be of assistance in evaluating specific effect studies as well as revising theoretical studies, such as height of burst computations. In addition to blast, thermal, visible and nuclear radiations were also measured. It is expected that these experiments, once the data are analyzed, will fill many of the gaps existing in theory prior to GREENHOUSE.

c. REMOTE WEAPON PERFORMANCE MEASUREMENTS

In an effort to simplify weapon proof testing in the future as well as to provide possible means of measuring weapon performance in combat, simplified instruments suitable for use in aircraft were tested. These instruments were designed to measure transit time, alpha and yield. Preliminary work was done at LAS VEGAS, NEVADA in January 1951 during Operation RANGER. Successful instruments to measure transit time are now available. Some difficulty in measuring yield with the BHANGMETER was encountered; however, improvements made in this device during the tests make it appear that a satisfactory instrument can be made available with further mechanical and electronic engineering. Further stud and experimentation is required in the development of the remote alpha measuring equipment.

[redacted]

e. For a more detailed discussion of Program 1.0, see Appendix "A".

8. PROGRAM 2.0 - BIOMEDICAL

The objective of the biomedical program was to obtain information which can be used in planning effective medical care for the victims of atomic warfare. Swine, dogs and mice were exposed in order to determine the blast, thermal and nuclear radiation effects as related to time and distance from ground zero. The biological effects observed were approximately the same as those predicted by laboratory tests. For animals exposed in the vicinity of ground zero the lethal range due to the blast effects did not extend as far as the lethal range due to the nuclear radiation effects. The thermal burns caused by the atomic explosions were due primarily to the visible light region of the spectrum and occurred during the first one-half second after the detonation. The nuclear radiation produced by the atomic explosions appeared to be 30% to 40% more effective biologically than the high voltage radiations produced in the laboratory. Measurements of radiation dosage by analysis of effects on plants, seeds and animals compared fairly closely with measurements obtained by radiation instruments and calibrated film. In the case of the larger animals, dogs appeared to be more satisfactory than swine in the determination of lethal radiation 584 dosages. This was probably due to the harmful effect of the enclosed containers in which the swine were exposed at shot time. Clinical studies made of animals that sustained more than lethal dosages indicated the essential similarity of radiation injury in man and large animals. One of the most significant pathological findings was the evidence of early radiation injury to the intestinal membranes. [redacted] Preliminary evaluation shows that serious blast and radiation injury can be expected out to about 1000 yards. For a more detailed discussion of Program 2.0, see Appendix "B".

DOE 6.1

9. PROGRAM 3.0 - STRUCTURES

a. The broad objectives of this program were to test methods of analysis which had been developed before the tests to provide predictions of damage to structures from atomic blast. Such methods will be used for predicting target damage for offensive operations and for preparing designs of structures to minimize damage in defensive operations. In order to carry out these objectives of the Army, Navy and Air Force, a well rounded program of tests on 26 buildings of various types and designs was conducted. In general, buildings were designed and planned so as to suffer some deformation, yet not fail completely. This goal was rather well met although a few structures collapsed and others had considerably less damage than had been predicted. An essential part of the program was the measurement of blast pressures and structural behavior by electronic recording, by motion picture photography and a complete survey of damage after the tests. Useful data were obtained from 95% of the transient measurements, which is an outstanding achievement. Since a large mass of data must be studied, final results will not be available for some time. The Public Buildings Service sponsored a program of tests on windows, glazing and methods of stopping glass fragments for the Federal Civil Defense Administration, which should provide useful information. A few tentative conclusions may be stated as follows:

(1) Results of limited analysis with measured pressures on the buildings indicate that they behaved generally as predicted. The chief problem is the prediction of the pressures on the various parts of the buildings as the wave passes over them.

(2) Current shelter designs of the Corps of Engineers offered adequate protection against the effects of the 50 kiloton burst at 1700 feet from the 300 foot tower. This distance was selected to provide the same pressure as that

RESTRICTED DATA
ATOMIC ENERGY ACT — 1946

occurring directly under the same bomb at the optimum height for a 10 pound overpressure.

(3) Analysis of the relationship of geometrically scaled models and prototype structures is promising and may well lead to useful methods of predicting damage from scaled models.

b. For a more detailed discussion of Program 3.0, see Appendix "C".

10. PROGRAM 4.0 - CLOUD PHYSICS

a. Program 4.0 was concerned in a broad sense with the measurement and documentation of the various properties of the atomic clouds, their size, appearance, electrical and radioactive characteristics, temperature, turbulence, water content, wind velocities, vertical and horizontal mixing, rate of growth, dispersion characteristics and also the related field of tropical meteorology. Significant results were obtained in all phases of the program. Several of the most important results from the standpoint of strategic and tactical application of the weapon are:

(1) It appears that a far greater than expected portion of the radioactivity is carried on particles of nonfilterable (submicron) size. This finding focuses attention upon the difficulty of filtering air for pressurized crew spaces in strategic and tactical aircraft.

(2) The order of magnitude obtained for velocity of the afterwind indicates that past thinking and conclusions have greatly overemphasized the importance of this phenomenon.

(3) Results obtained on the water content of atomic clouds indicate that "seeding" (dry ice, silver iodide, etc.) of an atomic cloud is not feasible.

(4) Extremely valuable data and experience in the field of tropical weather forecasting was obtained. Recently developed analysis techniques show promise.

b. For a more detailed discussion of Program 4.0, see Appendix "D".

11. PROGRAM 5.0 - RADIAC INSTRUMENT EVALUATION

The objective of Program 5.0 was to evaluate all ground and air radiac (Radiation Detection, Indication and Computation) equipment currently available as service or experimental items, to the end that improved equipment for military and civil defense applications may be designed and produced. Nineteen types of dosimeters, sixteen types of survey meters, three types of laundry monitors, and one mobile radiological field laboratory were tested. No individual dosimeter was found to be entirely adequate and there was little correlation between types. Several dosimeters can be made adequate with minor changes, although there is little possibility that any one type can be made adequate for all intensity ranges. No particular type of survey meter was entirely satisfactory, although several can be corrected by the elimination of minor flaws. Telemetering crater survey units dropped by aircraft performed fairly satisfactorily, although some modifications are necessary. Airborne radiac equipment performed adequately. For a more detailed discussion of Program 5.0, see Appendix "E".

12. PROGRAM 6.0 - PHYSICAL TESTS AND MEASUREMENTS

The objectives of this program were to determine many physical effects and characteristics of atomic bomb detonations. These included: particle size and distribution studies, thermal effects on materials, exposure of combat vehicles, fall-out distribution, interpretation of survey meter data, evaluation of filter materials, contamination and decontamination studies, radiation field of the atomic cloud, evaluation of protective clothing and collective protector equipment. Instrumentation, in general, operated very well. [redacted] The maximum thermal effect was observed from one-third to one-half second after detonation; dust greatly reduced thermal radiation, especially at close stations. Practically all thermal radiation damage occurs in the visible and infrared regions of the spectrum. The experiments with M-26 and M-46 tanks showed that, for a 50 kiloton, 300 foot tower detonation, both radiation and blast effects would cause a very high percentage of deaths among the crews within 1000 yards. Depot maintenance would be required on vehicles within 750 yards; beyond 1200 yards no damage would be incurred. The study of fall-out showed that over 90% of the total activity of the samples collected was contained in the greater than 20 micron fraction. Individual particles were mostly black spheres, either alone or attached to sand grains. The interpretation of survey meter data is continuing; no definite results are available now. Preliminary results on filter materials indicate that filter efficiency of the materials tested approximates that determined in the laboratory. In the contamination-decontamination studies it was determined that cleaning methods must be carefully selected on the basis of both the material and the type of contaminant. In studying the cloud radiation field it was found possible to accurately define the cloud boundaries, and that the greatest radioactivity occurred where the greatest particle density occurred. The study of protective clothing showed that ordinary laundry facilities are entirely successful in removing radioactive contamination. Collective protector equipment appeared to

587

operate satisfactorily. For a more detailed discussion of Program 6.0, see Appendix "F".

13. PROGRAM 7.0 - LONG RANGE DETECTION

Operation GREENHOUSE provided an opportunity for testing the world wide detection net operated by Headquarters, United States Air Force, and also permitted the gathering of much additional data which will be employed in evaluating atomic explosions produced by foreign powers. By collection of bomb debris in air and ground filters, measurement of atmospheric shock waves by acoustic devices, measurement of shock waves in the earth's crust by seismic instruments, and detection of bomb debris by atmospheric conductivity apparatus installed in aircraft, any suspected atomic explosion is capable of verification and, within limits, description as to location and yield. Because many of the Air Force detection installations are located in remote parts of the world, complete information from the world wide net concerning Operation GREENHOUSE has not yet been correlated. Some conclusions can be drawn, however, on the information available. Collection of samples of bomb debris was highly successful and preliminary results are gratifying. Acoustic signals from all shots were identified at a distance of 2,500 nautical miles east and west of ENIWETOK. Seismic installations detected all explosions at great distances, the greatest being 5,200 nautical miles on two shots. Each shot was also detected by Sound, Finding and Ranging (SOFAR) equipment at Point Sur, California. By Joint Chiefs of Staff decision, the Commander, Joint Task Force THREE was only responsible for activities within the MARSHALL ISLANDS area. Headquarters, USAF (AFOAT-1) should be consulted for further discussion of this program.

14. PROGRAM 8.0 - BLAST EFFECT ON AIRCRAFT

This program was primarily concerned with pressure, gust and temperature effects of an atomic explosion on aircraft in flight and on aircraft components on the ground. In addition, several specialized projects related to air operations and blast were carried on under this program.

a. BLAST EFFECT ON AIRCRAFT

Structural damage, varying from negligible to fairly severe, occurred on T-33 and B-17 drone airplanes. On "EASY" shot, one (1) T-33 drone went out of control shortly after arrival of the shock wave and crashed in the ocean. No data were obtained in this case since the telemetering system was inoperative throughout all tests. Some heat effects were noted on the drone aircraft, such as scorched paint and a burned tire. The crews of manned aircraft noted some, but not excessive, heat. However, it is clear now that consideration must be given to protection of the crew and certain portions of aircraft from heat, if the aircraft are to operate up to safe limits of blast and gust. Operations up to safe limits of blast and gust with protected crews may, however, be limited by the lethal radius of prompt radiation. For a discussion of experimentation in lethal effects of radiation, see paragraph 8 above and Appendix "B".

b. RELATED PROJECTS

These projects included tests of interferometer gauges, radar scope photography, measurement of effects of atomic explosions on radio propagation, aerial photographic damage study, and film fogging studies. The interferometer gauges, designed to measure air pressure directly, proved to be simple to operate and inexpensive, and, in general, were highly satisfactory. The results of the radar scope photography project are not yet available, although it is known that the equipment operated satisfactorily and that pictures were obtained. Similarly, no definite results are yet available concerning the effects of atomic explosions on radio propagation, although, here too, a large amount of data was obtained. Work is progressing on the aerial photographic damage study; apparently, the photographs taken were entirely satisfactory. A preliminary report on film fogging studies has already been forwarded to the Strategic Air Command, at whose request this project was initiated.

For a more detailed discussion of Program 8.0, see Appendix "G".

OPERATIONS

15. ORGANIZATION

JTF-3 was organized into four functional task groups designated as Task Groups 3.1, 3.2, 3.3 and 3.4. Forces were drawn from the Atomic Energy Commission and its contractors and from the three Services. Prior to the appointment of the Joint Proof Test Committee, preliminary plans and preparations had begun independently by the three Services and by the Santa Fe Operations Office (AEC) and by Los Alamos Laboratory. The basic plan for Operation GREENHOUSE was set forth in JCS 1998/13. Appendix "H" indicates the organization of JTF-3. The peak task force strength overseas was 8,916 personnel. Appendix "I" indicates the phasing of elements of the task force to ENIWETOK. Appendix "J" shows schematically the communications system of the task force.

16. Task Group 3.1 (TG 3.1), commanded by Dr. Alvin C. Graves, Los Alamos Laboratory, was activated 17 March 1950. The mission of TG 3.1 was to conduct all ex-

perimental programs and to design and construct all facilities with the exception of construction of facilities on ENIWETOK ISLAND. The nucleus of TG 3.1 was the "J" Division of Los Alamos Laboratory, headed by Dr. Graves, and formed after Operation SANDSTONE in 1948 to provide continuity in weapon test activities. Design and construction functions were performed by the firm of Holmes and Narver, who, at peak strength, numbered 1,800 personnel at ENIWETOK ATOLL. Other elements of TG 3.1 were drawn under contractual arrangements, or by assignment by CJTF-3 from the three Services, Service laboratories, universities and industry. Approximately 170 officers and 200 enlisted men were assigned to TG 3.1 to assist in administration or conduct of experiments as well as to receive special training. TG 3.1 was organized along military lines and at peak strength overseas numbered 2,401 personnel. The organization of TG 3.1 is shown in Appendix "K". TG 3.1 operated 50 miscellaneous boats and craft.

17. Task Group 3.2 (TG 3.2) was successively commanded by Brigadier General Frederick A. Butler, Brigadier General Don G. Shingler and Brigadier General Arthur R. Walk. TG 3.2 was activated on 12 January 1950 and deployed to ENIWETOK on 16 March 1950. The first mission of TG 3.2 was to construct facilities on ENIWETOK ISLAND, the design and materials for which were furnished by TG 3.1 through its contractor, Holmes and Narver. TG 3.2 consisted primarily of the headquarters of the 7th Engineer Brigade and the 79th Construction Battalion, with supporting services, until construction was completed. These two numbered units were deployed to the FAR EAST. (See JCS 1998/30). The peak overseas strength of TG 3.2 during the construction phase was 1,434 personnel. The second mission of TG 3.2 was to operate base facilities including those required for Task Group 3.4 on ENIWETOK ISLAND, JTF-3 off atoll communications less Airways and Air Communications Service (AACS), and to provide land security throughout the atoll. A force of 227 military police were assigned to accomplish this latter function. The peak overseas strength of TG 3.2 during the operational phase was 1,398 personnel. The organization of TG 3.2 for the conduct of its second mission is shown in Appendix "L".

18. Task Group 3.3 (TG 3.3), commanded by Rear Admiral Richard H. Cruzen, was activated on 15 July 1950. This task group consisted of three major ships; USS CURTISS (AV-4), USNS SERGEANT CHARLES E. MOWER (TAP-186) and USS CABILDO (LSD-16); two destroyers, USS SPROSTON and USS WALKER; VP 931 consisting of five P2V2 and four P2V3W aircraft, plus one PBM; USS LST 859; and the boat pool which consisted of sixty four miscellaneous boats and craft. The units which formed TG 3.3 were all assembled

RESTRICTED DATA
ATOMIC ENERGY ACT — 1946

590

and were in the operating area, or performing task force duties enroute, by 17 February 1951, except for the SERGEANT MOWER which reported for operational control on 11 March 1951. The peak personnel strength overseas of TG 3.3 was 2,585 which included 174 officers, 2,233 enlisted men and 178 civilians, exclusive of certain station vessels which were based at ENIWETOK and KWAJALEIN, under the Commander, Service Force, U.S. Pacific Fleet, for purposes of logistic support. No special manning of TG 3.3 was necessary since all units were in commission or in a status of being commissioned when assigned. The operations of TG 3.3 were generally without incident with the exception of two aircraft accidents causing major damage but no injuries. The organization of TG 3.3 is shown in Appendix "M".

19. Task Group 3.4 (TG 3.4), commanded by Major General Robert M. Lee, was organized by the Air Proving Ground Command on 24 March 1950, pursuant to a directive issued by Headquarters, United States Air Force. The Continental Air Command, the Tactical Air Command, and the Military Air Transport Service supported the Air Proving Ground Command by organizing, manning, equipping and training subordinate task units. The Air Materiel Command provided certain experimental aircraft and technical and logistical support of the task group. The 3200th Guided Missiles Wing, prior to the organization of TG 3.4, had been designated to perform the experimental air operations to be conducted during GREENHOUSE and had made considerable progress in the training of crews, refinement of drone operating techniques and the proving of new equipment to be installed on experimental aircraft. TG 3.4 operated all experimental aircraft; provided weather observation, reconnaissance and forecasting; provided operational air communications; operated liaison aircraft taxi service; air search and rescue; and documentary photography. TG 3.4 conducted simulated operations during the training period and on 15 November 1950 a complete detailed rehearsal of the air operations was conducted at Eglin Air Force Base. The delicate nature of some of the electronic test and control equipment, its unproved status and the extensive installation period seriously limited the time available for searching out and correcting defects. Extremely heavy tropical rains and an extended period of unusual high humidity prior to the first test contributed to the electronics difficulties. The radar control system (AN/MSQ-1) functioned well and closely positioned drone aircraft from radar readings, and the Target Position Indicator (TPI), associated with an AN/FPS-3 search radar, gave an excellent picture of the close-in air situation. The radio control system for drone aircraft functioned only after extensive field modification and after many essential radio services had been silenced.

The drone radio control system should be reengineered to utilize UHF (about 400-450 mcs), rather than the present 30-40 mcs band, and to render the equipment far less susceptible to interference. TG 3.4 operated the following aircraft: 16 QB-17 drones 16 DB-17 mothers, 5 QT-33 drones, 5 DT-33 mothers, 1 B-17 RADIAC airplane, 1 P2V RADIAC airplane, 12 WB-29s, 1 XB-47, 4 B-50s, 6 F-80Cs, 16 L-13s, 7 L-5s, 4 H-5s, 2 SA-16s, 2 SB-17s, 5 C-47s and 1 C-54. Experimental aircraft, both manned and drone were flown successfully on all tests. Control difficulties inherent in the use of drone jets contributed to the loss of three of these aircraft. One (1) B-17 drone on the last test was lost to remote control during the pre-detonation orbit and crashed immediately prior to the detonation. Three (3) L-13s were lost during a year's operation at ENIWETOK. There was one fatality as a result of air operations. The peak strength of TG 3.4 overseas was 2,397 personnel. The organization of TG 3.4 is shown in Appendix "N".

20. GARRISON FORCE

Coincident with the roll-up of the operating forces, a residual military garrison of 31 officers and 358 enlisted men was organized under the Commander, Task Group 3.2, and based on ENIWETOK ISLAND. The AEC's contractor organized a 452 man labor force, based on PARRY ISLAND, to carry on remaining AEC responsibilities in maintaining the proving ground facilities and in accomplishing the final clean up of AEC GREENHOUSE materiel. The military garrison force was organized from the elements of the three military task groups. This garrison force was designed to maintain stored Armed Forces equipment, provide local security of ENIWETOK ATOLL, support the U.S. Coast Guard long range navigation (LORAN) station on ENIWETOK ISLAND, operate minimum base facilities, and continue the installation in operational condition for use by succeeding task forces. On 1 July 1951, the Commander in Chief, Pacific and U.S. Pacific Fleet (CINCPAC) assumed responsibility for movement control, logistic support, and area security of the ENIWETOK area. Technical control over operation of the ENIWETOK PROVING GROUND remained with JTF-3. On 31 July 1951, those remaining military units assigned to JTF-3 were transferred to Joint Task Force 132. Operational control of other military JTF-3 elements, not organically assigned, was assumed by Joint Task Force 132 on the same date. The AEC's Manager of Santa Fe Operations is responsible for AEC activities at ENIWETOK. The organization of the garrison force is shown in Appendix "O".

21. SPECIAL AIRLIFT OPERATIONS

The Military Air Transport Service furnished special airlift for delivery of critical weapon components and scientific instruments to ENIWETOK and for the return of radioactive cloud samples requiring early laboratory analysis. A total of 9 westbound flights were dispatched to deliver the weapon components and scientific instruments. A total of 22 eastbound flights were utilized in the return of post-shot samples. Special security and salvage measures were taken on all flights carrying weapon components. Sample materials were given expeditious handling by transfer to waiting aircraft at HICKAM Air Force Base and by direct flight from HICKAM Air Force Base to KIRTLAND Air Force Base.

22. RADIOLOGICAL SAFETY

Responsibility for ensuring radiological safety followed command lines. Each element of the task force, operating in the vicinity of radiation, had its own trained personnel. Radiation dosages of personnel, in general, were maintained well below pre-established levels. The permissible radiological exposure was established at 0.7 roentgen per calendar week. This tolerance, slightly more liberal than the current 0.3 roentgen per week limit used for continuously exposed radiation laboratory personnel, was adopted. Under unusual circumstances, an additional accumulated exposure up to three roentgen in specific cases, where required for a limited number of individuals, could be authorized by the Commander. RADIAC (Radiation Detection, Indication and Computation) equipment performed adequately when used for the purpose for which it was designed. Specialized standard airborne RADIAC equipment is non-existent, however, a need exists for continued development work in this field. Fall-out predictions, with particular reference to health hazards of significance to the task force as well as to personnel in areas outside the immediate ENIWETOK Danger Area, were made the focus of particularly careful study. Upper wind analysis and trends of upper air resultant wind patterns, together with fall-out data on particulate matter, were of especial importance in operational decisions. Additions and improvements in fall-out predictability were evolved on successive shots from lessons learned on preceding shots. Slight fall-out, of no significance as a health hazard, occurred on inhabited areas of the ENIWETOK ATOLL after "DOG" and "ITEM" shots. The prompt fall-out which occurred after "DOG" shot was unexpected, since large particle fall-out had not been observed on Operation SANDSTONE. Other shots had their maximum fall-out over uninhabited islands of the atoll and over the open ocean. Experience on Operation GREENHOUSE has shown clearly that present highly sensitive instruments tend to greatly alarm even well trained laboratory technicians and Service trained monitors who work with laboratory dosage standards and instruments. It is believed that the continued employment of these standards and instruments can easily produce conditions of panic under practical operations, especially with inadequately trained monitors. Descriptions of radiological safety operations are found in Appendix "P".

23. WEATHER

Special weather facilities for Operation GREENHOUSE consisted of a weather central on ENIWETOK ISLAND, four (4) outlying island weather stations (an average of 750 miles from ENIWETOK), and an Air Force weather reconnaissance squadron based on KWAJALEIN ISLAND. In addition, the Navy P2V antisubmarine squadron furnished weather information at each position report. Wind direction and velocity, cloudiness, and rain had a direct effect on radiological safety, drone operations and certain experimental programs. On each shot the stress on these elements varied considerably. For example, rain could not be tolerated on "EASY" shot because of its attenuating effect on blast. Radiological safety, involving mainly the upper wind structure, was of prime importance on "GEORGE" shot because of the very large expected yield, lower tower and unstabilized surface. During the operation, two typhoons affected the area. The first one, Typhoon "GEORGIA", moved just south of ENIWETOK ISLAND shortly before the first shot. Heavy rain fell for several days while this typhoon was in the vicinity, but winds did not exceed 45 knots at the surface on ENIWETOK ISLAND. "DOG" operation was delayed one day due to interference in preparing instrumentation. The weather on "DOG" day was clear until about 10 minutes before the detonation when a thin, low cloud layer moved in and persisted for about two hours. This interfered somewhat with low level photography and with visual observation, but otherwise did not hamper the experimental program. The winds aloft produced some light fall-out on inhabited islands. On "EASY" shot the weather was favorable in all respects, although special measures were taken to observe chance showers approaching the shot island. On "GEORGE" shot the weather was dominated by a typhoon (JOAN) to the northwest producing exceptionally favorable winds from the fall-out standpoint, but marginal from a drone operational standpoint. Heavy rain and high humidity on the two days preceding the detonation, however, interfered considerably with instrumentation, both on the ground and in aircraft. Directions of take off and landing were 180° from normal and low cloud and shower activity during take off resulted in a reduction of the air effort. Showery weather at KWAJALEIN prevented the take off of the blast B-47 airplane. On "ITEM" shot, the weather was favorable although the upper wind resulted in very light fall-out at the southern end of ENIWETOK ATOLL. For a more detailed discussion of meteorological aspects of the operation, see Appendix "Q".

24. SECURITY

Operation GREENHOUSE began during a period of growing international tension. The USSR was given the capabilities of interference with or the compromise of the mission of JTF-3 by espionage, sabotage, overt action, observation or unauthorized instrumentation. The foundation of JTF-3's security policy and the primary safeguard against penetration of JTF-3 by foreign espionage was the "Q" clearance of all personnel who were to have any access to RESTRICTED DATA. In February 1951, certain changes were made in the Department of Defense's policy on access to RESTRICTED DATA by military personnel. However, JTF-3 held consistently to its policy of straight "Q" clearances. In addition to these clearances, National Agency Checks and other types of investigation were applied to the remainder of JTF-3 personnel who were not to have access to RESTRICTED DATA. The island geography of the atoll lent itself well to the establishment and control of EXCLUSION and RESTRICTED areas, all of which were guarded by military police. By a system of security control badges and access lists the traffic of personnel was limited to the necessities of their jobs. One security measure did cause individual delays at HONOLULU and KWAJALEIN and it involved a greater volume of communication traffic than should have been necessary. (JTF-3 agreed to comply with CINCPAC Serial 0116 which required a prior dispatch on all persons entering the ENIWETOK Danger Area). To counter possible hostile military actions or reconnaissance threats, air and sea reconnaissance of the Danger Area and ground and air reconnaissance of the atoll was conducted. The forces available in the event of emergency included two destroyers, a squadron of P2Vs, a flight of six F-80C interceptors and 227 military police, reenforced by a limited number of Army personnel for whom arms and ammunition were stocked. During the actual test period there was only one known violation of the Danger Area; a Japanese fishing vessel. Out of all the reconnaissance sightings and reports there emerged only one identified "possible submarine" and this was about 130 miles outside the Danger Area. There is no reason to believe foreign powers penetrated the Danger Area by sea or air.

25. LOGISTICS

a. CONSTRUCTION

The construction program on ENIWETOK ATOLL was initiated in October of 1947 by the AEC through the firm of Holmes and Narver, LOS ANGELES, CALIFORNIA. Task Group 3.2 augmented the contractor force. The construction effort consisted of both rehabilitating World War II structures and in constructing new facilities. Housing and messing, health and sanitation, utilities and recreational facilities were built to support 2,900 personnel on ENIWETOK ISLAND, 1,500 on PARRY ISLAND and 125 on JAPTAN ISLAND. Temporary living facilities were provided on shot islands to accommodate construction crews and scientific personnel preparing the test sites. Shot island housing was augmented by the use of a naval transport and one LST. The construction program included rehabilitation of 400,000 square feet of old buildings, construction of 400,000 square feet of new aluminum buildings, 200,000 square feet of tent slabs and frames, 12 miles of electric lines, 100 miles of submarine cable, 16 miles of water distribution lines and 10 miles of sewers and petroleum, oil and lubrication systems. Combination power and water distillation units permanently installed provide 3000 kilowatts of power in addition to meeting the fresh water needs of the atoll. The 7,000 foot coral runway and supporting taxiways, parking ramps and decontamination areas were rehabilitated and surfaced or compacted. Construction required directly by the experimental programs such as shot towers, test structures and instrumentation required approximately 35% additional effort to that tabulated above. The necessity of basing some JTF-3 elements at KWAJALEIN became evident during the initial planning period. In cooperation with the Commander, Naval Operating Base, KWAJALEIN, utilizing a Navy contractor firm already performing construction at the base, additional temporary facilities to support approximately 1,400 personnel were constructed. These facilities consisted of two new tent camps and rehabilitation of messing, recreational and health and sanitation facilities. In addition, some augmentation was made to the permanent facilities planned for KWAJALEIN. To reduce the requirement for new construction, one APL was berthed at KWAJALEIN and used at that site during the entire operational period.

b. TRANSPORTATION

Surface transportation was initially provided by the Navy through the Service Force, U.S. Pacific Fleet. The increasing load of JTF-3 cargo eventually necessitated utilization of Military Sea Transport Service (MSTS) for cargo and personnel movements. The Service Force, Pacific Fleet, continued to provide reefer ships, POL transportation, and storage afloat during the entire operation. Air transportation of cargo and personnel was provided by Military Air Transport Service (MATS), including special air mission flights for personnel and transportation of critical test material. JTF-3 submitted all transportation requirements directly to the furnishing agency without the necessity for processing through any of the separate Services. This direct channel assisted immeasurably in fulfilling emergency requirements and in making adjustments to requirements necessitated by the nature of Operation GREENHOUSE. JTF-3 liaison officers were stationed at principal ports and air bases supporting the operation. Total surface movements included 201 vessels calling at ENIWETOK which moved 13,575 passengers and 273,492 tons of cargo. 13,071 passengers and 1,850 tons of cargo were moved by air. See Appendix "R".

c. SUPPLY

Service supply support was rendered through the Overseas Supply Depot, FORT MASON, CALIFORNIA for Army items; Sacramento Air Materiel Area, MC CLELLAN Air Force Base, CALIFORNIA for Air Force items and the Naval Supply Center, OAKLAND, CALIFORNIA for Navy items. Petroleum, oil and lubricants of all classes was supplied by the Service Force, Pacific Fleet. Points of emergency supply were U.S. Army of the Pacific (USARPAC) for Army; Sacramento Air Material Area for Air Force and the Naval Supply Center, PEARL HARBOR, for Navy. The contractor firm of Holmes and Narver obtained construction and maintenance supplies through their commercial channels for transportation by Service vessels. Subsistence supplies were obtained by Holmes and Narver through the Naval Supply Center, OAKLAND, CALIFORNIA. Accountability for all supply items was maintained through establishment of appropriate property accounts at ENIWETOK and substocks at KWAJALEIN.

d. MAINTENANCE

Maintenance of equipment at ENIWETOK was limited generally to routine care and replacement. Major overhaul and repair items were returned to appropriate depots or shops in HAWAII or the continental U.S. Since all equipment originally shipped to ENIWETOK was in first class condition the provision of overhaul facilities was considered unwarranted in view of the expected short duration of the operation. This decision was substantiated by the experience encountered. High temperatures, humidity and heavy saline content of the air presented serious problems in control of corrosion, and maintenance of electronic equipment and intricate office machines. A systematic procedure for treatment to prevent corrosion was established early in the operation; however, this problem continued to require an inordinate amount of manpower. One centralized motor pool for general purpose Army and Air Force vehicles was established at ENIWETOK. This resulted in increased utilization, some reduction of manpower and a concentration of skills permitting more efficient use of men and equipment

Marine maintenance was accomplished by the USS CABILDO (LSD-16) for military water craft except the DUKWs which were maintained by TG 3.2 in the centralized motor pool. TG 3.1 marine maintenance was performed by Holmes and Narver with assistance from the USS CABILDO for specialized repairs beyond the capabilities of this installation.

c. SALVAGE

Salvage of damaged or worn equipment was handled by each Service and, generally, on items not salvageable locally, consisted of the return of the material to depots in HAWAII or the ZONE of INTERIOR.

FINANCIAL

26. The funding responsibility for Operation GREENHOUSE was divided among the three military departments, the Atomic Energy Commission and the Commander, Joint Task Force THREE. The departments, including the Atomic Energy Commission, were responsible for funding all of their normal operating costs. The Commander, Joint Task Force THREE funded all above normal Department of Defense operating costs from monies furnished him through the Air Force Management Fund which had been approved by the Research and Development Board. The Air Force was held responsible for furnishing full financial support for the Long Range Detection Program (Program 7.0), and the Atomic Energy Commission met all fund requirements for Los Alamos Laboratory experiments (Program 1.0). The Commander, Joint Task Force THREE was kept informed of all GREENHOUSE expenditures through the participating agencies' fiscal reports.

27. Funds budgeted directly for GREENHOUSE totaled $74,000,000. $52,000,000 was furnished by the AEC and $22,000,000 was furnished by the Department of Defense, through approval and supervision of the Research and Development Board. It is expected that actual obligations for GREENHOUSE will amount to $73,000,000 and, therefore, the Chief of Staff, USAF, Executive Agent was advised on 12 June 1951 that the balance of $1,130,751 in the Air Force Management Fund could be withdrawn for use on other projects. A statement of the application of funds is presented in Appendices "S" and "T".

28. A cost system was placed in effect in compliance with instructions contained in JCS 1998/13. Inasmuch as neither the military departments nor the Atomic Energy Commission had a cost system which could easily be adopted in its entirety for this operation, a modified system was established which accounted for the total cost of the operation by operating and capital costs, by test programs, by departments and by task groups. This modified system, although patterned somewhat along the

lines of the cost reporting system used by the Air Force, was a compromise between established service cost accounting systems, the system utilized by the Atomic Energy Commission and the ultimate system desirable for joint operations which only time and future experience can produce.

29. The final cost of Operation GREENHOUSE totaled $114,000,000 ($88,000,000 in operating costs and $26,000,000 in capital assets which represents a permanent proving ground plant). Of the total, $52,000,000 was expended by the Atomic Energy Commission and $62,000,000 by the Department of Defense. Of the total capital items of $58,500,000 furnished GREENHOUSE, $18,600,000 of capital items was returned to the contributing agencies, while $13,900,000 was consumed in the operation. The total operating cost of $88,000,000 reflects an AEC expenditure of $32,800,000 and $55,200,000 of Department of Defense effort. A complete breakdown of all costs incurred is presented in Appendices "U" and "V".

30. Necessary arrangements have been made to transfer to Headquarters, USAF, the close-out and final settlement of all GREENHOUSE funding responsibilities remaining after the deactivation of Joint Task Force THREE. Through mutual arrangements with Joint Task Force 132, continuity of funding has been established for those elements transferred.

REPORTS

31. A series of reports covering Operation GREENHOUSE in considerable detail is being prepared for distribution within the AEC and within the Department of Defense. These reports will constitute a GREENHOUSE library which will be officially deposited with Los Alamos Laboratory and with the Armed Force Special Weapons Project. Distribution within the AEC and within the Armed Forces will be made by these agencies. When completed, the GREENHOUSE library will consist of the following volumes:

a. History of Operation GREENHOUSE, Volumes I and II.

b. Technical Report on Communications, Operation GREENHOUSE, Volume III.

c. Meteorology of Operation GREENHOUSE, Volume IV.

d. Technical Scientific Reports of Operation GREENHOUSE, Volumes V through CXIX (119).

32. Volumes I, II, III and IV probably will be available from the printer in late summer, at which time distribution will be made. Some of the finished copies of the Technical Scientific Report volumes may be ready for distribution in late 1951, although most of them will not be distributed until early 1952.

599

33. In addition to the written reports, a Secret, RESTRICTED DATA, documentary motion picture of about 1 hour and 15 minutes duration is being completed by the Air Forces Lookout Mountain Laboratory. This film records the story of the operation and explains various principles of weapons and experimentation. Copies will be furnished the AEC and the Services. Viewing prints will be available in AFSWP. A possible public releasable motion picture on Operation GREENHOUSE, of about 20 minutes duration, is under process of production for the AEC. Lookout Mountain Laboratory is also establishing a film library of technical photography of the operation.

APPENDICES:

"A" - Program 1.0
"B" - Program 2.0
"C" - Program 3.0
"D" - Program 4.0
"E" - Program 5.0
"F" - Program 6.0
"G" - Program 8.0
"H" - JTF-3 Organization Chart
"I" - JTF-3 Phasing Chart
"J" - Communications Chart
"K" - TG 3.1 Organization Chart
"L" - TG 3.2 Organization Chart
"M" - TG 3.3 Organization Chart
"N" - TG 3.4 Organization Chart
"O" - Garrison Force Organization Chart
"P" - Radiological Safety
"Q" - Meteorology
"R" - Logistics Chart
"S" - Funding Chart
"T" - Funding Chart
"U" - Overall Costs
"V" - Experimental Program Cost Chart

600

SECRET

APPENDIX "A"

PROGRAM 1.0 - LOS ALAMOS EXPERIMENTS

1. GENERAL REMARKS

Program 1.0 was divided into three main parts:

a. Diagnostic measurements designed to measure detailed weapon performance during the process of energy generation.

b. Phenomenology measurements designed to measure and evaluate blast, thermal and visible radiation, and nuclear radiations, i.e., gamma rays and neutrons.

c. Remote weapon performance measurements designed to measure transit time and yield under combat conditions by means of airborne instruments.

In addition, this program included projects concerned with cryogenic, and timing and firing techniques.

2. DIAGNOSTIC MEASUREMENTS

The diagnostic measurements, especially those concerned with the understanding of the thermonuclear reactions were extremely complex but excellent results were obtained. Among the principal diagnostic measurements for the fission reaction were the following:

a. Measurements of "alpha" or the rate of rise of the nuclear reaction.

b. The quantitative chemical analysis of radioactive isotopes produced in the nuclear reactions with a view to determining energy releases. Samples for these measurements were collected successfully by drone and manned aircraft and attempted unsuccessfully by rockets and specially designed ground sampling devices. The use of manned sampling aircraft, first attempted on Operation RANGER, was successful and crews did not receive excessive total radiation dosages.

c. The "transit time" or time required for the device to become assembled and the reaction to occur after the firing signal reached the detonators.

d. Visible radiation measurements which included ball of fire observations and growth and rise of the atomic cloud.

The thermonuclear experiments required much more elaborate instrumentation designed to measure the detailed progress of the thermonuclear reactions. [redacted] Less elaborate but equally

DOE 6.1(

601

SECRET

important measurements were made by means of neutron cameras and threshold detectors placed at various distances from the bomb to determine the extent of the thermonuclear reaction. Other measurements were made in the high energy neutron spectrum.

PRELIMINARY VALUES FOR YIELD IN KILOTONS

[redacted]

3. PHENOMENOLOGY

a. BLAST

A portion of the blast program was designed to obtain the pressure - distance curve from an atomic bomb prior to reflection of the blast wave from the ground. This was done by means of detectors mounted on cables supported by balloons and by photographing the intersection of the shock wave with specially designed smok trailing rockets. These two techniques were highly successful. Other measurements of blast included pressure versus distance on the ground and attempts to obtain pressure versus time on the ground as a function of distance. The results of the ground measurements are at present somewhat puzzling but it is hoped that some of the anomalies may be resolved upon further study. A primary objective of the blast program was to establish the points of similarity and difference between the blast produced by an atomic bomb and that produced by high explosives. It is hoped that the free-air pressure curves obtained will develop information on this point.

b. THERMAL RADIATION

Measurements were made of the spectral distribution and time dependence

RESTRICTED DATA
ATOMIC ENERGY ACT — 1946

602

of the thermal radiation emitted from fission and thermonuclear devices. This series of measurements met with a high degree of success and it now appears possible to resolve various disagreements in the details of thermal radiation from nuclear explosions.

c. NEUTRONS

Neutron spectra were obtained as a function of distance and, at a few locations, as a function of time. The results of this project were highly gratifying in that they filled large gaps in previously available information on bomb neutrons; only the most meager data on neutron spectra were available prior to GREENHOUSE.

d. GAMMA RAYS

Measurements were made of the gamma ray spectra from a microsecond to a millisecond, and from a millisecond on. The objectives of these measurements were to determine not only the energies of the gamma rays as a function of distance, but their time dependence and distribution of the sources of this radiation as well. These data have not yet been analyzed sufficiently to comment on the degree of success of this series of measurements. The gamma ray and neutron data have relevance to the problem of lethal range for unprotected personnel in the vicinity of a nuclear explosion and the problem of adequately shielding against these radiations.

4. REMOTE WEAPON PERFORMANCE MEASUREMENTS

a. A specially devised instrument, the "BHANGMETER", which measured the time from the first appearance of light to the first minimum in the light versus time curve, was tested. This device is intended to give a direct reading of the bomb yiel The first model was not entirely satisfactory because its response to the rather broa light minimum actually present was indefinite. Some changes were made in this model, however, which included the photographing of an oscillograph sweep, and it is believe that a satisfactory device can be developed. A related experiment of significance to military intelligence was conducted to determine whether bomb yields could be determined over long distances by analysis of light. This experiment was suggested by experience on Operation RANGER whereby light from detonation was visible in LOS ANGELES At 550 miles from ENIWETOK, significant light was detected by airborne instruments from which estimates of yield could be made; however, further work is required to refine this technique.

b. A remotely recording airborne device to measure transit time was tested on the ground successfully. This device transmitted by radio a signal from the bomb to indicate the instant that the detonators were fired. Another signal indicated the first appearance of ionizing radiations. These signals were received at a remote, airborne receiver and the time difference, or transit time, measured directly.

c. Remote alpha airborne devices were tested on Operation RANGER but without complete success. No experiments were conducted on this device during GREENHOUSE and further work is required.

APPENDIX "B"

PROGRAM 2.0 - BIOMEDICAL

1. GENERAL

The fundamental objective of this program was to obtain information which can be used in planning effective medical care for the victims of atomic warfare, and for the victims of industrial accidents in nuclear energy plants.

2. FACILITIES

The physical facilities of the biomedical program on PARRY ISLAND, ENIWETOK ATOLL, consisted of personnel and administrative buildings, animal quarters and clinical laboratories, a total of 51 buildings.

3. ANIMALS

Careful care and attention was given to the breeding of swine, dogs and mice in the tropical climate to insure the development of pure strains suitable for test purposes. At test time, animals to be exposed were healthy and remarkably consistent in their response to injury. The extent of participation of the animals in the four tests is shown in the following table:

Shot	Projects	Number of Mice*	Dogs*	Swine	Stations**
DOG	4	1,170	0	0	16
EASY	16	11,390	164	178	173
GEORGE	8	1,230	0	22	60
ITEM	1	0	16	0	8
TOTALS		13,790	180	200	257

* Includes necessary control animals.

** Actual number of structures in which material was placed on the shot islands.

4. EXPOSURE EQUIPMENT

Five types of exposure equipment were designed and procured for the experimentation; cylinders, hemispheres, thermal shelters, high dose stand types and foxholes. All of the units were satisfactory except for one foxhole (400 yards from ITEM ground zero) which partially caved in. There was no general failure of any equipment, although some of the closest phantoms were damaged by flying debris and some of the electrical circuits failed because of excessive humidity on GEORGE shot. The cylinder and hemisphere units were very satisfactory and provided a unique basic design for exposure equipment to be used in tests of this sort.

5. MEDIAN LETHAL DOSAGE OF NUCLEAR RADIATION

a. The median lethal dosage (MLD) of nuclear radiation was obtained successfully for mice, dogs and swine. The MLD is defined as that dosage at which 50% mortality is to be expected. On EASY shot, 4,720 mice were exposed in 29 cylinder stations at distances ranging from 1,000 to 1,750 yards and all were recovered alive on E day, 6 hours after the detonation. The mortality rate over a period of 28 days was determined and a smooth curve relating dosage to mortality was obtained. The MLD occurred at the station which was 1,416 yards from ground zero.

b. On EASY shot, 19 swine were placed in each of nine stations at distances ranging from 1,300 to 1,750 yards. The mortality rate over a period of 30 days was determined. On the 30th day after the shot there were two swine living from the station at 1,650 yards and eight living from the station at 1,750 yards. The MLD, therefore, occurred at some distance between 1,650 yards and 1,750 yards from ground zero.

c. On EASY shot, 10 dogs were placed in each of nine stations at the same distance as the swine. The mortality rate was determined over a 30 day period. On E plus 30 days there were 2 dogs living from the station at 1,620 yards, 5 living from the station at 1,650 yards and 9 living from the station at 1,750 yards from ground zero. The MLD, therefore, occurred at about 1,650 yards.

d. The best data were those for mice, from which a smooth dosage mortality curve can be drawn. The observed MLD based on the theoretical gamma radiation yield for the EASY weapon was lower by a factor of approximately 0.7 than the MLD of mice of the same strain exposed to supervoltage X-ray. The MLD for dogs based on the theoretical gamma radiation was approximately the same as that obtained with supervoltage X-ray. When the MLD was based on measurement of film packs placed within the containers in which the dogs were exposed, a somewhat lower value was obtained. The MLD for swine, based on the theoretical gamma radiation, was conspicuously lower than the value obtained with supervoltage X-ray. Tentatively, this discrepancy is attributed to the hot, humid environment, which was tolerated poorly by the swine. It appears that for future field tests, dogs are more satisfactory than swine for the determination of MLD and for the study of therapy on the MLD. Results obtained from the radiation depth dosage (discussed later) offered some explanation for the discrepancies noted in determining the median lethal dosages of the animals.

6. THERMAL RADIATION INJURY

a. On EASY shot, 46 swine and 16 dogs were anesthetized and placed in six stations ranging from 1,325 to 5,600 yards from ground zero. Of these, 4 died as a result of the anesthesia. Satisfactory burns were obtained for study and biopsy on the animals placed in the five nearest stations.

b. On GEORGE shot, 22 swine were anesthetized and placed in two stations at 3,460 and 4,780 yards from ground zero. Of these, 10 died as a result of anesthesia and inclement weather. The circuits operating the mechanism for the study of time dependency failed because of moisture. The burns that were obtained were satisfactory for gross and microscopic study and for the demonstration of spectral dependency.

c. The equipment used in the burn study functioned satisfactorily; it was shown that the atomic bomb flash burn is caused principally by visible light, less so by infrared, and least of all by ultraviolet. The effort to estimate the time dependency of the burning was less successful. It seems quite certain that no burning occurs during the first maximum of the thermal emission. With the data obtained, it appears that all the burn is inflicted during the first portion of the second maximum and that burning ceases at about 0.3 to 0.5 seconds after the blast. Since this time interval coincides with the peak of the second maximum and since decrease in illumination does not occur until somewhat later, there is uncertainty regarding the significance of the cutoff. Considerable analysis of other phenomena that occur simultaneously is required before the time data can be accepted. Good kodachrome photographs of the burns and excellent biopsy material were obtained, which should aid in the precise clinical definition of this type of flash burn.

7. BIOLOGICAL DOSIMETRY

a. The principal system of biological dosimetry depends upon the measurement of the percent change in the weight of the thymus and spleen of mice on the 5th day after irradiation. Comparison is made with special controls subjected to identical treatment except for the radiation. The effect of total nuclear radiation was studied in hemisphere stations with aluminum domes; the effect of total neutron radiation in hemisphere stations with lead domes; and the effect of fast neutrons, in hemisphere stations with lead cadmium domes. For DOG shot, 480 mice were exposed; for EASY shot, 720; and for GEORGE shot, 360. All mice were recovered alive. A comparable number of special control mice were placed in the hemispheres as a part of the dry run for each shot. The mouse thymus-spleen system worked very well with the expected yield. A consistent difference was observed between the film pack dose estimate and the mouse dose estimate, with the estimate from the mouse system always

607

lower.

b. Flowering Tradescantia plants were exposed to DOG, EASY and GEORGE shots at distances where the predicted radiation intensity was sufficiently low to produce chromosomal aberrations which could be analyzed. Tradescantia were also placed in drone aircraft for each of the three shots to measure the integrated dose of radiation during the cloud pass. The estimates of dose based on the study of chromosomes agreed well with the preliminary reports of the calibrated film.

c. The Tradescantia system was successful and the results obtained were consistent and agreed well with the measurements made by the mouse thymus-spleen system. The closest agreement between the dose estimates based on Tradescantia and those based on calibrated film was obtained in the drone aircraft experiments where the dose rate was lowest.

8. NUCLEAR RADIATION DEPTH DOSAGE STUDIES

a. Depth dose estimations were made to investigate the quality of the nuclear radiation. The specification of the quality of a beam of ionizing radiation of whatever source is a major problem in clinical radiology. The conventional unit is the half value layer (HVL), and in the case of X-ray therapy the conventional technique involves the use of phantoms constructed from material of unit density. The ability to specify the quality of the radiation from a nuclear weapon is intimately related to the problem of the experimental production of radiation injury, since it is possible that energy dependency and dose distribution may be important limiting factors in determing the type of injury that results.

b. Spherical lucite phantoms were displayed on EASY and GEORGE shots. In each case the nearest group of phantoms was lost due to flying debris. The ionization chambers and film packs were recovered from all the others and were in good condition for study.

c. Swine phantoms which resembled the shape and bulk of the torso of the swine, or a man, were exposed on EASY and GEORGE shots. All were recovered and the film packs contained in them are being processed.

d. The data have not been analyzed from the phantoms that contained calibrated film. In those that contained ionization chambers, it was found that the HVL using lucite (density slightly greater than unity) exceeded 20 centimeters. This finding indicates a very energetic composite radiation, the mean effective energy of which was well in excess of 1.0 Mev. It was mentioned above that the biological estimates of dose at a given distance were consistently lower than that given by

608

calibrated film, or theory, by a factor of 0.7. That is to say, the relative biological efficiency of nuclear radiation was greater than unity when compared to supervoltage X-ray. These considerations indicate the need for further study of the energy dependence of biological effects caused by ionizing radiations with energies greater than 1.0 Mev.

9. BLAST INJURY

On "ITEM" shot, sixteen dogs were placed in 8 foxholes, 6 X 3 X 4 feet deep at distances ranging from 400 to 1,500 yards from ground zero. Radiation dosimeters and pressure gauges were also installed. The hole at 400 yards collapsed, burying the occupants. Live animals were recovered from all others. Severe radiation injury was sustained by all animals except those at 1,250 and 1,500 yards. Blast injury to the lungs and brain which might have been fatal ultimately was observed in animals placed at 600 and 800 yards.

10. CLINICAL STUDIES

a. Clinical studies of the characteristics and the time trend of radiation injury were performed. In the case of swine, such studies consisted of serially killing all of the group exposed to the same supralethal dose of gamma radiation. These animals were killed at intervals of hours and days during the first two weeks after the blast to determine the sequence and the extent of the pathological changes that occurred. In the case of the mice, 2,400 survivors of the dosage mortality study were returned to the Oak Ridge National Laboratory for life time study to observe the effects of nuclear radiation on longevity, the incidence of cancer and the occurrence of cataracts.

b. The clinical studies were successful and excellent Kodachrome photographs were obtained of every stage and type of radiation injury. The most significant findings (on the basis of gross examination alone since the histological specimens are still being studied) was the early evidence of injury to the intestinal mucous membrane. This early lesion disappeared after a few hours, but within several days another more severe involvement occurred. The gross appearance of these lesions suggested a vascular injury rather than damage to the epithelium alone. This observation is quite valuable and should become the basis for extensive experimental work in the future. Taken as a whole, the gross pathological findings indicated the essential similarity of radiation injury in man and large animals regardless of whether the source is a nuclear explosion or exposure of the whole body to supervoltage X-ray. Bacteriological studies failed to disclose bactermia except as a terminal finding in dogs and swine. In spite of this finding, it appeared that septicemia was the cause of death in many animals. The hematological studies displayed the typical time trend of the leukopenia and the lymphopenia and further demonstrated the fundamental similarity of radiation injury due to exposure of the whole body to nuclear radiation, or to supervoltage X-ray.

APPENDIX "C"

PROGRAM 3.0 - EFFECTS ON STRUCTURES

1. GENERAL REMARKS

The structures program was sponsored jointly by the Army, Navy and Air Force. In addition, the Federal Civil Defense Administration sponsored a test to determine the effect of blast on windows. The program comprised a total of twenty-seven test buildings and shelters erected at various distances from the "EASY" shot ground zero on three separate islands. The structures were designed in late 1949 on the basis of the best available information on blast loading and structural response. Use was made of experimental data from shock tubes, and laboratory tests of materials and elements under dynamic loading. A medium degree of damage between superficial and collapse was desired for test purposes. The structures were so located as to sustain median damage, based on energy yield predictions and pressure distance data furnished by the Commander, Task Group 3.1.

2. ARMY TESTS

The Army sponsored a three-story building having several independent sections of different types of construction, and a composite shelter of three sections; cubicular reenforced concrete, cylindrical reenforced concrete and cylindrical corrugated steel. Damage to the three-story building was slight, but it was sufficient to furnish a basis for checking design criteria and methods. The shelter sections were undamaged and provided adequate protection against blast and nuclear radiation effects.

3. NAVY TESTS

The Navy had twelve test structures, generally about 20 by 40 feet in plan, of a type that would be employed for magazines, storage, and personnel shelters. Precast construction was employed in most of the buildings because of its adaptability to overseas use and its relative cheapness. Two of the structures were of heavy reenforced concrete construction and were intended to test the feasibility of providing protection at a distance of only 83 yards from ground zero. Damage to most of the Navy structures was severe; however, much useful information was obtained on the comparative value of various types of buildings. Detailed data on the mode of failure of structural elements were also obtained.

4. AIR FORCE TESTS

Buildings sponsored by the Air Force were typical of those which might be attacked. There was no specific design to resist blast but rather a selection of

611

distance from ground zero which would provide the desired degree of damage. Target structures consisted of a section of a manufacturing type building with long spans (such as might be used in the manufacture of aircraft), one manufacturing type with short spans, and two residential type brick buildings of European type construction. There were in addition six simplified structures with various sized window openings to obtain basic information concerning the effect of openings on structural response to the blast. There was a one-quarter scale model of one of these structures and also a one-quarter scale model of the aircraft manufacturing type building. The purpose of these models was to obtain a comparison of the behavior of geometrically scaled models and their prototypes. Such information might permit a saving in the cost of structure tests if the relationship of scaled models and prototype structures can be firmly established. The results of the Air Force tests were mixed insofar as damage is concerned. It is expected that analysis of data on transient effects will provide very useful information on methods of predicting target damage.

5. CIVIL DEFENSE TEST

The Federal Civil Defense Administration sponsored and supported financially the program to determine the effect of blast on windows. Plans for the test were developed by the Public Building Service. The objective was to test various types of glass and glass substitutes, and windows of the type employed in offices and homes. There were also tests of methods of stopping flying glass by use of wire mesh, curtains and venetian blinds. The damage achieved in the windows and glazing test was well bracketed between extremes of complete and no damage. A satisfactory test was accomplished and much useful data will be provided.

6. CONDUCT OF TESTS

The analysis of the buildings and prediction of damage was accomplished by the Army, Navy and Air Force. The requirements for transient measurements and motion picture photography were established in collaboration with the Sandia Corporation and Edgerton, Germeshausen and Grier. Extensive measurements of the condition of structures before and after the tests and damage surveys were accomplished by sponsoring agencies and with the transient data furnished by the Sandia Corporation will be used in making complete analysis and reports.

7. INSTRUMENTATION

a. The important responsibility for measuring pressures on the buildings and for measuring the structural response of the buildings was assumed by the Sandia Corporation in accordance with agreements entered into by the Atomic Energy Commission

A group was formed at Sandia Corporation comprising corporation employees, enlisted personnel from the Army, Navy and Air Force, and college students, to obtain these measurements. Technical evaluation and procurement of existing equipment was accomplished effectively. In some cases equipment had to be developed or existing equipment adapted. Installation and operation of the instrumentation equipment by the Sandia Group provided useful data from more than 95% of the measurements planned.

b. Large dependence was placed on the measurement of transient effects involving a total of 1,065 gauge recordings. Blast pressures on the buildings, both inside and outside, and comprehensive measurements of structural response were made. Motion picture photography was used to record motions and modes of failure. Measurements were made of conditions of the buildings before and after being subjected to blast, such as rod and transit surveys, audio velocity measurements in concrete, micrometer measurements of distances and natural period studies of ten structures.

c. The Los Alamos Scientific Laboratory accomplished the still photography and the firm of Edgerton, Germeshausen and Grier accomplished the motion picture photography. These photographic records will be of great value in analyzing structural damage.

8. CONCLUSIONS

a. The complete analysis of results will require several months since it is necessary to take all the measured pressures and analyze each structure to determine whether the deformations calculated by the method established prior to the tests checks out with the measured deformations. In the work which has been accomplished thus far very good agreement has been obtained. The measured pressures, however, are quite different in many cases from those predicted by theory and shock tube experiments. It is in this field that the greatest amount of effort is indicated.

b. The shelter designs of the Corps of Engineers were proven adequate under test conditions at a distance of 1700 feet from the tower. This distance was intended to provide the same peak pressure as for a point directly underneath the same bomb at optimum height for a ten pound overpressure. The conditions of the test, particularly the effect of the ground, led to some uncertainty as to whether the shelters did receive the same pressure as would have been experienced directly underneath the same bomb. From a general viewpoint, however, the test results will be very useful in indicating the order of value of the shelter designs.

c. The analysis of models displayed in the tests is incomplete. The use of models to investigate diffraction effects on structures appears promising.

In this case rigid models could be used. If models are to be employed as a measure of structural behavior certain factors such as gravitational loads do not scale and means must be established for compensating for these variations from scaled behavior. The results of the tests emphasized the fact that models at less than one-quarter scale are impractical and also that models of very small size are of doubtful use because of the effect of irregularities of the ground on the blast wave.

APPENDIX "D"

PROGRAM 4.0 - CLOUD PHYSICS AND METEOROLOGY

1. CLOUD PHYSICS

a. This portion of the program was undertaken in order to fully document atomic clouds during their rise in order to obtain information of use in operational air drops, and to allow studies of entrainment of air, turbulence, and diffusion to be made. In addition, it was desired to determine in some detail the temperature and water vapor content of atomic clouds in order to evaluate the possibility of producing artificially stimulated precipitation.

b. Photographic documentation of the rising atomic clouds was carried on both from the ground and the air for DOG, EASY and GEORGE shots. On DOG shot, the ground cameras failed to obtain a record due to a low overcast, but adequate coverage was obtained from the air. Satisfactory ground and air coverage was obtained on both EASY and GEORGE shots and these films are now being processed. Rough analysis of data taken by ground observers, using theodolites, on GEORGE shot showed that the third shot attained an altitude of 26,200 feet in 1 minute and 45 seconds, an altitude of 47,500 feet in 3 minutes and 33 seconds, and a final altitude of 70,000 feet in 11 minutes and 4 seconds. The radius of the cloud at 26,200 feet was 1.2 miles, at 56,500 feet was 3.2 miles, and at 70,000 feet was 5.0 miles. It is interesting to note that the bomb cloud requires from 11 minutes to 12 minutes to reach maximum altitude regardless of yield. It is also interesting to note that GEORGE shot was the first cloud to actually penetrate the tropopause.

c. In order to study the temperature and water vapor content of the atomic cloud, the Kollsman Instrument Company developed a new aerograph which was capable of operation in drone aircraft on a fully automatic basis. A total of thirty aerograph flights were made in and around atomic clouds arising from the three shots.

d. Preliminary analysis of a portion of the flights reveals no striking temperature or humidity features in the atomic cloud as compared to ordinary clouds. The temperatures as indicated by the aerograph were lower inside the cloud than in the environment. This apparent anomaly is being investigated further to determine whether it is real. Study of the indicated air speed at the time of entrance into the cloud revealed that in the majority of the traverses a sudden increase in the air speed was experienced although the power, controls, surfaces, etc. remained at constant settings.

e. The humidity traces revealed rather low humidities in the atomic cloud.

These values grouped around 40 - 60 percent relative humidity. This is evidence that the portion of the cloud traversed does not contain liquid water in sufficient amount to entertain any speculation about creating rain by artificial seeding, at least in the tropics.

2. WIND MEASUREMENT

a. The wind measurement project of this program was designed to measure the wind produced by the rush of surface air into the rising column of hot gases produced by the rising fireball. The magnitude of such a draft wind on the area surrounding the blast has never before been measured, and has been the subject of considerable speculation. Twenty-five pitot type wind measuring instruments of standard design were modified for this type of measurement and were partially successful in obtaining "order of magnitude" results. One new and untested anemometer of the hot wire type, and another of the strain gauge type, were also tested for suitability in this type of service.

b. Useful afterwind data were not obtained on DOG shot due to the paralysis of the recording devices by the negative or suction phase of the blast which obscured a majority of the afterwind obtained. The results of this test, however, led to modifications of the instruments.

c. On EASY shot the magnitude of the surface component of the afterwind was found to be considerably less than anticipated, and measured from 26 to 32 miles per hour (including normal surface wind component) at distances from 1,200 to 2,300 yards. The duration of the afterwind was found to be approximately 15 seconds after passage of the shock wave at this location. This indicates that the large quantity of air which rises in behind the fireball is drawn from its immediate vicinity, and that a chimney action from ground level is not sustained for any appreciable length of time.

d. On the third (GEORGE) shot, three instruments yielded records at 1,260, 4,750 and 7,870 yards respectively. Although the pitot tube was destroyed on the recorder at 1,260 yards, the direction record indicated that for this large shot the afterwind phase lasted for 5 minutes at this position. The afterwind effects at the greater distances (indicated largely by alternation of wind direction) lasted only 12 and 7 seconds respectively, with minor changes of wind speed of 2 to 6 miles per hour.

e. It would appear, from the meager results of this test, that any large afterwinds which might result from the rising fireball must be confined to a radius

616

of approximately 1,200 yards from weapons of the present tactical size. Since this is within the range of total blast destruction, the only practical application of afterwinds would be their role in drawing ground debris into the rising cloud column. It is possible that with extremely large weapon yields the afterwinds may play a significant part in surface destruction, although this appears to be rather unlikely.

3. TROPICAL WEATHER FORECASTING

a. This project was a part of a long range program in tropical weather forecasting and was considered to be a part of the GREENHOUSE program only because of the many weather observations which were available during the test period. This work was under the direction of Dr. C. E. Palmer, University of California at Los Angeles, an eminent authority on tropical forecasting.

b. It is too early to determine the results of the study of the meteorological data which were obtained during Operation GREENHOUSE; however, it can be mentioned that an improved method of forecasting, stressing streamline analysis, was tested and found to be encouraging. It should be pointed out that the usual forecasting techniques employed in temperate latitudes, involving the interpretations of highs and lows in barometric pressure, and fronts and air masses, are entirely inadequate in the tropics due to the very minor pressure variations and the uniformity of air masses. The field of tropical forecasting is almost a virgin one and will undoubtedly involve the formulation of many entirely new concepts.

4. ATMOSPHERIC CONDUCTIVITY

a. The last project of this program was the study of the ionic structure of the cloud. A total of four aircraft were equipped with suitable equipment for the measurement of conductivity. Two of these were L-13 liaison aircraft, which were equipped with one small ion conductivity chamber for low altitude crater and local fall-out surveys. The others were long range B-50A aircraft designed for tracking the cloud up to 3 days after shot time; these were fitted up as flying laboratories. These aircraft were equipped with instruments to measure both positive and negative small ion density and large ion density simultaneously with continuous records of atmospheric nuclei counts, electrostatic field, humidity, pressure, temperature, air speed and samples of the atmosphere.

b. The plan of operations was to intercept the atomic cloud 4 hours after shot time with the B-50As and run contours around the outer edge continuously to obtain size and rate of growth of the cloud, and at the same time determine the density of large and small ions on the fringes of the cloud. This was done from 4 hours after blast to 72 hours after blast.

c. General contours of conductivity around the cloud showed it to be about 300 to 400 miles long by 50 to 150 miles wide at 6 hours after the shot; and 600 to 1,000 miles long by 100 to 200 miles wide at 30 hours after the shot. The above information was obtained at 25,000 feet for the wind patterns which existed at the times of DOG and EASY shots. The existing wind patterns indicated that vertical mixing occurred between the 20,000 - 35,000 foot altitudes. The position and size of the cloud could not be explained otherwise, since the cloud was several times longer and farther away than predicted by 25,000 foot wind patterns alone, or by fall-out, since the size of the particles measured was believed to be extremely small.

d. One rather unexpected result of the tests was an indication that a surprisingly large portion of the radioactivity might have been carried on submicron particles which were too small to be filtered out by the normal filter methods. This was first suspected when the activity collected on the filter papers failed to account for the actual ionization measured by a factor of better than 50 times. So far it cannot be positively stated that these submicron particles are the major contributors to the activity of the cloud as compared to the 4 to 10 micron particles collected by the filter papers, but it is very difficult to interpret the evidence collected to date in any other manner.

e. The L-13s made flights at elevations ranging from 200 feet to 4,000 feet. It was found that at an altitude of 200 feet the contamination contours on the shot island and adjacent islands could be obtained rapidly from the air and that they agreed very closely with the ground contours drawn by the radiological safety monitors. At higher altitudes, the entire atoll was examined from the air and the pattern of fall-out from the cloud was easily observable.

APPENDIX "E"

PROGRAM 5.0 RADIOLOGICAL INSTRUMENT EVALUATION

1. GENERAL

This program was designed to test and evaluate, under the conditions of an atomic bomb detonation, the many radiological instruments, both surface and airborne, that have been under development by the Armed Forces since Operation SANDSTONE and by the Atomic Energy Commission for civil defense purposes.

2. GROUND RADIAC EQUIPMENT

a. Specific objectives of this portion of the program were the general evaluation of available instruments and the formulation of recommendations covering:

(1) Adequacy of equipment for military and civil defense applications.

(2) Adequacy and feasibility of existing military characteristics.

(3) The direction of future development.

(4) Improved test methods.

b. Sound evaluation of radiac equipment could be achieved only at weapon test sites because the wide ranges of radiation intensities and energies in mixed radiation fields which result from atomic explosions cannot be duplicated in the laboratory. The factors of intensity and energy are of primary significance in the design and use of all types of ground radiac equipment. Nineteen types of dosimeters, sixteen types of survey meters, a mobile radiological field laboratory, and three types of laundry monitors were tested. These included equipment developed by or under the sponsorship of the Army, Navy, Atomic Energy Commission, and the National Bureau of Standards.

c. Generally, no dosimeter was found to be entirely adequate. The degree of inadequacy varied among instruments. While some types were consistent in themselves, little intercorrelation among types was observed. It should be noted, however, that certain types can be made adequate with minor changes. Over the dosage range that is of common interest to the Department of Defense, the Atomic Energy Commission, and the Federal Civil Defense Administration, viz., zero to approximatel 600 roentgens, it appears that particular types of dosimeters are best suited for particular ranges within the stated limits. Up to 50 roentgens, self-reading pocket electroscopes are most feasible. For higher dosage ranges up to approximately 600 roentgens, solid-state (such as a color changing crystal) and liquid state (such as a color changing organic liquid) are more feasible than gas interaction (such as

617

argon-alcohol) types. Future tests are required to retest dosimeters modified as a result of Operation GREENHOUSE and to test promising new dosimeters. It is also apparent that more stringent laboratory testing of new models should be performed prior to actual field testing.

d. As in the case of the dosimeters, no particular type of survey meter was found to be entirely adequate. Some types proved completely useless but others behaved excellently except for a few minor, correctible flaws. In general, the beta detection capabilities of the various instruments were not satisfactory. This is believed due to the lack of explicitness in the military characteristics which should be amplified so as to provide sufficient range and a reasonable degree of uniformity of sensitivity among the different instrument types. It is also recommended that laboratory test facilities be extended to simulate various climatic conditions.

e. Operation of the mobile radiological field laboratory threw a light on a number of important factors. The original designs and procedures were too sweeping in scope to allow for efficient field laboratory operation. The laboratory should have been designed and equipped to perform a few specific procedures adequately. Instead, the procedures were developed after the field laboratory was physically in existence. During the period of operation, procedures were developed which in effect provided the type of information required for laboratory analysis. On the basis of these procedures, as well as on the findings reported from tests performed on the precursor to the present model of the field laboratory, certain modifications were found to be desirable. These modifications limited the scope of the field laboratory but stressed procedures which yielded the maximum of useful information and so, increased the efficiency of operations. It was found necessary to augment the equipment supplied, both electronic and chemical. It was also found necessary to remove some of the equipment originally supplied. Future operations and tests are required to indicate necessary further developments and modifications.

f. The results of the laundry monitoring will be reported on in more detail in the final report but early results indicate that present procedures are not entirely satisfactory.

3. AIRBORNE RADIAC EQUIPMENT.

a. The specific objective of this part of the program was the test and evaluation of Navy and Air Force airborne radiac equipment under conditions of an actual atomic bomb detonation. The high radiation intensities and wide range of energies necessary to properly evaluate such equipment are available only at such times.

b. The general types of equipment tested were gamma dosimeters and beta monitors for aircraft interiors, cloud trackers and detectors, airborne ground intensity survey meters, and droppable, telemetering crater survey units. The radiac equipment was installed in a Navy P2V-2 aircraft and in an Air Force B-17 aircraft. The B-17 emphasized tracking the atomic cloud while the P2V-2 emphasized test of the cloud-tracking equipment for only the first hour or less, devoting attention then to ground survey and dropping of the telemetering units into the crater area.

c. The recording gamma dosimeters operated in excellent fashion throughout the sufficiently high-intensity areas were entered to permit full-scale deflection of the recorders. The cloud-tracking equipment was able to detect the cloud at distances up 20 miles but the operation was handicapped by such things as power failure. The range of detection was highly dependent upon the size of the cloud which, in turn was dependent upon the yield of the weapon. The lowest yield shot in which the project participated gave the least conclusive and least satisfactory of the results.

d. The ground survey equipment was handicapped by maintenance and operational problems, but in general the results were satisfactory for the purpose. The droppable, telemetering crater survey units were successfully monitored in only about 50% of the cases. The principal cause of this deficiency was believed to have been the failue of the antennae to erect properly after the units landed on the ground. A contributing cause lies in the fact that each unit transmits only 5 minutes of each hour and uncertainty in the precise time of transmission made it difficult to receive each unit at the proper time. The uncertainty in time of transmission arose from inherent inaccuracies in setting the transmission time on the clock mechanism. This source of error was removed before the third shot by starting the clock mechanisms. at precisely determined times shortly before launching the units from the aircraft.

e. The beta cabin monitor performed satisfactorily in both project aircraft In order to prevent an excessive radiation dose, the aircraft avoided too close an approach to the atomic cloud. Of necessity, therefore, the green light, indicating safe conditions, remained on at all times. Similar equipment, however, was installed in a drone aircraft which penetrated the cloud and records indicated that it operated satisfactorily at red light, or danger levels.

f. All of the radiac equipment installed in the two project aircraft performed satisfactorily during at least one shot and, in all cases, sufficiently well to establish the validity of their operating principles and achievement of their designed performance. Occasional lapses from optimum performance are attributed to stringent operating conditions during the test missions, and were occasioned largely by failure of accessories or components, e.g., power supplies, tubes, etc. Such failures are to be expected under field conditions in experimental equipments of this type. In no way do they bring the basic designs into doubt and, in any event, are remediable without further development work. A possible exception to this statement is the antenna erection difficulty previously described. Work to secure improved designs is underway.

APPENDIX "F"

PROGRAM 6.0 - PHYSICAL TESTS AND MEASUREMENTS

1. GENERAL

The general objectives of this program were to determine many physical effects and characteristics of an atomic bomb detonation about which relatively littl or nothing was known before Operation GREENHOUSE. This information is not only useful in planning future analytical and laboratory work, but it also contributes materially to defense planning.

2. CLOUD PARTICLE SIZE AND DISTRIBUTION

a. The objective of this part of the program was to obtain data on the composition, concentration, specific activity as a function of particle size, and particle size distribution, of the particulate matter in the radioactive cloud produced by an atomic bomb detonation. For this purpose, samples of the atomic bomb cloud were collected during the period H hour plus 5 to 20 minutes at altitudes from 16,000 to 30,000 feet. This was accomplished by instrumenting each of the twelve filter collecting B-17 drone aircraft with four types of apparatus for collecting of cloud samples, and for particle size separation of particulate matter; a snap sampler, an electrostatic precipitator, a cascade impactor, and a conifuge.

b. The snap sampler operated satisfactorily and obtained an average of six samples per eight attempts for each of the three shots in which the project participated. The samples obtained are still undergoing detailed analysis by a civilian contractor and detailed information will be available in the final report.

c. The electrostatic precipitator operated efficiently in slightly over 50% of the sampling attempts. Present data from these instruments indicate that the median diameter of the radioactive component of the cloud was 0.8 micron. This applies to EASY shot only, since the rest of the data are still being studied.

d. The cascade impactors operated satisfactorily and preliminary analysis of the samples obtained thereby for DOG shot indicated that the maximum activity was deposited on the fourth jet which has a calibration average particle diameter of 0.6 micron. It should be emphasized that this is preliminary information. The cascade impactor samples appear to be well suited for particle size and radioactive analysis.

e. The low sampling rate of the conifuge limited the usefulness of its samples on these tests. It is better adapted for conditions where dilute samples are more desirable.

f. Radiochemical analyses completed on samples from DOG shot indicate that the fission yield curve roughly approximates that of thermal-neutron fission, with a ratio of fission yields at the curve maxima and minima of about 200.

g. Decay rate measurements have been made on three samples of the cloud from each of the three shots. These samples were taken at maximum, medium, and minimum altitude of each shot and included both efficient and inefficient collections. Present data indicate a difference in the shape of the decay curves between efficient and inefficient collections.

3. THERMAL EFFECTS ON MATERIALS

a. The objectives of this part of the program were to obtain data on the effects of thermal radiation on materials, which would provide an adequate base for the future conduct of a laboratory program, and to determine the degree of correlation between the thermal-radiation effects of an atom bomb and the effects of sources presently being used in laboratory studies. This part of the program participated in EASY shot only.

b. Results showed that the stations were well-selected as to location and were well-designed and well-instrumented for the execution of the project. Results to date indicate that the duration of exposure and the total radiation received at various stations were lower than had been calculated. The total energy received at the far stations was greater than that received at the close stations probably because of obscuration by dust of the lower part of the fireball. Both the peak intensities and the effects on materials, however, decreased successively from the close to the far stations. The maximum intensity was observed at about 1/3 to 1/2 second after the detonation.

c. It is tentatively concluded that material damage is closely dependent on both the total energy and its rate of delivery: that for practical purposes therefore the total energy delivered cannot be used alone as a criterion of damage.

d. No significant amount of damage due to ultraviolet radiation was observed. For practical purposes, the total damage can be attributed to radiation in the visible and infra-red regions of the spectrum. The data have not been studied to a degree to permit differentiation between relative effects in these spectral regions.

4. EXPOSURE OF COMBAT VEHICLES

a. The objective of this part of the program was to determine the tactical effectiveness of atomic weapons when employed against concentrations of armored vehicles, in this case, ten 45-ton tanks. The data have not yet been fully reduced and the results given herein are subject to modification in the final report. It should also be remembered that these results apply to the peculiar surface conditions of the test site and for an atomic weapon detonated under the low-level conditions of a tower burst. For weapons detonated at or below the surface, or at heights of 1,000 feet or more, the results presented here may not apply at all.

b. Within the tanks, lethal radiation dosage was obtained through 750 yards; median-lethal dosage through 1,000 yards; serious radiation sickness through 1,250 yards; moderate radiation sickness through 1,400 yards. The accelerations imparted to vehicles up to 750 yards, and the resulting movements, would probably cause serious if not fatal injuries to the operating crews. From 1,000 yards out, the accelertions and resulting movements were of no significance. Within 1,000 yards, the rise in temperature of the interior walls and the rise in internal air pressure were found to be of secondary importance when compared with other factors. Outside of 1,000 yards, these effects were of no significance.

c. With regard to physical damage of the vehicles, the majority of damage was limited to external accessories and appendages. The limited amount of major damage resulted from the overturning of two tanks and the removal of a turret from anoth The type of maintenance required to return the damaged vehicles to complete combat effectiveness is indicated below:

500 yards - Depot Maintenance for one tank; Organizational Maintenance for the other.

750 yards - Field and Depot Maintenance.

1,000 yards - Field and Organizational Maintenance.

1,200 yards and beyond - No maintenance required.

d. Some general conclusions concerning the tactical effectiveness of atomic weapons when employed against 45 ton tanks under the conditions of this particular 300-ft. tower detonation are:

(1) Vehicles and their operating crews will not be affected beyond about 1,500 yards from ground zero.

(2) Vehicles will have immediate 100% combat effectiveness beyond 1,000 yards from ground zero.

(3) Operating crews of vehicles located from 1,000 to 1,500 yards will encounter no immediate combat casualties. They will, however, eventually suffer varying degrees of disability due to radiation

625

6. INTERPRETATION OF SURVEY-METER DATA.

a. The purpose of this experiment was to obtain information concerning the interpretation of survey-meter readings in terms of hazard. For this purpose, it is necessary to know not only the ionization associated with the fission-product activity, but also the beta and gamma ray energies which produce the ionization.

b. The effective gamma ray energy of the radiation field surrounding ground zero ranged from 0.1 to 0.2 Mev for two shots. Since the average energy of the incident radiation was around 0.7 Mev, it is clear that a very high flux of relatively low-energy radiation must have been present as a result of scattering and degradation of the incident photons. Since it is well established that, except for properly designed ion-chamber instruments, radiation-detecting instruments are unreliable for energies below 0.2 Mev and because much low-energy gamma-ray activity is present in fission fields, it is important that great care be exercised in the future design of survey instruments for use in contaminated areas.

c. Seven types of survey instruments were tested to determine their response to radiation fields emanating from samples of fission-product aggregate. The gamma dose rate in roentgens and the beta dose rate in equivalent roentgens were calibrated with secondary standards at heights ranging from 20 centimeters to 1 meter above the surface of radioactive plaques. Survey instruments were then exposed to these calibrated fields. The work is continuing and the results will be fully tabulated in the final report.

7. EVALUATION OF FILTER MATERIALS.

a. The objective of this project was to evaluate the filtration efficiency of five standard and developmental filter materials against the airborne particulate contamination present in the atomic bomb cloud. These filter materials are incorporated in gas masks, collective protectors, and other devices designed for respiratory protection and air filtration. The project participated in the first three shots; twenty-three out of twenty-four satisfactory samples were obtained from the filter collecting B-17 drones which penetrated the atomic cloud.

b. So far, all samples have been counted for beta activity, and decay data are being taken over a period of 8 weeks on selected samples. Radio-autographs are being made, and information on alpha activity is being gathered. The data are currently being corrected for counting errors and decay, prior to final compilation and analysis of results.

626

c. Preliminary results indicate that the installation and operation of the filter-material samplers was satisfactory for obtaining an adequate sample for the determination of filter efficiency against cloud contaminants. The filter efficiency of two of the five types of filter material tested approximates that determined by standard laboratory test methods using non-radioactive aerosols. The decay of selected samples from one shot taken at the site closely followed the expected early decay of gross fission products.

8. CONTAMINATION AND DECONTAMINATION STUDIES.

a. The objectives of this part of the program were to study the contamination characteristics of standard materials; to determine the efficiencies of decontaminating agents and methods; and to determine the capabilities of those methods in full-scale operations.

b. The radioactive decay rates of the samples collected for study seemed to show significant differences for different shots. Some doubt exists whether the generally used decay expression is accurate enough for the close estimation of expected dose which might be accumulated as a result of a military operation during or following an atomic attack. This point is being studied now. A slight decrease in decontamination efficiency of various materials was noted, both through aging and as the result of alternate wetting and drying. The decrease was not enough, however, to have a significant bearing on military or field operations.

c. It has been found that the order of efficiency of different decontaminating agents was about the same for the removal of contamination from samples obtained at Operation GREENHOUSE, as far the removal of synthetic aerosols on which laboratory testing is based. However, the laboratory contaminants were removed much more efficiently than were the GREENHOUSE contaminants. It is concluded, therefore, that laboratory testing can assess relative merits of cleaning agents, but cannot predict their actual field efficiency at present.

d. Of the various factors which affect the contaminability of materials it was found that details of exposure overshadowed differences due to the characteristics of the material. There seemed to be little effect due to hardness or chemical composition. A noticeable decrease in contaminability was observed if the surface was very smooth. However, this effect was of relatively little importance after the surface became only slightly rough.

e. No consistent trend was found in the study of the fifteen proposed industrial decontaminating processes studied, except that steam cleaning without chemical additives gave consistently poorer results than any other method. Laboratory findings, which indicate that maximum efficiency is obtained when the cleaning method is carefully selected on the basis of both material and the type of contaminant having been substantiated. The selection of any standardized method will inevitably lead to a procedure which is not optimum with respect to many conditions which might be encountered in field operations.

9. CLOUD RADIATION FIELD.

a. The objectives of this project were to determine the radiation intensity within the atomic bomb cloud; to correlate this intensity with the physical or particulate boundary of the cloud; to resolve the manner in which this radiation intensity fluctuated in relation to the distribution of the radioactive particles composing the cloud; and to determine the relation that the radioactivity has to the visible boundary of the cloud.

b. The rate meters and jet impactors which were designed for use by this project operated in a satisfactory manner. The rate meters indicated peak intensities of as high as 24,000 r/hr and, where the drones in which the equipment was installed actually penetrated the bomb cloud, the jet impactors defined clearly the physical cloud boundaries. It appears to be generally true that the highest radiation intensities appear within the particulate cloud and at the same points in time and space as the greatest densities of particulate radioactive matter. This will be more evident from the graphical presentations which will be contained in the final report.

10. TESTS OF PROTECTIVE CLOTHING.

a. The object of this experiment was to test protective clothing with reference to protective value, susceptability to contamination, susceptability to decontamination, and its handling and disposal under field conditions.

b. Preliminary laundering decontamination methods developed in a test program at the Oak Ridge National Laboratory were tested under conditions of field contamination from atomic weapon bursts. Normal clothing materials showed little difference in contaminability except that water-repellent finishes appeared to pick up more contamination and to resist its removal to a greater degree than non-water-repellent materials. Contamination due to fall-out material was removed as readily as was contamination by surface materials which had been activated by the detonation. Contaminated clothing was decontaminated satisfactorily by laundering with both alkaline and with acid cleaning agents, using commercial-type corrosion-resistant metal laundry equipment. Commercial launderies can safely, and on a practical basis, decontaminate radioactively contaminated launderable clothing. Personnel decontamination was satisfactorily accomplished without the use of special detergents, commercial toilet soap proving as efficient as specially formulated detergents.

11. EVALUATION OF COLLECTIVE PROTECTOR EQUIPMENT.

a. The object of this experiment was to evaluate Chemical Corps protective shelter methods and equipment during an atomic bomb detonation.

b. The collective-protector unit was located within the Corps of Engineer shelter and was completely protected from blast damage by the use of a specially designed anti-blast closure. Although the collective-protector ceased to operate 5 minutes after the detonation, the anti-blast closure unit and the collective-protector were in operation during the detonation and were subjected to the blast with its accompanying heavy load of radioactive particulate matter following the shock front. It is felt that this load of matter was unusually heavy due to the absence of vegetation on the test site, frequent pre-shot grading of the surface, and the high walls of loose sand which formed the protective walls along other experimental installations. Under more normal surface conditions, practically 100% removal of radioactive particulate matter could be expected. The method used for measuring the activity of the air stream is not believed to be the ultimate in experimental technique. Considerable difficulty exists in differentiating between induced activity, background activity, and the activity due to particles in the air stream. The energy spectrum of the various particles as well as their distribution within the air stream add complexity to the problem. In addition, the response time of the instruments and their counting efficiency must be adequate for the velocity of the particulate matter passing the tube. For these reasons the measurement of particulate activity in an air stream under the operational conditions encountered remains a difficult problem.

c. No conclusions can be drawn now concerning the efficiency of operation of the anti-blast closures in the field installations because the activating overpressures for each of the field installations is not known at this time.

APPENDIX "G"

PROGRAM 8.0 - EFFECTS ON AIRCRAFT

1. GENERAL REMARKS

This program was designed primarily to give information necessary for the safe operation of atomic bomb carrying aircraft and to develop design criteria for future aircraft. In addition, several other projects concerned with airborne devices and techniques were studied under this program.

2. EFFECTS ON AIRBORNE AIRCRAFT

a. The test for determining the effects of an atomic explosion on aircraft in flight was the most extensive project of this program. Special instrumentation for the measurement of blast, gust, and temperature effects was installed in Air Force airplanes. These were flown at predetermined altitudes and distances from the zero point of the explosion. Distances were based on the predicted yields of the shots. Complete analysis of the data received is now under way at the Air Material Command; therefore, only preliminary results or indications are available at this time.

b. On "DOG" shot one (1) T-33 jet drone, one (1) B-17 drone, two (2) manned B-50Ds and one (1) manned XB-47 participated in the test. Distances at shot time from zero point varied from 9,260 feet (T-33 drone) to 52,100 feet (B-50D). Distances at shock arrival time varied from 11,000 feet (T-33 drone) to 40,900 feet (B-50D). Altitudes varies from 7,800 feet (T-33 drone) to 29,000 feet (B-50D). No structural damage resulted on any of the airplanes. Damage due to heat was caused on the T-33 drone and on a B-17 drone at 15,000 feet altitude and 16,150 feet slant range. The T-33 (which is all metal construction) had scorched paint in several places. On the B-17, the fabric surfaces on the under side of the ailerons and elevators were burned away. Black paint was scorched in several other places. The crew of the XB-47 at 25,700 feet slant range reported feeling considerable heat. Recordings on the specialized instrumentation were received and are being analyzed.

c. On "EASY" shot, one (1) each of the T-33 drones and B-17 drones were positioned to receive blast loads in excess of 90% of the ultimate designed load factor of the aircraft. Two (2) T-33 drones, two (2) B-17 drones, one (1) manned XB-47 and two (2) manned B-50D airplanes participated in the test. Distances at shot time varied from 6,540 feet (T-33) to 38,000 feet (XB-47). Distances at shock arrival time varied from 6,920 feet (T-33) to 33,000 feet (XB-47). Altitudes varied from 6,500 feet to 33,000 feet. The low T-33 went out of control shortly after

630

shock arrival time and crashed in the ocean. The cause could not be established, and due to inoperative telemetering system, no data were obtained. The telemetering system failed completely on all tests. The low B-17 (11,000 feet altitude) drone's fabric surfaces had been covered with aluminum foil, a good reflective surface, and though heat was high (over 200°F), no major damage resulted to these surfaces. Considerable damage was apparent to painted sections and one tire was burned to the extent that it blew out on landing. Some structural damage was done to the airplane, but not to the extent that it was unflyable. After complete inspection it was considered safe to fly to the U.S. with minimum load aboard. The airplane has been returned to the Air Material Command for detailed inspection. The other B-17 drone (12,000 feet altitude) went through the top of the atomic cloud and minor structural damage was done. There was no structural damage on the manned airplanes and no reported abnormal heat from the explosion.

d. On "GEORGE" shot, due to inclement weather, it was decided just prior to take off time to fly all drones as manned airplanes. Positions were changed to greater distances from the explosion for crew safety. Participating in this shot were one (1) T-33, three (3) B-17s and the two (2) B-50Ds. Heavy rain at KWAJALEIN prevented the XB-47 from taking off. No structural damage was suffered on any airplanes. Several crews reported noticeable heat, but at distances involved this heat was not excessive.

e. Analysis of the data is continuing at the Air Material Command, Massachusetts Institute of Technology and the University of California at Los Angeles. Preliminary analysis indicates the following general conclusions:

(1) Blast and Gust - The permissible overpressure of one-fourth pound per square inch now employed for operational aircraft was definitely proven low. One (1) pound overpressure is much more realistic and it is believed that Air Force aerodynamists will be able to establish safe limits for each type of airplane as a result of these tests. Safe gust velocities, which an airplane can withstand, vary with speed and altitude. Safe operating altitudes and speeds, based on bomb yields, will be established by the Air Material Command as a result of these tests.

(2) Thermal Radiation - As bomb yields increase, the range of thermal radiation increases. These were the first tests in which factual data were obtained. It is evident that for operational aircraft, protection from heat will have to be afforded the crew and portions of the airplane such as fabric sur-

631

faces, paint, etc. Thermal effects studies relative to the design of aircraft should be continued.

(3) Nuclear Radiation - The results of Program 8.0 when considered in connection with Program 2.0 point to the conclusion that aircraft operations up to safe limits of blast and gust with crews and aircraft protected from heat may be limited by the lethal radius of prompt radiation. In addition, flight through the atomic cloud up to within 30 minutes of detonation is extremely hazardous due to radiation.

(4) The MSQ-1 radar used for the remote control system for drones gave very good results; however, it was expensive, highly complex and required a large number of personnel to maintain and operate. A simpler system with a high degree of reliability and requiring fewer personnel should be developed. Investigation of automatic Shoran techniques is suggested.

3. EFFECTS ON THE GROUND

Another portion of this program was the determination of the effects of the blast, thermal and nuclear radiation on aircraft structural members. These structural components consisted of conventional aircraft parts such as an F-80 fuselage, F-47 wing, vented and unvented airfoils, and specially designed rigid and swept wing airfoils. They were exposed at distances varying from 4,000 feet to 16,000 feet from ground zero. The results of this test under static conditions will be correlated with the effects on airborne aircraft under dynamic conditions to ascertain whether ground tests may be utilized in the future to obtain much of the needed information pertaining to blast effects on aircraft structures. Four (4) identical test installations were made on four islands of the atoll. Results from all test sites appear satisfactory and data are now being analyzed at the Air Material Command. From visual inspection it appeared that the models reacted to the loads and pressures as predicted by the theoretical studies. No definite conclusions or recommendations can be made at this time.

4. INTERFEROMETER GAUGES

The object of this portion of the program was to obtain pressure versus time data at test site locations, and to test a new type of pressure gauge commonly referred to as the "BUCK" gauge. This gauge utilizes the principle of the interference bands of light produced on the mirrored surfaces of a quartz diaphragm. As the pressure on the diaphragm varies the thickness of the film of air which separates the plates, the interference fringes are displaced giving a direct measurement of the pressure. This gauge is simple to operate, inexpensive and requires a minimum of personnel. Four (4) gauges were installed at each test site. Reduction of data and plotting of curves were accomplished within 48 hours after the shot. The gauge itself proved satisfactory and will be valuable for future tests.

5. RADAR SCOPE PHOTOGRAPHY

The object of this portion of the program was to obtain photographs of radar scopes during the atomic explosion for analysis and evaluation as a method of measuring bombing accuracy and estimating bomb damage. Pictures were taken of A and B scopes of the AN/APQ-24 radars on two (2) B-50Ds for "DOG", "EASY" and "GEORGE" shots. Equipment operated satisfactorily and excellent pictures were obtained. Radar returns, about 15 decibels above background, moved with approximately the velocity of sound. These served to positively locate ground zero. This is a low level phenomenon and is almost certainly closely related to humidity, and possibly to turbulence. It is doubtful whether total energy can be determined with the present technique since the velocity of the shock wave cannot be measured with sufficient accuracy in the early stages. Whether the present technique can be adapted to determination of ground zero in other localities will depend on the results of continued experimentation on tests at continental sites. The film from the GREENHOUSE tests is still being studied at the Air Material Command in collaboration with the Operation Analysis Section of Headquarters, USAF, and final conclusions will be available in a short time.

6. MEASUREMENT OF EFFECTS OF ATOMIC EXPLOSIONS ON RADIO PROPAGATION

The object of this portion of the program was to find what effects, is any, occurred in the transmission and reception of radar and radio waves, both direct and reflected, during and after an atomic explosion. Possible sources of interference are blast, radiation and ionization. These tests were conducted on "DOG", "EASY" and "GEORGE" shots. Both short range (within the atoll area) and long range (as far as JAPAN and HAWAII) radios were monitored by recorders. Ionspheric studies were made by the National Bureau of Standards. All equipment operated satisfactorily and data are being analyzed and evaluated by the Signal Corps and the National Bureau of Standards at the present time. No conclusions or recommendations can be made at this time.

7. AERIAL PHOTOGRAPHIC DAMAGE STUDY

This test was designed to check photographic interpretation of damage against actual damage caused by an atomic explosion. This was accomplished by taking photographs, both vertical and oblique, of the main buildings of the structures program before, during and after "EASY" shot. This test presented an opportunity to combine typical operational photography with known structures and measured pressures. It also provided a means of training personnel in predicting structural damage resulting from blast and incendiary effects of an atomic weapon. The addition of low-oblique pictures gave additional details of damage and also an overall pictorial record of the results of the test. The accomplishment of these objectives was realized and a group of excellent pictures was obtained.

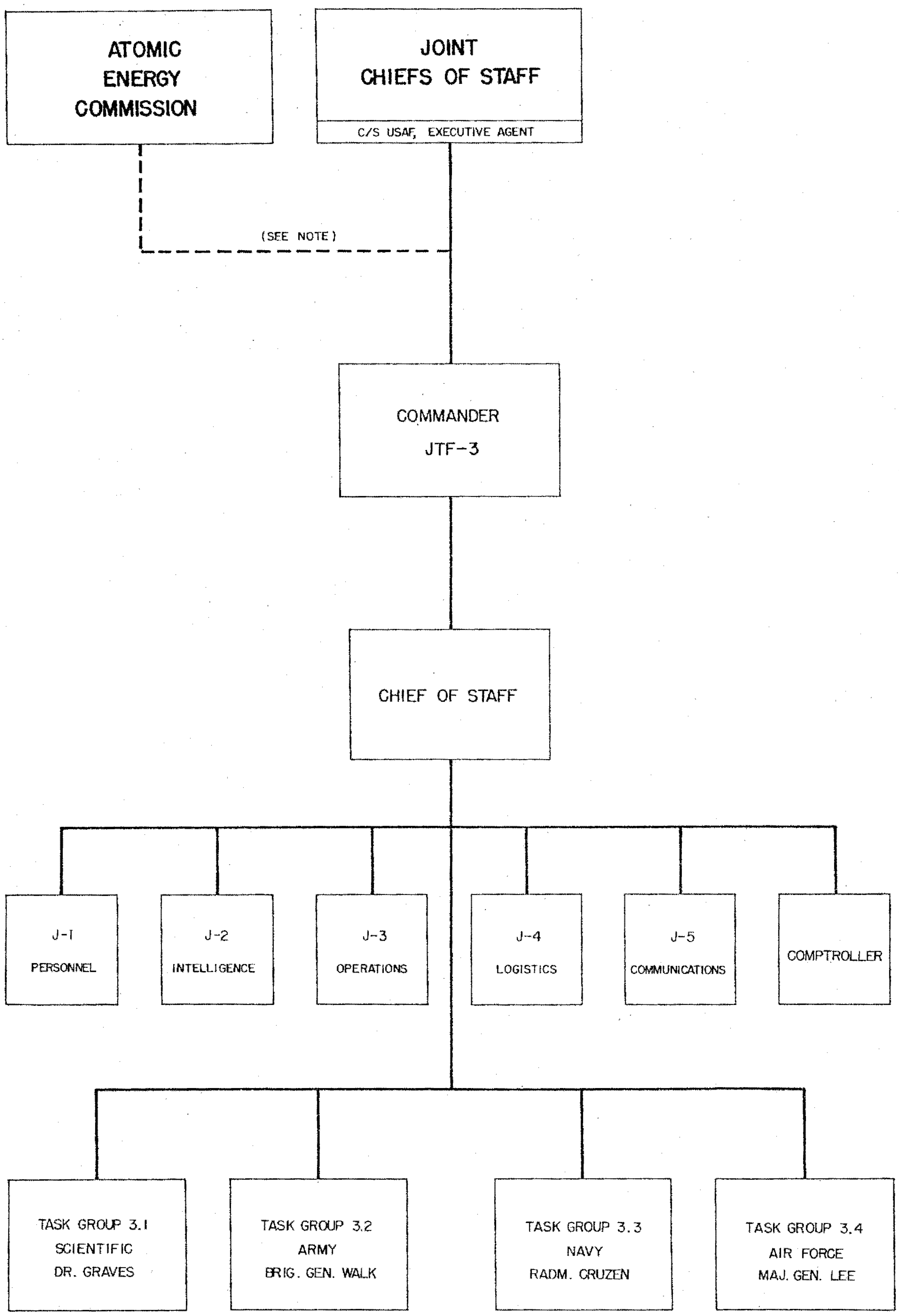
8. FILM FOGGING STUDIES

a. The last project of this program was a survey of the effects of film fogging as a function of nuclear radiation dosage. It was undertaken at the request of the Strategic Air Command. The main experimental work was performed on "GEORGE" shot. The film was Air Force types "N" and "L" and it was exposed to radiation under simulated operational conditions. Loaded A-5A magazines were placed at four similar stations in the Strategic Air Command RB-29 and the two (2) WB-29 manned samplers. Two magazines were placed in each of the AEC drones, one in the bomb bay and one in the radio compartment. Ten (10) magazines were placed on the ground in the vicinity of the explosion, with each film type represented at five locations.

b. Early information on the film that has been developed indicates that the film density (fogging) increases with the dosage, that in the lower dosage level the readability of the film is good, and that "L" type film is more dense than "N" type film for an equal dosage. However, "N" type film shows more mottling. Also, it appears that there is more random fogging on film carried in bomb bay and unpressurized or unsealed compartments, probably due to particulate contamination. The dosage range was from about 0.5r to greater than 100r. The final GREENHOUSE report will cover not only the complete results of the experiment, but will also correlate them with the results of other film fogging studies made by Los Alamos Laboratory on other shots.

SECRET

ORGANIZATION JOINT TASK FORCE THREE



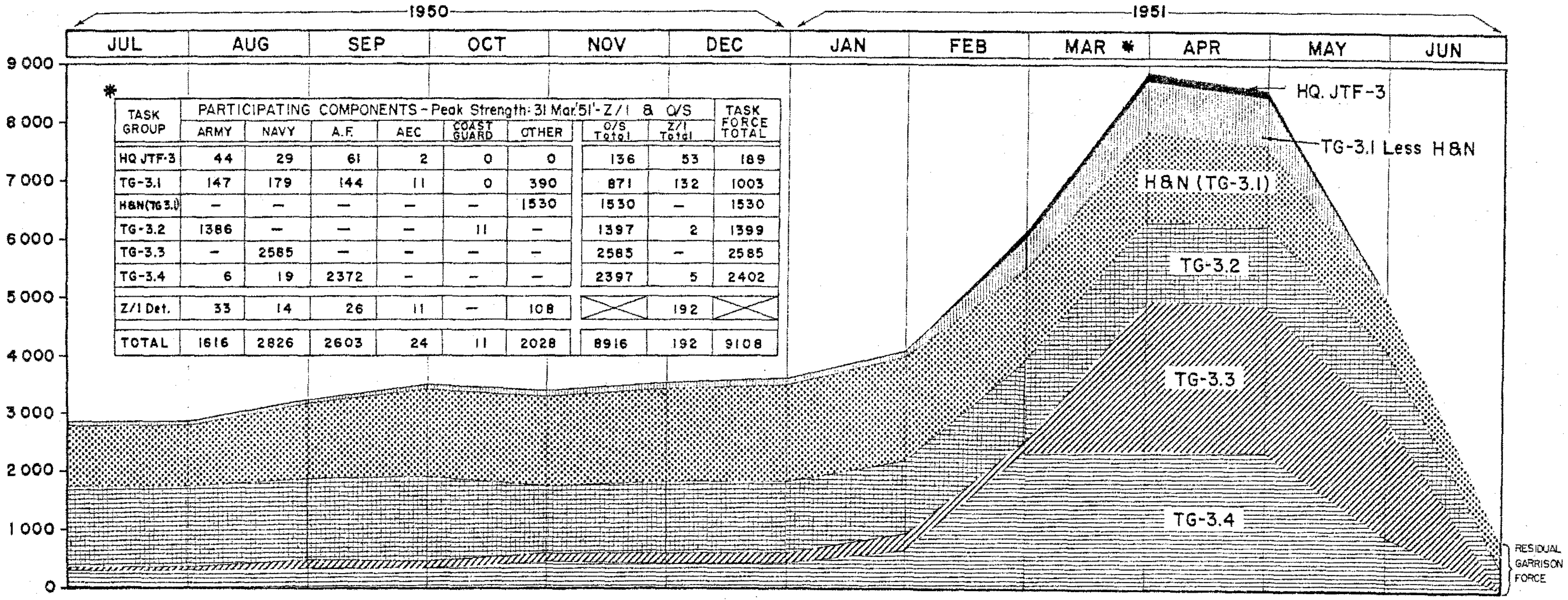
NOTE:
CJTF-3 DESIGNATED AS AEC REPRESENTATIVE AND ASSUMED RESPONSIBILITY FOR CONDUCT OF TESTS AT ENIWETOK, PERIOD 1 FEBRUARY 1951 -- 11 JUNE 1951

SECRET

APPENDIX "H"

JOINT TASK FORCE THREE

OVERSEAS PHASING BY TASK GROUPS



*

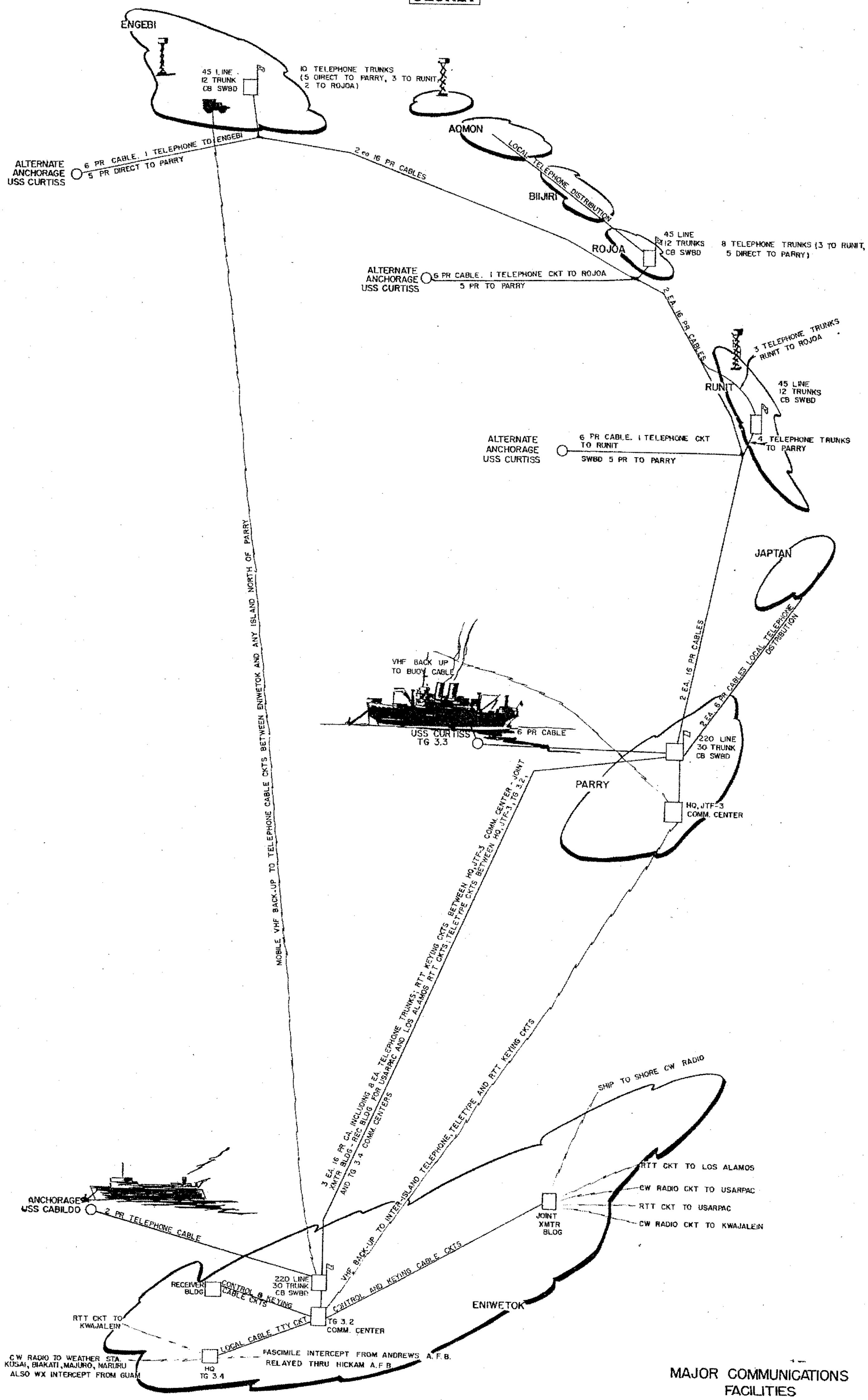
TASK GROUP	PARTICIPATING COMPONENTS - Peak Strength: 31 Mar.'51 - Z/I & O/S								TASK FORCE TOTAL
	ARMY	NAVY	A.F.	AEC	COAST GUARD	OTHER	O/S Total	Z/I Total	
HQ JTF-3	44	29	61	2	0	0	136	53	189
TG-3.1	147	179	144	11	0	390	871	132	1003
H&N (TG 3.1)	—	—	—	—	—	1530	1530	—	1530
TG-3.2	1386	—	—	—	11	—	1397	2	1399
TG-3.3	—	2585	—	—	—	—	2585	—	2585
TG-3.4	6	19	2372	—	—	—	2397	5	2402
Z/I Det.	33	14	26	11	—	108		192	
TOTAL	1616	2826	2603	24	11	2028	8916	192	9108

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
HQ-JTF-3	0	0	0	0	0	0	0	126	136	129	17	0
TG-3.1 Less H&N	36	36	56	94	97	99	99	521	871	817	67	2
H&N (TG-3.1)	1050	1305	1508	1556	1590	1676	1810	1591	1530	1390	864	452
TG-3.2	1396	1392	1434	1157	1227	1230	1257	1398	1397	1385	1171	** 389
TG-3.3	58	143	119	146	172	176	285	188	2585	2521	2053	0
TG-3.4	304	326	326	431	408	417	637	2339	2397	2339	915	0
TOTAL	2844	3202	3443	3384	3494	3598	4088	6163	8916	8581	5087	843

** INCLUDES ATTACHED USN DETACHMENT OF 1 OFF. 20 EM AND A USAF DETACHMENT OF 13 OFF. 117 AM.

APPENDIX "I"

SECRET



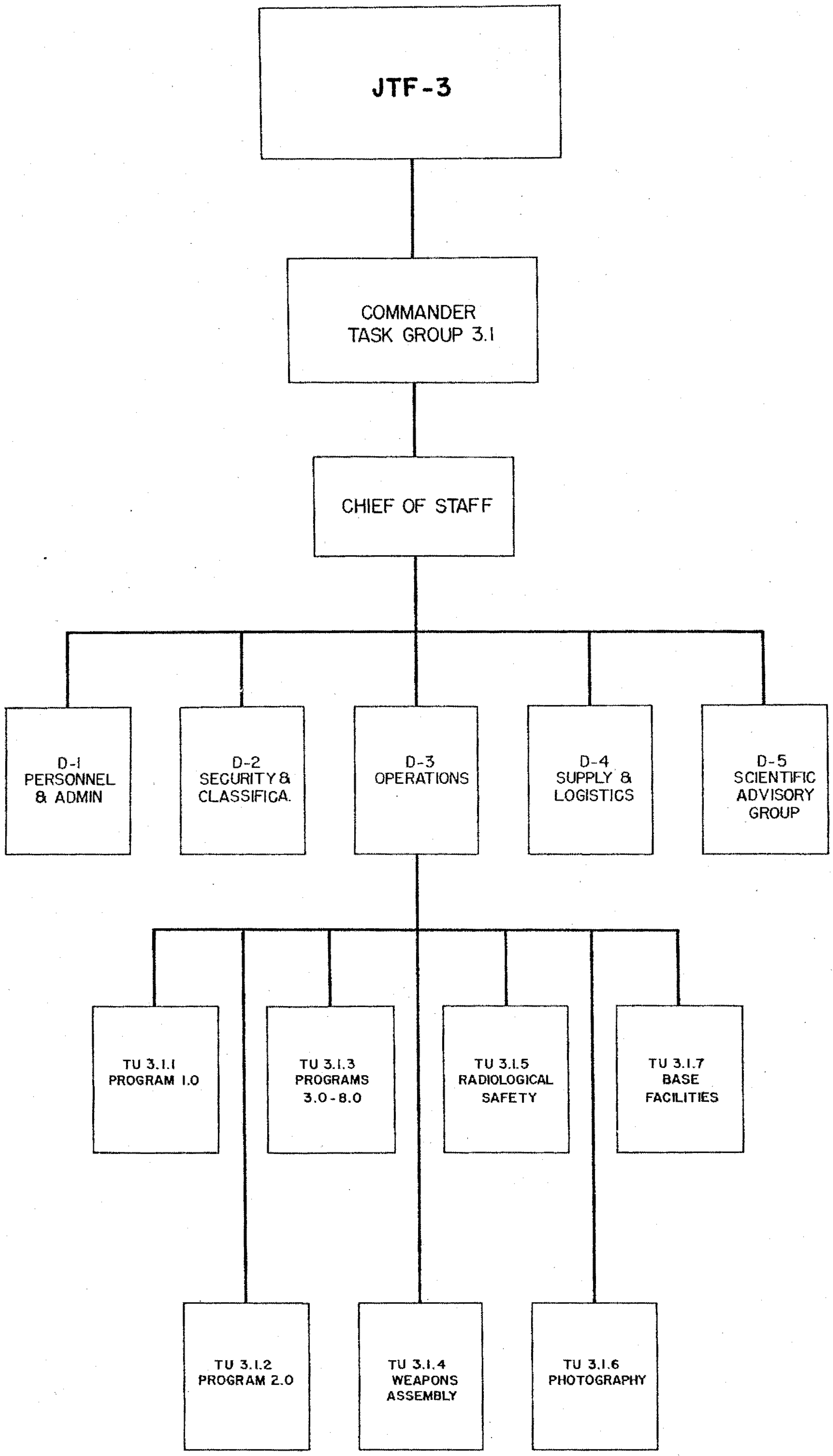
MAJOR COMMUNICATIONS
FACILITIES

JOINT TASK FORCE THREE

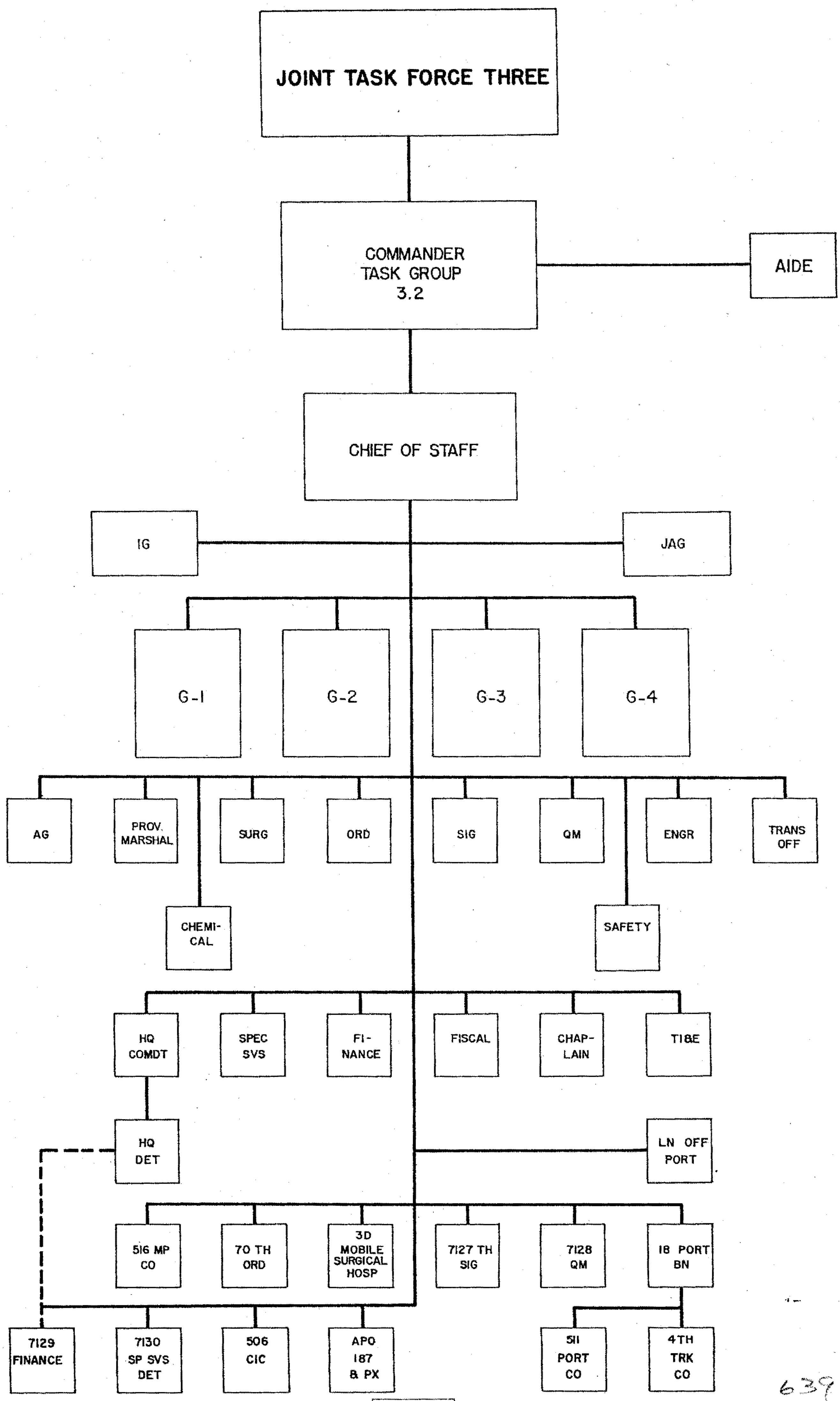
SECRET

APPENDIX "J"

ORGANIZATION TASK GROUP 3.1



ORGANIZATION TASK GROUP 3.2

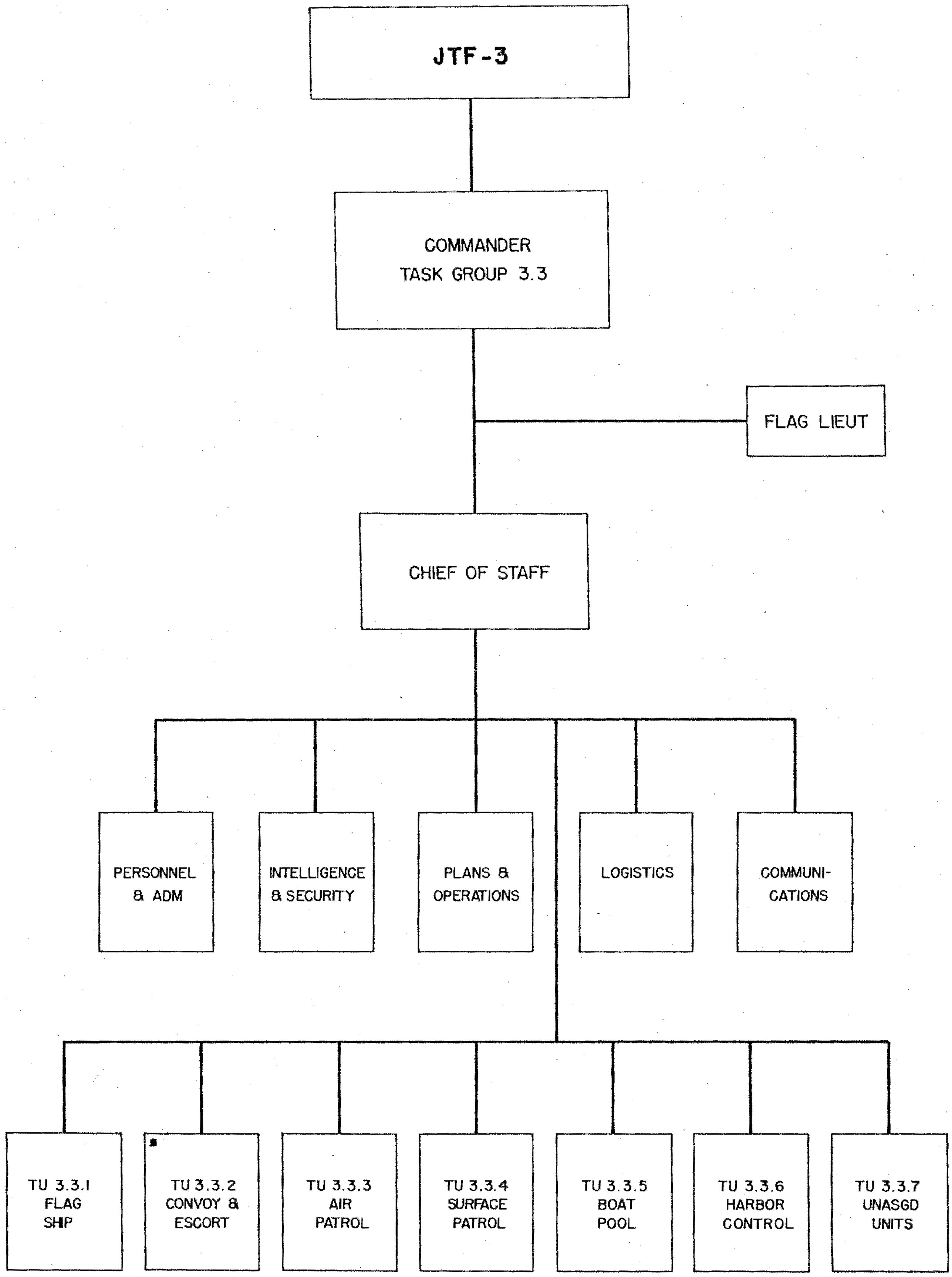


639

APPENDIX "L"

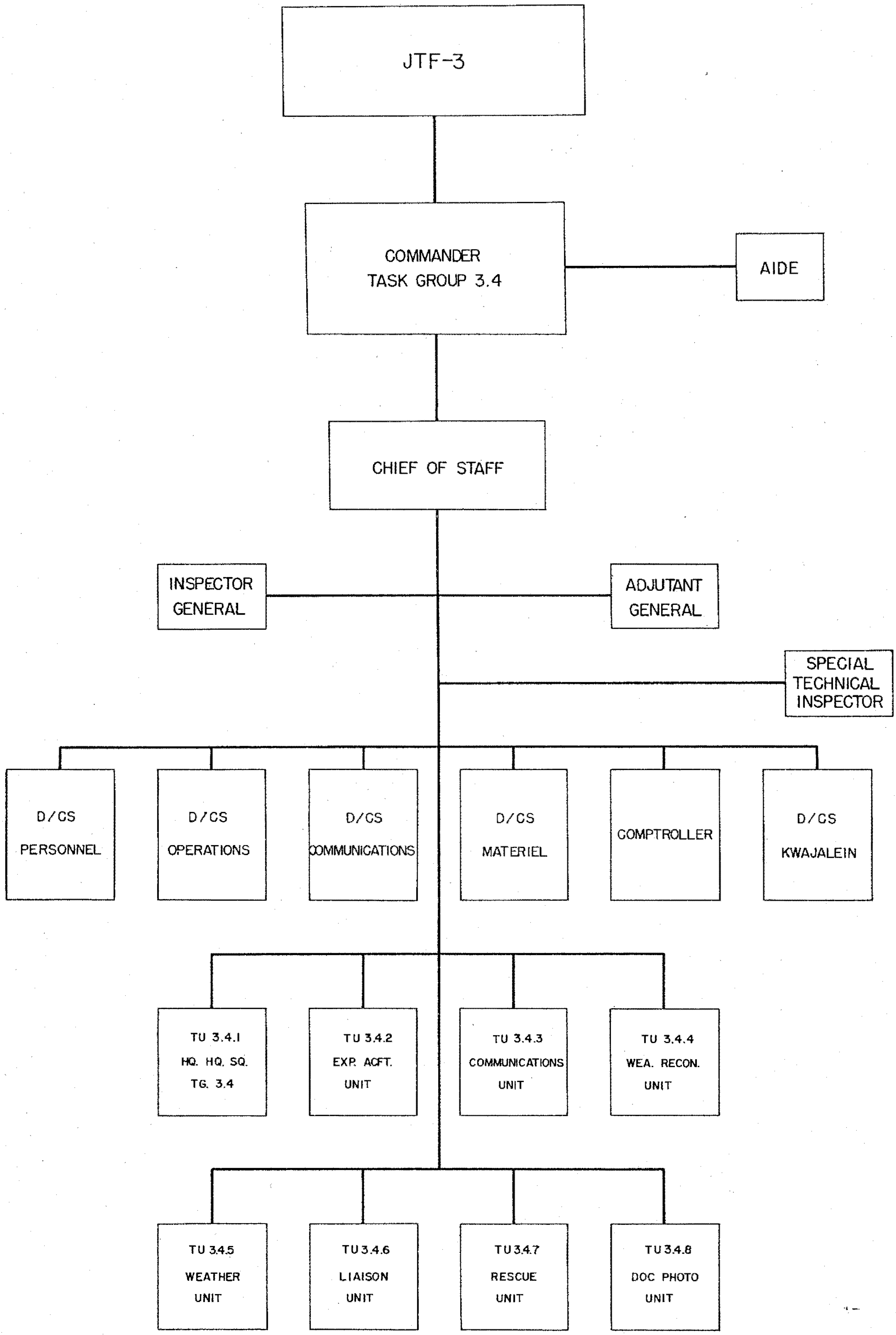
SECRET

ORGANIZATION TASK GROUP 3.3



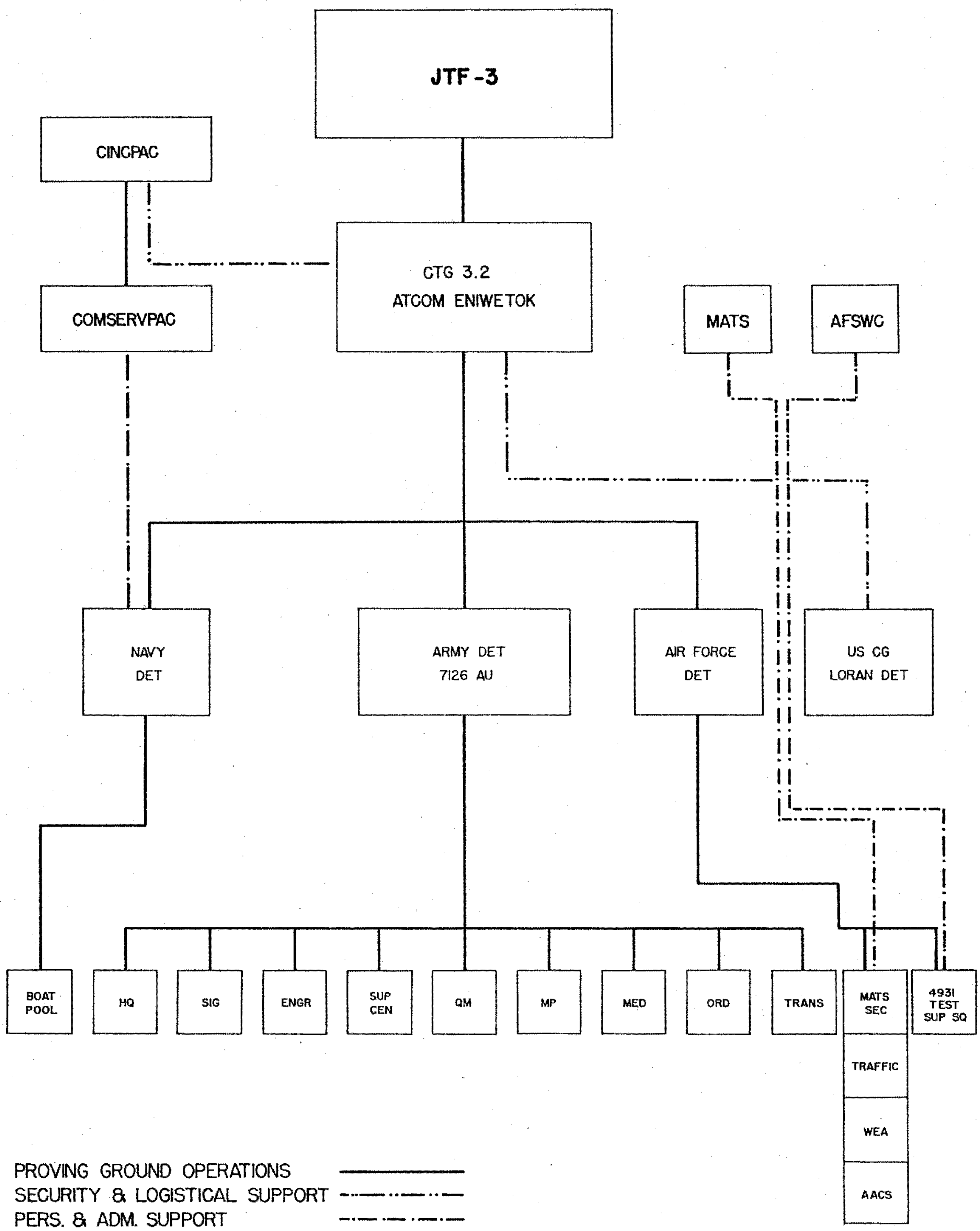
* OPERATIONAL ONLY DURING MOVEMENT TO AND FROM ENIWETOK

ORGANIZATION TASK GROUP 3.4



SECRET

GARRISON FORCE ORGANIZATIONAL CHART



PROVING GROUND OPERATIONS
SECURITY & LOGISTICAL SUPPORT
PERS. & ADM. SUPPORT

642

SECRET

APPENDIX "O"

APPENDIX "P"

RADIOLOGICAL SAFETY

1. GENERAL

a. Radiological Safety (RadSafe) of all military and civilian personnel is a command responsibility. Therefore, the RadSafe organization for GREENHOUSE consisted of units of trained personnel and suitable radiac equipment in each of the task groups. In this way the RadSafe units of individual task groups could cope with their problems as self contained units, utilizing training methods peculiar to their service requirements. The RadSafe unit (Task Unit 3.1.5) of the Scientific Task Group (Task Group 3.1) was established to be the primary technical servicing agency to the task force in general. For maximum benefit in training, this unit was composed of representatives from the Army, Navy, Marine Corps, Air Force, U.S. Public Health Service, Los Alamos Scientific Laboratory, and a representative from the University of Iowa. As such, this unit provided all ground monitoring services associated with experimental projects, laboratory services, exposure records, monitoring of sample removal and packaging and protective clothing.

b. The radiological safety phase of Operation GREENHOUSE had three main objectives. First, it insured that task force personnel would not be exposed to dangerous amounts of radiation. Second, it served as a large scale training exercise in routine radiological operations, Third, it provided a means for evaluating all available types of radiological instruments under field conditions. All three of these objectives were met successfully and several new concepts of the functions of RadSafe in the field have emerged.

c. It was learned during this operation that presently established personne dosages are unrealistically low for field application to personnel occasionally exposed to radiation and that many of the available radiological survey meters are too sensitive for routine field use. Individual dosages which were permitted on the operation are only 0.1 roentgen per day, or 0.7 roentgen per week. These dosages have been established on the basis of long term exposure for workers in constant contact with radioactive radiation. It is felt that they are far too low for personnel such as military and civil defense who are only occasionally exposed to radiation. Many surveymeters presently available have scales in the low milli-roentgen range. Readings obtained on these instruments tend to unduly alarm using personnel of limited experience, especially when the instruments go completely off scale at (for example) 50 milli-roentgen per hour. These instruments have a distinct place in the laboratory, or in the field prospecting, but they are unsatisfactory for field Rad-Safe work utilizing military personnel. This was clearly brought out on several occasions when experienced military monitors, trained in measuring radiation on a laboratory scale, became unduly alarmed at observing unexpected radiation intensities of a few tens of milli-roentgens after "DOG" and "ITEM" shots. Although the intensities observed were far below levels capable of producing a realistic health hazard, these monitors became alarmed because their instruments were so sensitive that they showed large readings. As a result of these reports at the time, some military echelons seemed to be alarmed. It is believed that further training in similar exercises for military personnel should be carried out with less sensitive instruments in order to obtain a more realistic approach to permissible dosages.

2. PRELIMINARY OPERATIONS

Prior to the first shot, personnel of all task groups were trained in the us of radiac (Radiation Detection Indication And Computation) equipment. RadSafe personnel assigned to the Scientific Task Group became acquainted with the personnel and with the special problems of the group.

3. "DOG SHOT"

a. At the Commander's weather briefings for the "DOG" shot rehearsal, and for "DOG" shot, a three dimensional device was used to display the forecast of upper air winds over zero point. The winds were related to fall-out as a function of drift of all portions of the atomic cloud from ground to maximum height which the cloud was expected to reach. In addition to this use of the wind directions and velocities, an attempt was made to relate general atmospheric stability and precipitation probability to favorable or unfavorable fall-out considerations.

b. The presentation and discussion resulted in a forecast SURFACE RADEX (Radiological Exclusion area). This was disseminated by the Commander, Joint Task Force THREE to all the task groups and was valid for one (1) hour after detonation. If fall-out proceeded according to the forecast, the RADEX could then be cancelled at H plus 1 hour and normal operations would then be resumed. Usual RADSAFE precautions would be taken thereafter for lagoon traffic.

c. It was planned that actual clearance to enter islands of the Atoll would be the result of a detailed, but rapid, island survey by low flying aircraft. Rad-Safe clearances for individual uninhabited islands would be granted at about H plus 3 hours. All essential work on shot islands would go forward because seasoned Rad-Safe monitors were provided for all such essential working parties. These monitors were especially trained and, with their experience and professional qualifications, were capable of "on the spot" evaluation.

d. After "DOG" shot, landing was made on the shot island as planned although the landing dock had been partly demolished. Some radioactivity was reported at the dock at H plus 30 minutes. At H plus 50 minutes information was received at the JTF-3 Operations Control Center (OCC) that the quick aerial survey of atoll islands showed no significant contamination on any islands except the shot island. A message lifting the SURFACE RADEX for lagoon surface traffic was sent out at H plus 90 minutes (0810).

e. At about 0830M reports of radioactive fall-out on ships in the south end of the lagoon, and on JAPTAN and PARRY ISLANDS, started to arrive at the OCC from various sources through the RadSafe Center (Task Unit 3.1.5) on PARRY ISLAND. At 1100M reports were received that the background radiation intensity level was rising on ENIWETOK ISLAND.

f. Records from radiation intensity meters on PARRY ISLAND showed that two slight waves of fall-out affected PARRY ISLAND at about H plus $2\frac{1}{2}$ and H plus $4\frac{1}{2}$ hours. Peaks of radiation intensity of about 40 mr/hr indoors were reached at about H plus 3 and H plus 6 hours. Ships of Task Group 3.3 in the southern end of the lagoon were affected during the first fall-out wave (H plus $2\frac{1}{2}$ hours). Also, some ships noted intensities varying up to 20 to 30 mr/hr. This was due partly to the fall-out just mentioned and partly to radioactivity in the water down-wind from the zero point.

g. At 1100M, Commander, Task Unit 3.1.5 (Special Assistant for Radiological Safety to Commander, JTF-3) recommended that all boat traffic be stopped north of RUNIT except regularly scheduled trips of scientific personnel with monitors. In the interest of avoiding any unnecessary exposures of personnel, even to the low levels of radiation mentioned above, personnel were ordered indoors on PARRY, JAPTAN and ENIWETOK ISLANDS with only essential work being permitted. These controls were maintained until the morning of D plus 1 Day. On D plus 1 Day, RadSafe clearance was granted for all islands with a few exceptions. On D plus 2 Day, RadSafe clearance was granted for certain additional islands, and for airstrips on RUNIT and ANIYAANII ISLANDS.

h. Monitor control was established on the shot island on "DOG" day by Task Group 3.1. Task Group 3.4 accomplished scientific "urgent" tasks without incident and the decontamination problem for planes was minor in scope. Task Group 3.3 accomplished necessary decontamination of ships and boats expeditiously. Water sampling on other atolls within a 400 mile radius of ENIWETOK was performed by amphibious aircraft. No health hazards were noted in any of the water samples.

i. The "DOG" shot fall-out was not expected since it involved much larger particles than had been observed on other atomic explosions. A detailed study was made of particle size, time of arrival, and upper wind structure. This study showed that the particles were of sizes ranging from about 50 to 200 microns in diameter; that they arrived at times corresponding to their fall-out from altitudes of 25-35,000 feet assuming the validity of Stoke's law for falling spheres; and the upper wind field was such as to permit the observed fall-out. This study showed that conditions leading to such a fall-out could be readily anticipated in the future. As a result, detailed plotting of resultant upper winds was made an integral part of RadSafe forecasting techniques.

j. A meeting of RadSafe and scientific personnel of the task force was held 13 April to discuss the fall-out which occurred on inhabited islands after "DOG" shot. It was the consensus of the meeting that:

(1) The fall-out did not constitute a health hazard.

(2) The particles which fell out were relatively large - 50 to 200 microns - and consisted of both coral sand grains and metallic globules.

(3) The radioactive portion of each particle was a very small particle, either attached to the outer surface of the coral grains, or included within the metallic globules.

(4) Explaining and forecasting fall-out of particles of the size observed was practicable using upper wind resultant plots.

4. "EASY SHOT"

a. Between "DOG" and "EASY" shots additional training of personnel of all task groups and calibration of equipment continued, utilizing lessons learned from "DOG" shot.

b. The lessons learned from "DOG" shot with regard to hitherto undiscovered fall-out data for a tower detonation were used in the evaluations of RadSafe factors for the "EASY" shot forecasts to the Commander.

c. A form of resultant wind plot for all levels up to the tropopause had been used for briefings at the Commander's conference for the "DOG" shot. For the "EASY" shot much greater attention was given to this resultant wind plot, since it was evident that fall-out of relatively large particles must be considered. Particular emphasis was placed on possible fall-out from the 30,000-45,000 foot levels, where much debris was evidently concentrated. An enlarged plot of resultant wind plot on an illuminated transparent Combat Information Center plotting board was used for briefing, and proved highly successful.

d. As a result of a favorable upper wind trend from H minus 30 hours until H minus 6 hours briefing, and a minimum shower probability, although the wind velocities decreased appreciably, a favorable fall-out forecast was made at the H minus 6 hours Commander's conference:

(1) The very heavily radioactive lower portion of the bomb cloud stem (0-15,000 feet) with debris, induced radioactive material, and unfissioned material was forecast to fall in a SURFACE RADEX with a DRIFT CONE extending from 200° to 260° true, with a radial distance of 20 miles. Fall-out of significance as a health hazard was expected to occur only on uninhabited islands west of zero point.

(2) Using fall-out data from "DOG" shot and resultant wind plots for significant levels from 30,000 to 45,000 feet, particles from 60 to 150 microns in diameter, with fall-out times of H plus 1.5 to 3.0 hours, were forecast to be deposited out to about 4 to 5 miles to the southeast. With a generous six (6) mile radius for diffusion and dispersion, it was stated that very minor fall-out might occur as far south as PARRY ISLAND. The atomic cloud mushroom was forecast to reach the tropopause level and to move easterly.

(3) Fall-out was essentially as forecast, although no detectable amounts reached inhabited islands - PIIRAAI ISLAND (7 miles away) was the farthest southeast that detectable fall-out occurred. The mushroom did reach the tropopause and moved generally easterly. Restoration of normal operations, other than scheduled project trips, was purposely delayed on "EASY" shot for about six (6) hours rather than the one hour period used on "DOG" shot. Other RadSafe phases were normal.

e. RadSafe operational data was available in satisfactory quantity and quality at the OCC, suitable for immediate use as required. This utilized experience from "DOG" shot, during which corresponding time, such data were not readily available at the OCC.

5. "GEORGE SHOT"

a. The expected yield of the "GEORGE" shot was so great that extremely favorable fall-out conditions were required by CJTF-3 in order to avoid any possibility of mass evacuation of personnel from the atoll. Because of this requirement, RadSafe planning criteria for favorable fall-out patterns were set up well in advance of "GEORGE" day. Favorable fall-out patterns were designated as (1) MOST FAVORABLE, (2) FAVORABLE and (3) CONDITIONALLY FAVORABLE. These were integrated with the resultant upper wind plots in the same way that was done on "EASY" shot. From experience it was found that the trend of the upper wind plots was of greater importance for firm operational decisions than actual forecasts of specific winds at specific levels.

b. As a result of the technique of observing trends of the resultant winds, it appeared at H minus 30 hours (the time for critical decision by the Commander) that of the three criteria for favorable fall-out, the MOST FAVORABLE pattern would be valid, and evacuation of personnel from the atoll ceased to be an important planning consideration. This favorable trend persisted longer than usual because of a typhoon (JOAN) which hovered about 150 miles northwest of ENIWETOK ATOLL, moving very slowly north-northwest. The immediate result of this distrubance was a prolonged northeastward movement of all air above the zero point.

c. Heavy fall-out was predicted to be in a fifty mile sector bearing 015°-085° true from zero point. Delayed fall-out (i.e., 1.5 - 4.0) hours after H hour was predicted to occur within the same bearings at radial distance of 30 to 120 miles The mushroom was forecast to reach great heights (i.e., above 50,000 feet) and was forecast to move southeast.

d. As had been forecast, practically no fall-out occurred on any of the atoll islands. Some contamination on adjacent islands can be attributed to direct blast of particular matter. With practically no fall-out, normal operations were resumed at H plus 3 hours. Exclusion areas after the shot were limited to islands close to zero point, plus some islands with residual contamination from "DOG" and "EASY" shots.

e. RadSafe phases, in general, were normal. Some contaminated water, up to one mile from the lagoon side of the atoll, was found near zero point islands of the EBERIRU GROUP but this did not hamper post-shot operations.

6. "ITEM SHOT"

a. Again, experience from other detonations of Operation GREENHOUSE was utilized in operational planning of RadSafe factors. A favorable upper wind pattern began to deteriorate at "ITEM" minus 2 days. The wind pattern at the H minus 30 hours Commander's briefing indicated FAVORABLE RadSafe factors with a trend towards CONDITIONALLY FAVORABLE. At the H minus 18 hours briefing a continued deterioration of the wind pattern was forecast and it was decided to move up the scheduled shot time as far as possible, from 0930M to one-half hour before sunrise. By the H minus 6 hour Commander's briefing the FAVORABLE trend appeared to be one which would be sustained. This took into account the considerations that unfavorable northerly wind components above 20,000 feet would remain very light for at least three to six hours after shot time. All heavy fall-out (significant as a health hazard) was forecast to be in a downwind cone of 220° to 280° true, with radial distance up to 40 miles. Heaviest concentration at upper levels was forecast to fall-out southwest from zero point.

b. Primary fall-out occurred essentially according to this pattern. However, ENIWETOK ISLAND received some delayed fall-out above expectation for two reasons: (1) light, variable wind conditions above 20,000 feet gave a larger spread to the predicted areas of fall-out southwest of zero and, (2) already changing wind pattern aloft began to change more rapidily at H plus 3 hours to a more normal "trade wind flow".

c. Fall-out on ships of Task Group 3.3 in the southern part of the lagoon and on ENIWETOK ISLAND was generall in two waves. The first one, with sustained intensity up to 40 mr/hr, occurred at H plus 4 hours. The second wave, with sustained intensities up to 100 mr/hr occurred at H plus 10 hours on the extreme southerly portion of the atoll.

d. By 1730M, sufficient cloud tracking by aircraft had been done to enable a snap picture of boundaries to be defined for estimating probable fall-out duratio[n]. For distances up to 100 miles south and north of the atoll, planes made no contact with the atomic cloud at 10,000 foot levels. However, upwind (i.e., to east and east-southeast) of the atoll, planes made contact at 10,000 and 25,000 foot levels at 1500M while a plane at 1900M, 120 miles east of the atoll, did not make contact.

e. On the basis of the observed winds in the lower 9000 feet, a forecast was made by the RadSafe Officer of JTF-3 to Task Unit 3.1.5 (RadSafe Center) that th[e] H plus 10 hours wave of fall-out should commence decreasing at 2000M or about H plus 14 hours.

f. At no time did these levels, however, reach significant proportions as a health hazard from the standpoint of permissible exposure levels or from particle size (inhalation) hazard.

g. At H plus 4 hours, lagoon traffic restriction was lifted and by H plus 7 hours, unrestricted traffic between inhabited islands and islands on the eastern side of the atoll was authorized.

h. The delayed fall-out at H plus 10 hours was due to rapid changes in the upper wind directions, commencing at H plus 3 hours. The changes were from a variable wind condition at shot time above 20,000 feet to a normal trade wind pattern

i. By "ITEM" plus 1 day, radioactivity on contaminated islands southwest and west of zero point had decayed by a factor of 10. Unrestricted reentry was permitted to islands on the eastern half of the atoll except ENGEBI, EBERIRU, and RUNIT.

APPENDIX "Q"

METEOROLOGY

1. GENERAL

a. In accordance with plan, the weather central on ENIWETOK ISLAND had completed the transition from a class CR Air Weather Service Station to a completely operational weather central by 1 February 1951. Both Air Force and Navy personnel were assigned to this central.

b. Establishment of the outlying stations at MAJURO, BIKATI, NAURU, and KUSAIE was delayed ten days beyond the original target date because certain important technical equipment components failed to arrive at PEARL HARBOR on schedule. LST 859 finally departed PEARL HARBOR on 20 January 1951 with all critical items and personnel aboard. All outlying stations were fully operational on 22 February 1951. No difficulty was experienced throughout Operation GREENHOUSE at any of the stations, beyond the usual and expected minor equipment and personnel failures, all of which were remedied in a very short time.

c. Information obtained by the four stations, plus KWAJALEIN and ENIWETOK, was of a type never before available on such a large scale in the tropics. Recent developments in the electronics field had produced automatic tracking equipment capable of tracking balloons with attached radio transmitters to high levels with excellent reliability.

d. The performance of the Task Unit 3.4.4 (57th Strategic Reconnaissance Squadron - Weather) was outstanding in all respects. The flexibility of the squadron in meeting ever-changing requirements was notable, and permitted forecasting quality beyond reasonable expectations. Information on the position and intensity of both typhoons GEORGIA and JOAN was furnished by the task unit at times when such information was vital to the success of Operation GREENHOUSE.

e. The anti-submarine patrol squadron (VP 931) also made a valuable contribution to the success of the weather program. Employing a concise reporting code devised for Operation GREENHOUSE, their effort permitted a closely detailed description of the weather within a radius of 150 miles of ENIWETOK, an important consideration in the tropics, where weather is extremely random in nature, and where accurate forecasting is impossible without a mass of detailed information.

f. In all, 526 personnel were concerned full time with the obtaining and analysis of weather information, and in direct support of this. These included the Task Force Staff Weather Officer and his deputy, 402 personnel assigned to the Weather Reconnaissance Squadron (Task Unit 3.4.4) and 122 personnel assigned to the Fixed Weather Unit (Task Unit 3.4.5). This figure does not include personnel of the anti-submarine squadron whose weather reporting duties were of collateral nature, nor weather personnel associated with Project 4.5 whose duties were primarily research.

g. The Weather Central was able to cope effectively with the huge mass of raw data coming in at all times, translate the data into usable form, and meet all requirements of the command without delay or confusion. New methods of tropical analysis were employed with some success.

h. One disappointing feature of the operation was the failure to establish a reliable and satisfactory radio facsimile link between the ENIWETOK Central and Andrews Air Force Base, Maryland. Although the necessary requirement had been established through proper channels, and agreement reached that the facsimile link for transmission of special charts would be fully operational by 1 January 1951, the service was never satisfactory and made little contribution to the operation until about 20 April 1951. The charts actually received, however, were very useful.

i. Similarly, obligations assumed by the Navy at YAP, TRUK, and PONAPE were not completely fulfilled. The Chief of Naval Operations had directed that special upper wind equipment be installed at these locations, personnel augmented, and special reports be made available for Operation GREENHOUSE. Various difficulties were experienced with equipment due to non-delivery of critical items and apparently poor condition of that which did arrive. While their surface reports were of considerable value, the lack of reliable upper wind data to high levels was a handicap.

j. The primary mission of the weather program was to furnish weather information and forecasts necessary for the accomplishment of the tests and the completion of related experimented programs. This mission was successfully accomplished.

2. MAJOR EVENTS

The following is a chronological, generally non-technical, summary of major events concerning the weather program in GREENHOUSE. All times and dates are MIKE (180° east longitude), except those specifically indicated as ZEBRA.

a. TYPHOON GEORGIA

(1) First indications of a suspicious development in the equatorial Pacific were noted on 16 and 17 March 1951. This unusual development consisted of a well developed deep current with extremely strong south winds, to an altitude of 55,000 feet over KUSAIE.

GOERGIA apparently developed as a cyclonic eddy on the left side of this deep current and was first reported westnorthwest of PONAPE on 18 March 1951 by an aircraft on a routine weather reconnaissance mission duty from GUAM. From the area near PONAPE, GEORGIA moved almost due east, gradually increasing in intensity and passing about 30 miles south of KWAJALEIN during the evening of 20 March 1951, disrupting all operations in that area because of extremely heavy rains.

(2) In-flight reconnaissance reports established definitely that GEORGIA changed from a tropical disturbance to a typhoon some time between midnight of 20 March 1951, and the afternoon of 21 March 1951. By 2000 hours on 21 March 1951, evidence of stagnation and curvature to the north was apparent, and at the 1200Z Commanders' weather briefing, 22 March 1951, the potential threat to the ENIWETOK AREA offered by complete re-curvature was pointed out. At this time a special weather watch was established in headquarters, and arrangements for rapid communications with the Weather Central on ENIWETOK were completed. The last report on GEORGIA which can be accepted as a valid typhoon report was made 0630Z, 23 March 1951. At that time GEORGIA was in the vicinity of 11° north and 171° east, approximately 450 miles east of ENIWETOK ATOLL. After analysis of the evening reconnaissance summary that day, definite advice was issued from Headquarters, Joint Task Force THREE that GEORGIA was weakening.

(3) The next scheduled reconnaissance flight aborted and there were no useful reports available for almost 14 hours. In an effort to amplify information, Commander, Task Group 3.3 was requested to send out anti-submarine planes from KWAJALEIN in an effort to make a positive or negative report on the existence of an "EYE". All reports were negative.

(4) At 0135Z, 24 March 1951, a center of moderate low pressure was located by reconnaissance aircraft 240 miles eastsoutheast of ENIWETOK and it was definitely established that GEORGIA was no longer a typhoon. Special weather watches were secured in the early evening of 24 March 1951.

(5) The last evidence of the existence of GEORGIA was noticed the next day when a squall area, tracked by surface radar, passed just south of ENIWETOK moving rapidily westward. Weather at ENIWETOK was very poor during the day with overcast cloud cover, scattered squalls, and a 30 knot gusty wind from the east.

(6) The total effect of GEORGIA upon Operation GREENHOUSE was a one day postponement of DOG shot necessary because of the heavy rainfall and the disruption of normal routine while preparing for possible emergency.

b. DOG SHOT:

(1) DOG-X-RAY rehearsal was completed without incident. Briefing charts were finalized, times of conferences established, and methods of presentation clarified. DOG-X-RAY weather forecasts were verified in all essentials.

(2) DOG shot weather briefings commenced at H minus 78 hours, and continued at 12 hour intervals, with the H minus 6 hours briefing terminating formal conferences. At the first briefing, a generalized forecast for "average trade wind conditions" was issued, and the operation order was issued.

(3) This forecast remained essentially unchanged. The appearance of a cirrus cloud overcast on the morning of 7 April 1951 caused some alarm, but when it was established by a special flight that the base of the overcast was above 30,000 feet, concern was eliminated.

(4) In the late after-noon of DOG minus 1 (7 April 1951), a special reconnaissance was flown to the east of ENIWETOK in a C-47 manned by Weather Central personnel. A broken layer of strato-cumulus cloud was encountered, and based upon experience and calculations it was forecast to arrive over ENIWETOK at about 0400, 8 April 1951, and to pass over by 0600.

(5) Weather conditions and the forecast were discussed in detail at H minus 6 hours briefing. All conditions were considered favorable, including upper winds for particle fall-out.

(6) The only departure from forecast weather conditions resulted from the untimely arrival of the strato-cumulus cloud deck from the east 10 minutes before shot time, causing some interference with

ground station photography. Drone operations were not appreciably affected by this cloud over.

(7) Observed upper winds were substantially as forecast. Radioactive fall-out over the southern part of the atoll, which commenced about two hours after detonation, was not expected or forecast. Extensive research based upon this experience gave a fairly positive conclusion that the particles were of sizes not previously observed, about which little or no knowledge existed. It is suspected that weapon yield was a large contributing factor. Obviously, the total number of weapons fired to date still does not permit a conclusion with absolute statistical validity. In any event, the research did produce a methodology by which particle fall-out can be predicted with far greater certainty than previously. (See Appendix "P" for details).

c. EASY SHOT:

(1) Experience with DOG shot had focused attention upon prompt fall-out. To avoid this fall-out over inhabited islands, resultant winds from the surface to 30 - 40,000 feet are rather critical. As shot day for EASY approached, an additional and positive requirement was established: that there be no precipitation over ENGEBI at shot time. These two requirements are almost mutually exclusive. With ENGEBI north of PARRY and ENIWETOK, ideal fall-out conditions require winds aloft with a southerly component, while best weather and minimum precipitation occurs with northerly winds aloft.

(2) In recognition of the random nature of tropical shower occurrence, an effort was made to provide some degree of flexibility in the shot schedule. Arrangements were made to provide a short postponement of shot time, with the order for postponement to be issued as late as 15 minutes before scheduled time of detonation.

(3) Orders to provide special weather information of the type desired were issued. A weather reconnaissance aircraft was ordered to approach ENGEBI from a point 300 miles upwind of ENGEBI, arriving at a post 5 miles offshore at H minue 20 minutes, then to reverse course and leave the area. The anti-submarine destroyer patrolling off ENGEBI, was moved into a position 10 miles upwind, and instruc-

ted to report cloud and shower activity every 15 minutes, starting at H minus 75 minutes. ASW aircraft patrolling the area bearing north through southeast from ENGEBI were ordered to submit weather reports every 15 minutes. The Weather Central was ordered to increase the frequency of upper wind soundings. This effort marked what is perhaps the most intense effort in the history of meteorology for a single place and short time.

(4) As EASY day approached the weather briefing schedule was modified to permit more latitude and less physical strain on the command echelon. The first formal briefing was scheduled for H minus 30 hours, with information to be furnished prior to that time based upon availability of information and changes in the weather of interest to the command. It was soon evident that the new procedure had merit and flexibility.

(5) On EASY minus 3 days, a forecast for average trade wind weather was issued.

(6) On EASY minus 2 days, decreasing trade wind velocity and consequent minimum cloud and showers were forecast for shot day. This outlook continued unchanged.

(7) At the final briefing (H minus 6 hours), a forecast for minimum cloud, no showers, and an increasingly favorable upper wind situation was issued.

(8) The operation proceeded on schedule. The intense effort to provide special information was successful to an outstanding degree, and the forecast verified in every detail.

(9) Results of particle fall-out research were immediately apparent. Fall-out occurred precisely as forecast.

d. GEORGE SHOT:

(1) Because of the large expected weapon yield, radiological safety was established by the Commander as the most critical of all weather criteria, even to the extent of sacrificing portions of the drone program, elements of photographic coverage, and other important but not critical programs.

(2) As GEORGE day approached, weather over a large part of the Central

Pacific gradually deteriorated, due to the formation and growth of typhoon JOAN, which formed in the TRUK-PONAPE area, pursued an erratic course while growing gradually in strength, and finally passed 180-200 miles northwest of ENIWETOK on a northeasterly course.

(3) By H minus 30 hours, due to the approach of JOAN, local weather was very unfavorable because of cloud and rain. It was predicted however, that the weather would be satisfactory by H hour, and that the currently perfect upper winds would remain favorable until the afternoon of GEORGE Day, then would become unfavorable. (Typhoon JOAN, to the west and south, had induced south and southwest winds at all levels to 50,000 feet - a perfect fall-out pattern for a high-yield shot).

(4) The H minus 18 hours briefing was attended by personnel responsible for drone instrumentation who pointed out that recent and continuing heavy rain was producing difficulty in electronic equipment, and that the drone program would suffer if presently scheduled H hour was adhered to, because of difficulty in drying out equipment.

(5) The forecast for satisfactory weather and excellent upper winds was adhered to, and GEORGE Day was confirmed by the Commander, with H hour changed to 0930 to assist in the drying out of electronics equipment and to permit drone operations in daylight. Furthermore, the winds were forecast to be from the southwest and this introduced the additional operational difficulty of takeoffs 180° from the normal direction.

(6) Special weather briefings continued (2200 8 May and 0145 9 May). The forecast remained unchanged.

(7) Precipitation stopped at about 1800, 8 May, and a gradual improvement in the weather began. Winds aloft persisted strong from the southwest.

(8) By 0800, 9 May, large breaks began to appear in the lower and middle clouds. At 0900, the immediate ENIWETOK area was covered with about 5/10 cloud with a large hole approaching the shot island. At 0930 the large break in the clouds was centered over-

the shot island, and GEORGE was detonated under perfect conditions of wind and weather.

e. ITEM SHOT:

(1) Normal weather requirements were established for ITEM Shot since the yield was not expected to be excessive and because no special instrumentation problems were anticipated.

(2) At informal weather briefings preceding ITEM Day, normal trade wind weather was forecast.

(3) At the first formal briefing at H minus 30 hours, continued trade wind weather was forecast with the upper wind pattern tending to become less favorable.

(4) At the H minus 18 hours briefing, the weather outlook continued favorable but the upper wind pattern was forecast to be only conditionally favorable for H hour. It was recommended that H hour be moved up as much as possible, and the Commander decided to detonate the weapon at one half hour before sunrise.

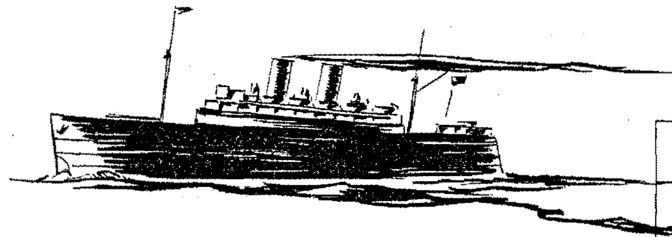
(5) At the H minus 6 hours briefing, the previous forecast was confirmed and plans for detonation at one-half hour before sunrise continued.

(6) Weather conditions at H hour were extremely favorable with no rain, and very little cloudiness. Light fall-out occurred over the southern part of the ENIWETOK ATOLL because of the upper wind structure. The decision to advance H hour was undoubtedly very fortunate as a later H hour would have produced considerably more fall-out over inhabited islands.

LOGISTICAL SUPPORT - OPERATION GREENHOUSE ~~SECRET~~

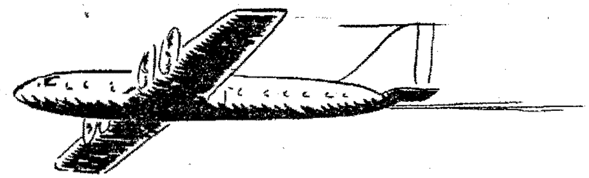
WATER

ENIWETOK	SAN FRANCISCO
WESTBOUND	EASTBOUND
222,226 M/TONS	51,266 M/TONS
6,558 PASSENGERS	7,017 PASSENGERS



AIR

ENIWETOK	SAN FRANCISCO
WESTBOUND	EASTBOUND
1208.0 TONS	642.2 TONS
6,440 PASSENGERS	6,631 PASSENGERS



		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
WATER M/TONS	EAST	—	—	—	—	641	18	220	252	763	1140	—	1659	815	1047	1036	6587	9822	24072	3194
	WEST	*11823	4789	16911	13626	7874	11879	5887	11843	9651	15751	14522	16754	18209	28406	13214	4967	14987	922	291
	TOTAL	11823	4789	16911	13626	8515	11897	6107	12095	10414	16891	14522	18413	19024	29453	14250	11554	24729	24994	3485
AIR TONS	EAST	25.5	17.0	31.0	14.0	20.0	20.9	24.2	25.6	26.7	40.2	44.1	39.0	36.7	53.1	49.3	153.1	339.0	238.4	181.2
	WEST	26.8	28.0	57.6	47.0	63.0	70.1	67.5	61.5	64.9	79.2	123.7	101.1	206.1	191.6	220.4	191.7	153.1	96.6	73.7
	TOTAL	52.3	45.0	88.6	61.0	83.0	91.0	91.7	87.1	91.6	119.4	167.8	140.1	242.8	244.7	269.7	344.8	492.1	335.0	254.9

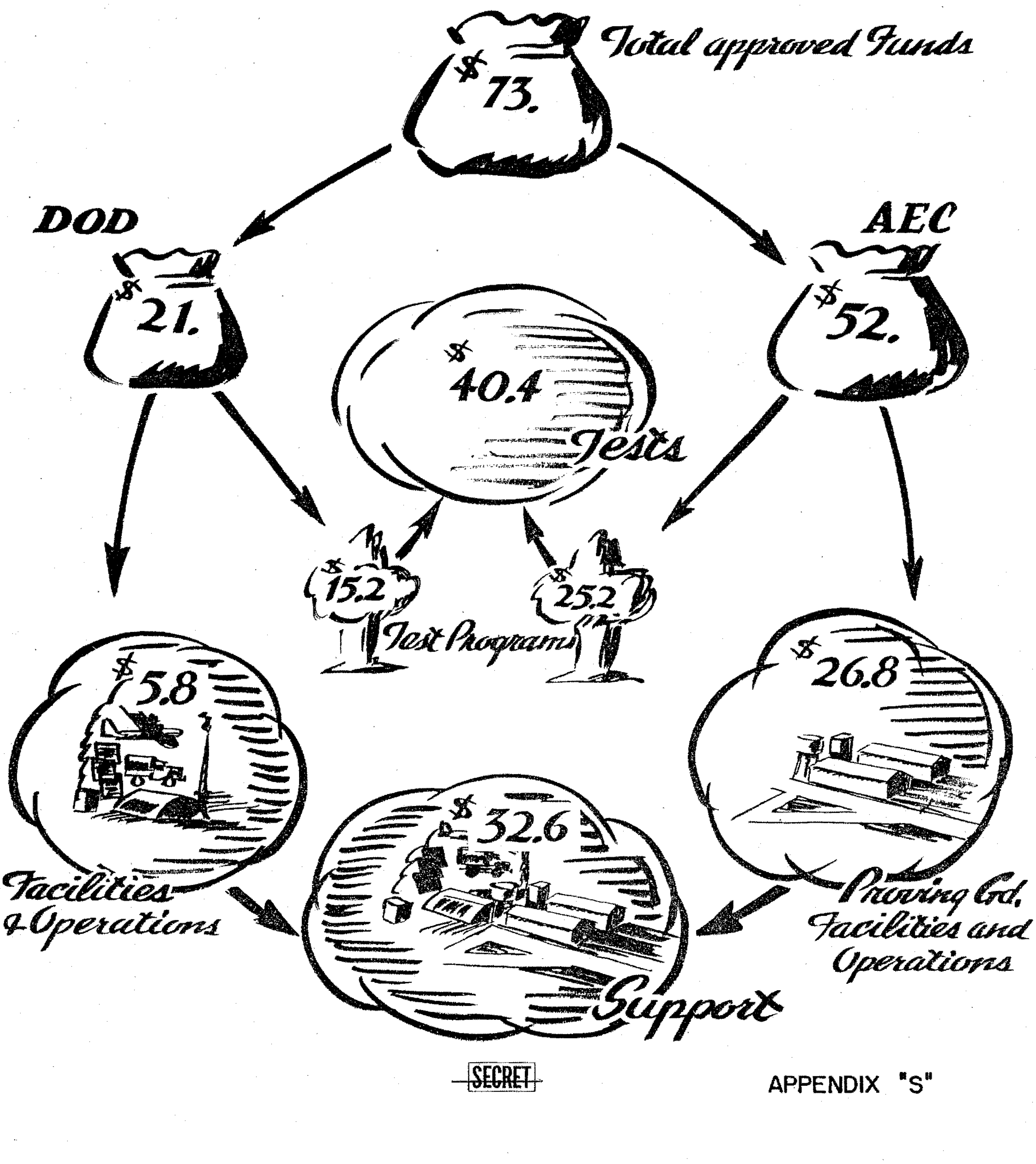
* CUMULATIVE FIGURE FOR MONTHS OF JULY 1949 THRU JANUARY 1950.

~~SECRET~~

APPENDIX "R"

SECRET

"Greenhouse" Funding Program (in millions)



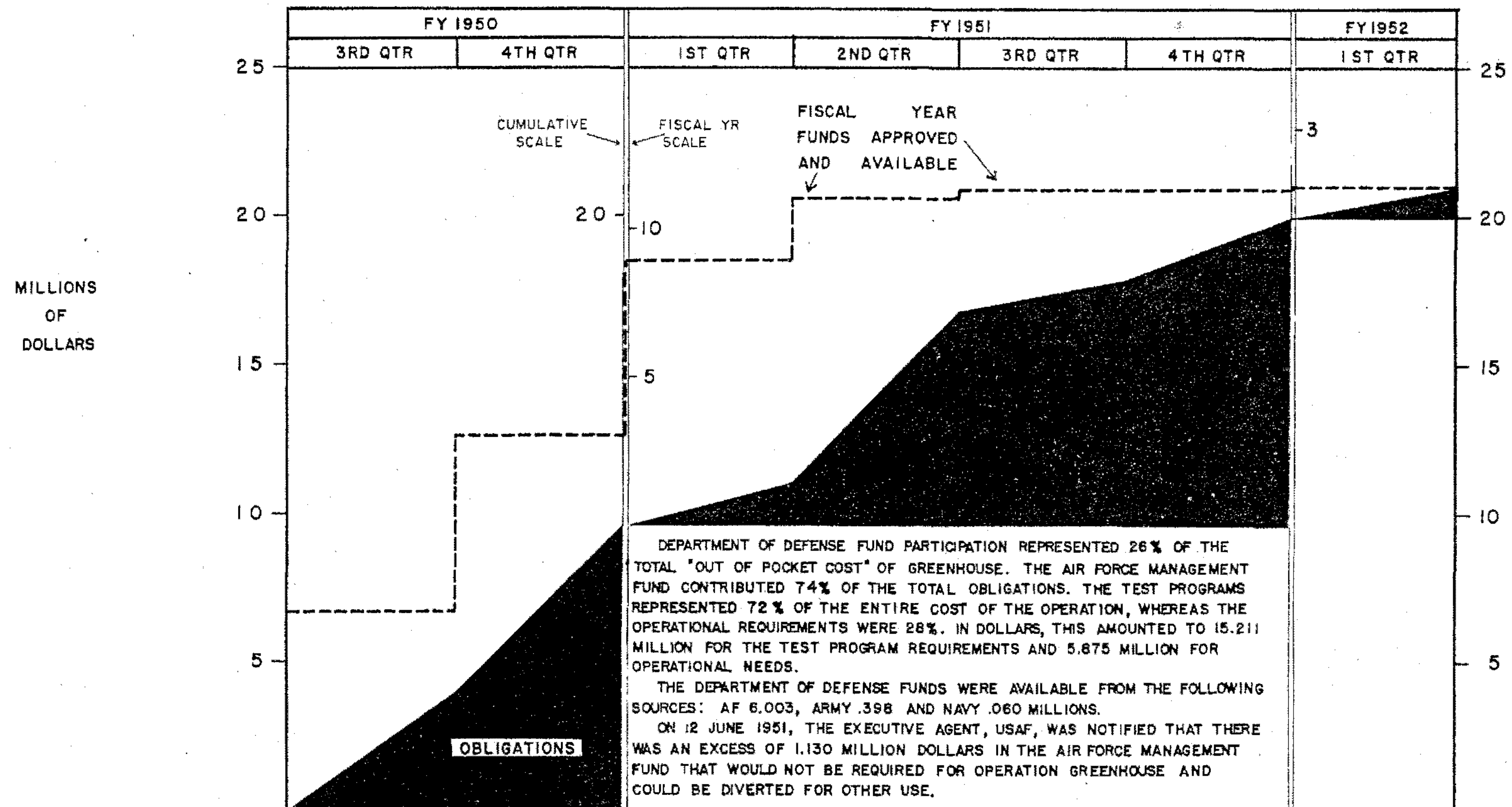
SECRET

APPENDIX "S"

660

SECRET

"GREENHOUSE" FUNDS PROGRAM, FYS '50, '51 & '52
DOD



DEPARTMENT OF DEFENSE FUND PARTICIPATION REPRESENTED 26% OF THE TOTAL "OUT OF POCKET COST" OF GREENHOUSE. THE AIR FORCE MANAGEMENT FUND CONTRIBUTED 74% OF THE TOTAL OBLIGATIONS. THE TEST PROGRAMS REPRESENTED 72% OF THE ENTIRE COST OF THE OPERATION, WHEREAS THE OPERATIONAL REQUIREMENTS WERE 28%. IN DOLLARS, THIS AMOUNTED TO 15.211 MILLION FOR THE TEST PROGRAM REQUIREMENTS AND 5.875 MILLION FOR OPERATIONAL NEEDS.

THE DEPARTMENT OF DEFENSE FUNDS WERE AVAILABLE FROM THE FOLLOWING SOURCES: AF 6.003, ARMY .398 AND NAVY .060 MILLIONS.

ON 12 JUNE 1951, THE EXECUTIVE AGENT, USAF, WAS NOTIFIED THAT THERE WAS AN EXCESS OF 1.130 MILLION DOLLARS IN THE AIR FORCE MANAGEMENT FUND THAT WOULD NOT BE REQUIRED FOR OPERATION GREENHOUSE AND COULD BE DIVERTED FOR OTHER USE.

	FY 1950 3RD QTR	FY 1950 4TH QTR	FY 1951 1ST QTR	FY 1951 2ND QTR	FY 1951 3RD QTR	FY 1951 4TH QTR	FY 1952 1ST QTR
FUNDS APPROVED & AVAIL.	6705	12609	8950	11054	11319	11319	1031
AFMF	2273	8177	6652	9134	9399	9399	923
DEPT	4432	4432	2298	1920	1920	1920	108
OBLIGATIONS	3973	9619	1491	7274	8336	10436	1031

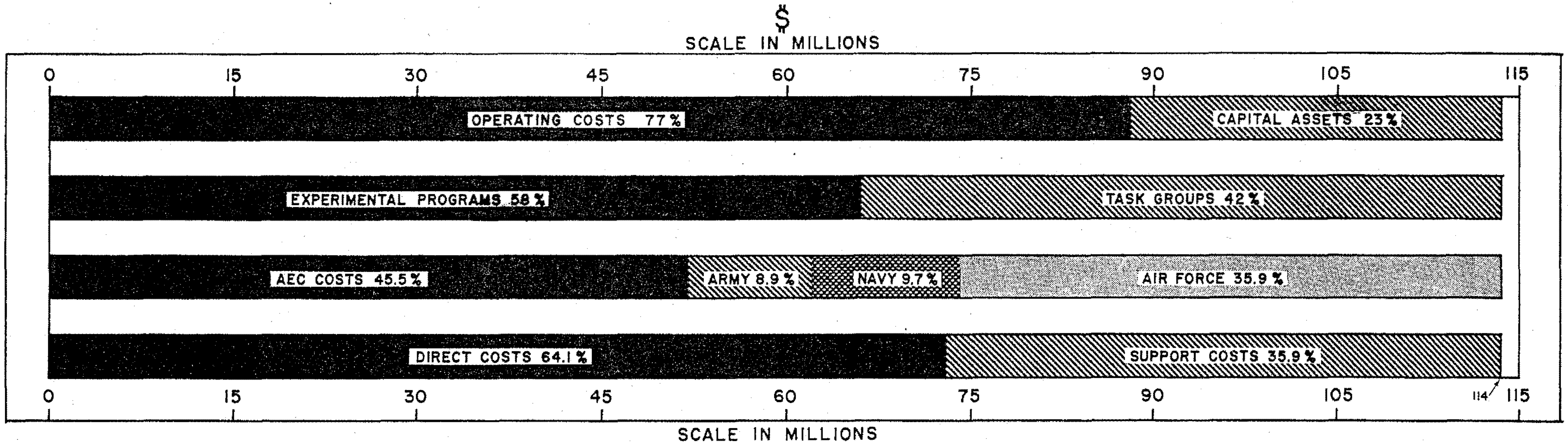
PROGRAM 7.0 (USAF RESPONSIBILITY) INCLUDED IN ABOVE.

SECRET

APPENDIX "T"

SECRET

COST-OPERATION GREENHOUSE



COMMENTS:

The final cost of operation GREENHOUSE totals $114 Million. $88 Million represents the operating costs and $26 Million, capital assets. These assets consist of a permanent proving ground plant of which $18 Million is for buildings and facilities and $8 Million, recoverable equipment. Of the total capital items of $58.5 Million furnished GREENHOUSE, $13.9 Million was consumed in operation-broken down by departments: AEC-$9.5 Million; Army-$2.0 Million; Navy-$.6 Million; Air Force-$1.8 Million and public building service. After the completion of the operation, $18.6 Million of capital items was returned to the participating agencies.

Significant cost areas of the GREENHOUSE operation are reflected as follows: Modification of aircraft by USAF-$15.6 Million; Transportation-$9.5 Million of which MATS contributed $5.1 Million and MSTS $4.1 Million; the remainder of $.3 Million furnished by commercial. Communications operating cost totaled $1.5 Million with an additional $10 Million of capital items which included fixed station radio teletype transmitting and receiving associated equipment-30%; tactical equipment, such as boat pool, MP radios and telephone back-up equipment-50%; power units-15% and maintenance equipment-5%.

The $88 Million of consumed effort in GREENHOUSE was contributed by departments: AEC-37%; Army-9%; Navy-11% and Air Force-43%.

DEPARTMENTAL

DEPARTMENT	OPERATING	CAPITAL	TOTAL	EXP. PROG. COST
AEC	38,812,394	9,255,134	52,067,528	25,357,663
ARMY	7,845,383	2,327,184	10,172,567	3,536,119
NAVY	9,774,371	2,182,819	11,957,190	7,865,806
AIR FORCE	37,870,853	21,193,220	40,010,073	29,319,042
TOTAL	88,303,001	25,904,357	114,207,358	66,078,630

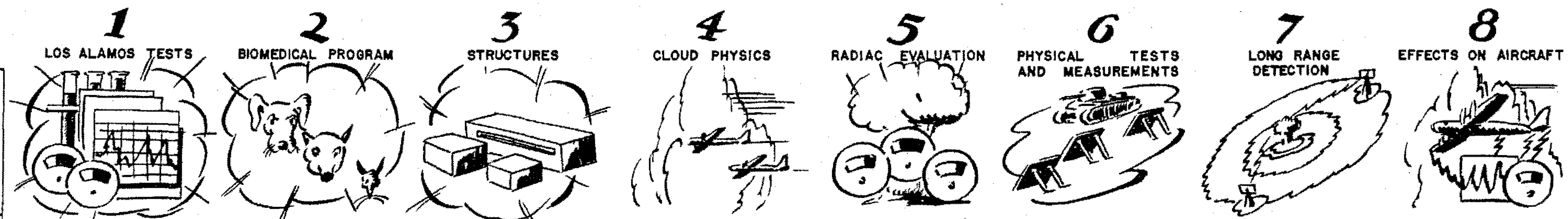
SECRET

APPENDIX "U"

662

SECRET

EXPERIMENTAL PROGRAM SUMMARY



PROGRAMS	1 LOS ALAMOS TESTS	2 BIOMEDICAL PROGRAM	3 STRUCTURES	4 CLOUD PHYSICS
PARTICIPATING AGENCY	LASL NRLH NBS EG&G BRL AFSWP NOL UCRL NRLK	BUMED US PUBLIC HEALTH LASL	OCE BU YDS & DOCKS AF SANDIA CORP EG&G LASL	AFCRL AMC LASL
PERSONNEL ENGAGED	MIL. 67 / CIV. 301 / TOT. 368	MIL. 86 / CIV. 25 / TOT. 111	MIL. 57 / CIV. 81 / TOT. 138	MIL. 12 / CIV. 14 / TOT. 26
SCOPE AND PURPOSE	STUDY OF WEAPON PERFORMANCE & PHENOMENOLOGY.	STUDY OF BIOMEDICAL EFFECTS OF RADIATION.	STUDY OF DESIGN CRITERIA & VULNERABILITY OF STRUCTURES IN DEFENSE & OFFENSE.	INVESTIGATION OF CHARACTERICS & BEHAVIOR OF ATOMIC CLOUDS & STUDY OF TROPICAL WEATHER.
SIGNIFICANT EQUIPMENT OR ANIMALS USED	WEAPONS, TIMING & CONTROL EQUIPMENT, MEASUREMENTS EQUIPMENT, STRUCTURES FOR HOUSING EQUIPMENT, & CRYOGENICS LABORATORY.	ANIMAL LABORATORY ON JAPTAN. DOGS, MICE, & PIGS USED IN EXPERIMENTS. TOTAL USED 200 PIGS, 180 DOGS, 13,790 MICE TOTAL RAISED 240 PIGS, 230 DOGS, 28,000 MICE	2 ARMY STRUCTURES 12 NAVY STRUCTURES 12 AIR FORCE STRUCTURES 1 PUBLIC BUILDINGS SERV. RECORDING INSTRUMENTS FOR COLLECTION OF DATA.	GROUND & AERIAL CLOUD PHOTOS. ANEMOMETERS (FOR MEASUREMENT OF NEGATIVE WIND). COLLECTION OF METEORLOGICAL DATA. AIRBORNE IONIZATION CHAMBERS.
FUNDS OBLIGATED * TOTAL: $ 40,475,202	$ 23,879,815	$ 1,947,650	$ 6,228,737	$ 313,000
ADJUSTED COST TOTAL: $ 51,273,858	23,879,815	3,320,106	5,226,745	962,642

PROGRAMS	5 RADIAC EVALUATION	6 PHYSICAL TESTS AND MEASUREMENTS	7 LONG RANGE DETECTION	8 EFFECTS ON AIRCRAFT
PARTICIPATING AGENCY	LASL OCSO NRDL BU AER AMC	ACC NRDL BRL OQMG LASL BU AER	AFOAT-I TRACER LAB USC & GS NOL ESL NEL NRL ARMOUR B & HS LASL	AMC LASL
PERSONNEL ENGAGED	MIL. 22 / CIV. 13 / TOT. 35	MIL. 26 / CIV. 56 / TOT. 82	MIL. 25 / CIV. 65 / TOT. 90	MIL. 28 / CIV. 22 / TOT. 50
SCOPE AND PURPOSE	EVALUATION OF RADIATION DETECTION EQUIPMENT.	STUDY OF PHYSICAL TESTS & MEASUREMENTS WHICH INCLUDED CLOUD PARTICLE DISTRIBUTION, THERMAL EFFECTS, CONTAMINATION & DECONTAMINATION PROCEDURES & OTHERS.	DETECTION & ANALYSIS OF ATOMIC EXPLOSIONS AT LONG RANGE USING RADIO-CHEMICAL, RADIOLOGICAL, SEISMIC & SONIC METHODS.	STUDY OF BLAST & GUST EFFECTS ON AIRCRAFT & INVESTIGATION OF DESIGN CRITERIA.
SIGNIFICANT EQUIPMENT OR ANIMALS USED	GROUND RADIAC EQUIPMENT, P2V & B-17 EQUIPPED WITH RADIAC EQUIPMENT.	AIRBORNE SNAP SAMPLERS, CONIFUGES, CASCADE IMPACTORS, ELECTROSTATIC PRECIPITATORS & THERMAL PRECIPITATORS, 10-40 TON TANKS, RECORDERS FOR COLLECTION OF DATA, SURVEY METERS, FILTER MATERIALS, PROTECTIVE CLOTHING, & COLLECTIVE PROTECTOR EQUIPMENT.	PLANES, FILTERS, RADIOLOGICAL, SEISMIC & SONIC EQUIPMENT.	B-17, T-33, B-50D & B-47 DRONE & MANNED AIRCRAFT, RECORDING INSTRUMENTS FOR COLLECTION DATA. STATIONERY AIRCRAFT SECTIONS, PANELS & MODELS. RADAR PHOTOGRAPHS.
FUNDS OBLIGATED * TOTAL: $ 40,475,202	$ 285,000	$ 1,373,000	$ 1,736,000	$ 4,712,000
ADJUSTED COST TOTAL: $ 51,273,858	457,931	770,072	1,966,309	14,692,238

LEGEND FOR AGENCIES:

UCRL – U OF C RADIATION LAB
NRL – NAVAL RESEARCH LAB
BRL – BALLISTICS RESEARCH LAB
BU AER – BUREAU OF AEROLOGY-USN
AMC – AIR MATERIAL COMMAND
NOL – NAVAL ORDNANCE LAB
AFCRL – AF CAMBRIDGE RESEARCH LAB
ACC – ARMY CHEMICAL CENTER

OCSO – OFFICE OF CHIEF SIGNAL OFFICER
ESL – EVANS SIGNAL LAB
BUMED – BUREAU OF MEDICINE – USN
OQMG – OFFICE OF QM GENERAL
USC & GS – US COAST & GEODETIC SURVEY
NEL – NAVAL ELECTRONICS LAB
ARMOUR – RESEARCH FOUNDATION
B & HS – BEERS & HEROY SURVEY

LASL – LOS ALAMOS SCIENTIFIC LABORATORY
AFOAT – AF OFFICE OF ATOMIC TESTS

* EXCESS OBLIGATIONS OVER REPORTED COSTS ARE REFLECTED IN COMMON TO PROGRAM COSTS ($ 14,804,772) OR IN CAPITAL ITEMS WHICH WERE CREDITED T OF GREENHOUSE OPERATIONS.

SECRET

APPENDIX "V"