THE HISTORY

OF

AIR FORCE PARTICIPATION IN THE ATOMIC ENERGY PROGRAM, 1943-1953

(In Five Volumes)

VOLUME II

FOUNDATIONS OF AN ATOMIC AIR FORCE AND OPERATION SANDSTONE, 1946-1948

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PART TWO

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CHAPTER XI

MODIFICATION PROGRAMS AND SPECIALIZED EQUIPMENT

Aircraft Modification Programs: SADDLETREE and GEM

By the end of World War II 46 aircraft, all B-29's, had been modified to carry the atomic bomb. At this time further modification was discontinued for a period of about one year. By November 1946, when the T&TLC attempted to locate the remaining aircraft, it was found that less than half remained in operational use, these being assigned to the 509th Bombardment Group at Roswell and Project W-47 at Kirtland. Eighteen of the remainder were in storage under the AMC, while four had been destroyed.[1]

Meanwhile, in July the Air Materiel Command had issued orders for the modification of 19 additional B-29's in order to supply bomb carriers for the build-up of the atomic striking force. This second series of modifications, described as was the first under the code name SILVERPLATE (Cancelled), was carried out at Sacramento Air Materiel Center during 1947 as Project DOM-515. Unlike the first modifications, which were hand made, the second series consisted of a standard installation which had been worked out in late 1946 by Major Robert L. Roark of the Aircraft Projects Section, AMC, who had also supervised the first series.[2]

In May 1947 the code name SILVERPLATE was discontinued (because of the broad and somewhat uncertain signification it had acquired and some question of its having been compromised) and replaced by SADDLETREE (Confidential) as a designation for the aircraft modifications only. It was apparently originally intended to limit this to the modifications on the remaining B-29's under Project DOM-515 and to employ new code words for the B-50's and B-36's. This was not, however, adhered to, and the designation was to be applied also to the modification of those aircraft as atomic bomb carriers.[3]

The most serious handicap in carrying through the SADDLETREE modifications on the second series of B-29's modified under Project DOM 515 was the Restricted Data classification placed on the bomb bays as a result of the Atomic Energy Act of 1946. Beginning in February 1947 the AAF began efforts through the MLC to persuade the AEC to remove this classification so that specially cleared personnel would not be required to work on them; however, the AEC ruled in May "that any aircraft modification which would allow a reasonably accurate estimate of size, weight, and shape of the bomb or which would reveal any important details of the fuzing and firing mechanics must continue to be Restricted Data as defined in the Atomic Energy Act of 1946." In July the AAF renewed its effort to secure an emendation of this ruling, contending that only the sway bracing and flight test box revealed Restricted Data. The former could be removed in two hours, while the latter was stored by the AEC itself. The AEC agreed to this by October 1947.[4]

This problem had an influence in stimulating the development by the AMC of a new rack, designed by Major Roark, which by the separation of eight bolts could be removed intact, together with much related equipment including hoists and a common junction box for pull out cables. Col. J. R. Sutherland explained this as follows:[5]

> This rack will utilize C-7 hoists of which we have two at present and will procure more and will raise the bomb to its proper location without the necessity of juggling equipment to make (CI) fall in line with its attachment point. The whole set-up looks very good, and we will rush it in hopes of trying it in the first couple of B-50's.

The bomb bay carrying system was further improved during the course of the year, and by early 1948 an X type frame had been developed which could be removed by extracting only four bolts. It weighed only 150 pounds exclusive of the hoists, which were separately removable. The British FG bomb release was also replaced by the new U-1 pneumatically operated release, which had been developed by Major Roark of the AMC. The C-7 hoist was to be replaced by the C-9, with irreversible gears, although these were not actually available in production quality until late in 1948. The new carrying system freed the aircraft from reliance on hydraulic pits and also made it possible to declassify the plane by the quick removal of the frame, popularly designated Roark's rack, and the flight test box.[6]

The first B-50's were scheduled for delivery beginning in September 1947, and at the direction of Headquarters, AAF, the AMC in June 1947 established Project DCM 565C for the modification of 36 of these. They were to be turned over to the 509th Bombardment Group, SAC, to replace the SILVERPLATE B-29's with which it was equipped. Because of delay in delivery of the B-50's the modification program had to be rescheduled to begin 1 February 1948, with the first modification to be completed in May and the last six in December.[7]

The SADDLETREE modification performed on the second series of B-29's under Project DCM 515 had become quite elaborate compared to the original SILVERPLATE modification. Estimated by Colonel Sutherland to require 3469 man hours per aircraft, it included installation of Curtiss electric reversible propellers, manifold fuel system, special wiring and equipment, special fire extinguisher, bomb bay equipment, additional crew position, LB kit, ring-out box, mechanical salvo system, and special hoist, as well as removal of all but the tail turret and rework of the tunnel. It was expected, however, that the modification of the B-50 would require a considerably smaller amount of time, since some of these modifications would have been incorporated during production. The above estimate as to man hours proved overly optimistic, the B-29's modified under DOM 515 at Sacramento Air Materiel Area actually requiring about 6,000 hours each.[8]

The program for modifying aircraft for atomic operations underwent a great expansion, both horizontal and vertical, during the early part of 1948 as the result of three somewhat inter-related developments. First, as the result of a series of threatening international incidents, the Joint Chiefs of Staff directed in JCS 1745/5, 21 January 1948, a rapid build-up of operational atomic capability. This had an intermediate goal of 225 atomic bomb carrying aircraft and 8 bomb assembly (CHICKENPOX) aircraft, to be attained by 1 January 1949. The directive also established goals for bomb commanders, weaponeers, and assembly teams.* Strongly emphasized by the Chief of Staff, USAF, the requirement passed to the AMC, where it became the basis for an extensive program of planning. The planes were intended to equip 6 groups of 30 aircraft each, plus 5 per group for attrition.

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* See Chapter X.

Two other considerations which were to strongly influence the modification program established were the needs for global operational capability and for extending the operational range of atomic bombers. General George S. Kenney, Commanding General of the SAC, was insisting strongly that all SAC bombers be able to operate anywhere in the world.* This would require modification of the aircraft for such environments as the arctic, desert, and tropics. The fact that the major potential enemy was the Soviet Union and the increasing attention being given to Alaska as an operational base emphasized the importance of the first of these regions, where operational capability would also be the most difficult and costly of attainment. Beginning in 1947, much attention was also given by both the SAC and AMC to the use of aerial refueling as a means of range extension. Although operation from forward bases was planned in the event of war, the possibility of losing these bases was believed to be real, or even a likelihood. The B-36 would be available beginning in 1948, with a designed range of 10,000 miles, but the early version was being very critically regarded by the SAC, which doubted that it would be fast enough to be successful as an operational bomber against post-war jet interceptors.[9]

In order to provide the 225 SADDLETREE modified bombers by 15 December 1948, the date established by Headquarters, USAF, to fall within the first JCS deadline of 1 January 1949, Headquarters directed AMC to establish the following projects as the basis for a new modification program:

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*The SAC directive contained this requirement. See Chapter VI.

Project	Quantity	Model
DOM 595C	80	B-29
DOM 565C	72	B-50A
DEL 1038	18	B-36B
DEL 1042	23	B-50B

Project DOM 565C represented a doubling of the 36 aircraft in the original project, while the others were new projects. All aircraft would be given the SADDLETREE modification. The 193 aircraft thus provided, added to the 32 already operational within the Strategic Air Command, would meet the JCS requirement for 1 January 1949 of 225 atomic carriers.[10]

During February and March the AMC was notified of additional requirements for the winterization and modification for air refueling of aircraft intended for atomic operations. This would include B-29's, B-50's, and F-80's. The B-36 remained in a doubtful category as far as large scale procurement was concerned. The B-36A, of which 23 were to be procured, would not carry the atomic bomb without major modification, since its four bomb bays were designed for bombs of 4,000 pounds or smaller. It also contained various defects which made it of doubtful operational utility.* Procurement of the B-36B in quantity would depend on further evaluation, while it was already seen that the 18 to be modified under Project DEL 1038 could not be completed during 1948.

During March 1948, following a conference on the ninth among representatives of the AMC, SAC, and Headquarters, USAF, the modification program began to take on a much more definite outline. Head-

* See Chapter XII.

quarters, USAF, at the urging of the SAC had directed that a winterization requirement be definitely established for all bombers and escort fighters in the program. The AMC estimated that this requirement alone would consume 11,500 manhours for the B-29, 7,500 for the B-50, and 1,250 for the F-80. The estimate for the SADDLETREE modification had also been increased to 10,000 for the B-29 and 5,000 for the B-50. The AMC stated that the total program, given it by Headquarters, USAF, would require 2,048,500 man hours to complete, as follows:

Project	Quantity	Model	M/H'rs per A/C	Total
DOM 1149A	48	F-80A	1,250	60,000
DOM 594C	15	B-29	11,500	172,500
DOM 595C	80	B-29	14,700	1,176,000
DOM 565C	72	B-50A	7,500	540,000
DOM 1961	10	C-97A	10,000	100,000

All the above aircraft except the C-97's were to be winterized. The C-97's were to be given the CHICKENPOX modification only. The B-50's and B-29's were to be given the SADDLETREE modification except for the 15 B-29's on DOM 594C, which already had received it and were to be obtained from the SAC.[11]

To permit carrying out such an extensive program without interference with other essential projects the AMC proposed that the winterization requirements be reduced and that most of the modification work be performed under contract by the manufacturers of the aircraft in question. Under the revised program only 18 of the 80 B-29's under DOM 595C would be winterized, the remainder being given SADDLETREE and global electronics modifications only. This would provide one group of B-29's, SADDLETREE modified and winterized down to minus 65 degrees Fahrenheit for Alaskan operation. The number of C-97's modified for CHICKENPOX support would be reduced from ten to seven, since only that number would be available during 1948. The AMC proposed that the F-80's be winterized by Lockheed and the B-50A's winterized and SADDLETREE modified by Boeing under contract. The C-97's would also be modified by Boeing, while the B-29's would be both winterized and SADDLETREE modified in AMC depots. The AMC requested that $7,037,000 be allocated for the program, which of course had not been provided for in Project 421 funds, and that it be assigned a 1-A priority.[12] These proposals were approved by Headquarters, USAF, on the same day. Shortly afterward the AMC assigned the program the unclassified code word GEM.

Almost immediately, however, the program underwent drastic changes, principally as the result of a Headquarters, USAF, directive that provision for air-to-air refueling be incorporated in some of the aircraft. Project DOM 598C was set up for the modification as tankers of 40 B-29's, these to be obtained from storage. Projects DOM 599C and DOM 501D were established for the modification as receivers of 36 B-29's and 36 B-50's, these being obtained respectively from the planes processed under Projects DOM 595C and 565C. Project DOM 594C, for the winterization of 15 B-29's from the 509th Bombardment Group, was also abolished, and the requirement for a full group of winterized planes met by increasing the requirement under DOM 595C from 21 to 35 aircraft. Aircraft to be modified as tankers (SUPERMAN) were to be altered as follows:

1. Stripped of all combat equipment (turrets, guns, fire control equipment, armor, etc.).
2. Self sealing fuel cells to be replaced by non-self sealing nylon cells.
3. Large single bomb bay tanks to be installed.
4. AN/APS-10 radar equipment to be installed.
5. Main tires to be replaced by B-50A tires.
6. Refueling equipment to be installed.

The receiving aircraft (RURALIST), all of which would have been previously given SADDLETREE modification and winterization, would be altered as follows:[13]

1. Stripped of armament except for tail guns.
2. Large single tank installed in aircraft bomb bay.
3. Refueling equipment installed.

As the result of other changes in the program directed by Headquarters, USAF, two new projects were added also. DEL 1038, the project previously established for SADDLETREE modification of 18 B-36B aircraft by 15 December was included in the GEM Program, with an added requirement for winterization. It was also decided to establish a separate new project, DOM 1964, for the CHICKENPOX modification of the six YC-97's which would be available during 1948, leaving DOM 1961 as a project to be accomplished later when the ten C-97A's included became available. The GEM Program, which was now for the first time officially established as a whole, was described as follows:[14]

Project	Aircraft	Quantity	Deadline	SADDLE-TREE	Global Elect.	Winter-ization	RURAL-IST	SUPER MAN
DOM 595C	B-29	80	15 Dec 48	X				
*DOM 599C	B-29	36	15 Dec 48	X		X	X	
DOM 598C	B-29	40	15 Dec 48		X			X
DOM 565C	B-50A	36	15 Dec 48	X	X			
DOM 501D	B-50A	36	15 Dec 48	X	X		X	
DEL 1042	B-50B	23	15 Dec 48	X	X		X	
DEL 1038	B-36B	18	15 Dec 48	X	X			
DOM 1149A	P-80A	48	15 Aug 48			X		
DOM 1964	YC-97	6	15 Dec 48	CHICKEN-POX				

*Drew planes from DOM 595C

Winterization was added to the requirements for the C-97 projects shortly afterward.

Objectives for the GEM Program beyond the immediate goals established in the above projects were transmitted to the AMC from Headquarters, USAF, on 13 May. These may be summarized as follows:[15]

1. All B-50's and B-36B's to be SADDLETREE modified on the production line.

2. All B-50's to be prepared for RURALIST modification on the production line to permit ready modification when needed.

3. All B-36's to be SUPERMAN modified on a retrofit basis after they were released by the SAC from the transition program.

4. All SADDLETREE aircraft except B-36's not RURALIZED on the production line to be RURALIZED by retrofit as soon as possible.

5. Four squadrons of B-29's to be SUPERMANNED as soon as possible.

6. All F-13's, B-29 ECM, and B-29 weather aircraft in units or scheduled for units to be RURALIST modified. (about 165 aircraft)

7. All FB-50's on schedule for the SAC to be RURALIST and SADDLETREE modified on the production line. (14 aircraft projected) Superman B-29's to be provided to support these (4 aircraft projected).

8. All reconnaissance B-50C types to be RURALIST modified in production (one group of 36 Unit Equipment aircraft planned).

9. All reconnaissance B-49's to be RURALIST modified in production (no firm numerical requirement).

10. Each of the three strategic reconnaissance groups to be provided with a peacetime strength of 16 tanker aircraft. (16 tankers to support three squadrons, totaling 36 unit equipment aircraft, of strategic reconnaissance).

The above program was further modified on 6 May to provide for global electronics on the 80 B-29's on Project DCM 595C, for Alaskan electronics on the 36 B'29's on Project DCM 599C, and for winterization of all aircraft in the program except the 80 B-29's on Project DCM 595C.[16] It may be noted that the distinction between Alaskan and global electronics lay in the provision by the former of special items of stand-by and rescue equipment considered particularly desirable for operations in the Far North.

Various changes and modifications in the program continued to be made during the summer of 1948, mainly consisting of additional requirements to be included. These took two forms, requirements deadlined to be fulfilled along with the original program by 15 December and requirements for which no deadline was set but presumably to be accomplished during 1949. One of the principal problems was presented by a special requirement that 68 B-29's be modified by 30 September 1948 so that the Strategic Air Command would achieve an early capability of 100 operational atomic carriers. This requirement, doubtless a reflection of the rapidly increasing international tension culminating in the Berlin Blockade, was personally pressed by General George S. Kenney, and approved at Headquarters, USAF, by Gen. Muir S. Fairchild, Vice Chief of Staff, and Lt. Gen. H. A. Craig, DCS/M, despite some objections originating in AFOAT and the AMC that the 1 January schedule might be jeopardized and quality of workmanship lowered.[17]

The AMC was directed to proceed with this emergency requirement early in July, utilizing funds already allocated for the over-all program. It was planned that 46 of the 68 aircraft would be secured by accelerating the modification of that number of the 80 B-29's on Project DOM 595C and to modify (SADDLETREE) an additional 22 B-29's drawn from Project SAC8SB-17. All modification work would be done by the Maintenance Division, AMC.[18] This accelerated phase of the program collapsed, however, when the SAC discovered that the 22 B-29's from SAC8SB-17 were early models deficient in range, that Curtiss electric propellers were not available for these craft, and that they were lacking in other features considered indispensable for long range atomic operations. The program was accordingly cancelled by Headquarters, USAF, on 4 September with the proviso that Project DOM 595C would proceed as quickly as practicable, but with the original deadline.[19]

Non-deadlined requirements, attached to the GEM Program, continued to accumulate during the summer of 1948, with no action being taken immediately because of the lack of funds budgeted for them during fiscal 1949. Referred to as the GEM Follow-On Program, by 11 August they included the following:

1. 15 B-50A aircraft from Project DOM 565C to be RURALIST modified;
2. 30 B-50B aircraft from Project DEL 1042 to be given SADDLETREE, RURALIST, winterization, and standard electronics modifications;
3. 14 RB-50B aircraft from Project SAC 8PB-12 to be given RURALIST, winterization, standard electronics, and photo reconnaissance modifications.
4. 84 TB-29 aircraft from Project SAC 8SB-18 to be given SUPERMAN modification;
5. 10 YC-97A aircraft from Project 1961 to be given CHICKENPOX and winterization modifications.

In addition it was believed that there would be a considerable further increase in the follow-on program.[20]

In the light of these increases it was obvious that the cost of the program would many times exceed the $7,037,000 originally estimated. By the end of July $39,276,600 had been made available for the GEM Program, this including $25,000,000 from Project 110 E FY 1948 Supplemental Funds and $14,276,600 from Project 421 FY 1949 Special Modifications Funds. However, the Air Materiel Command now reported that an over-commitment of $414,355 existed and that it would be necessary to close down vital parts of the program, including the Boeing-Wichita Plant, unless additional funds were forthcoming without delay. It also estimated that $3,743,000 would be necessary to complete the modifications scheduled for 15 December 1948, $30,000,000 to carry out the follow-on program outlined above, and $35,000,000 to complete the additional projects likely to be established. As an interim measure to meet this situation Headquarters, USAF, made $15,400,000 available from Project 421 FY 1949 funds.[21]

By October the estimated costs of the GEM Program had become firmer. The estimated costs of the phase with deadline date of 15 December had fallen to $35,529,045. The follow-on program was now divided into two phases--the first having a deadline date of 30 June 1949, with estimated costs of $37,019,251, and the second having a deadline date of 30 June 1950, with estimated costs of $27,692,766. Authorization having been given the AMC to utilize additional FY 400 series funds to complete the 15 December phase, the immediate problem was to secure funds for the second phase. To meet this need it was necessary for Secretary Symington to request release of part of the $150,000,000 included in the Air Force supplemental appropriation for fiscal 1948. After a detailed justification of the GEM Follow-On Phase to Secretary of Defense Forrestal, in early November the desired funds were released, and the follow-on part of the program became active.[22] The follow-on program which was released by AMC for planning purposes on 29 October, will be dealt with in Volume III.

Despite the concentrated effort put into and high priority placed on the first large-scale aircraft modification program since the end of the war, it proved impossible to meet the 15 December 1948 deadline on the first phase, or even to meet the JCS requirement for 225 atomic bomb carriers on 1 January 1949. During the summer it became obvious that the 15 December deadline on Project 1042 for the modification of 23 B-50A's could not be met because of a strike at Boeing Wichita. By October it was also clear that at least 18 of the B-50A's would not be completed by Boeing Seattle in time for modification by Boeing Wichita under Project 501D to meet the 15 December deadline. AMC also reported to Headquarters, USAF, that it would be impossible to substitute B-29's, SADDLETREE modified, by the stipulated date.[23] Although figures are not available for 15 December, a compilation of 31 December 1948 gave the following report on the status of the GEM Program:[24]

				In Work	Available	Delivered
DEL 1038	B-36B	18	SADDLETREE Stand. Elect. Winteriz.		5	13
DCM 595C	B-29	36	SADDLETREE Stand. Elect.	6		40
DCM 560C	RB-29	10	Ferret 2 Arct. Elect. Winteriz.			10
DCM 565C	B-50A	36	SADDLETREE, Wint. 21 RURALIST, Stand. Elect., 15 Arctic Elect.			36
DCM 598C	B-29	40	SUPERMAN 20 Arctic Elect. and Winteriz. 20 Stand. Elect.	19	2	19
DCM 1964 SAC 8SC-12D SAC 8SC-4D	YC-97	8	SADDLETREE SUPPORT Winterization			8

				In Work	Available	Delivered
DCM 501 D	B-50A	36	SADDLETREE, RURALIST, Stand. Elect., Winteriz.	19	11	6
DCM 599C	B-29	36	SADDLETREE, RURALIST, Arctic Elect., Winteriz.	35		
DCM 1149A	F-80A	48	Arctic. Elect. Winteriz.			48

It was expected at this time that the requirements for the first phase of GEM would not be finally satisfied until March.[25]

Project CHICKENPOX

Project CHICKENPOX,*first designated Project HATCHERY, was the second AAF project for the modification of an aircraft for specialized atomic use, the first being SILVERPLATE. It originated during the fall of 1945 as an effort to cope with the complex assembly operations required for the Mark III, Model 0, atomic bomb and permit the use of that weapon with greater operational flexibility. More specifically, it involved the modification of the fuselage of a large cargo plane, the C-97, then existing only in the X version, so that it would serve as a mobile assembly room for the bomb. This would eliminate the necessity for installing the elaborate assembly and testing equipment at a number of fixed bases. It might also incidentally provide a limited means of transport.

On the recommendation of Maj. Gen. Curtis E. LeMay, at the time serving as AAF member on the newly constituted Advisory Board to the Officer-in-Charge of the Atomic Bomb Project, the aircraft selected was the C-97, two of these being allocated in December 1945 from the production scheduled for mid-1946. Brig. Gen. Alden R. Crawford, Acting

*The word is classified Confidential.

AC/AS-4, directed the Air Technical Service Command to establish a project with a 1-C priority to carry out the modification. At the same time he suggested that the C-74 be evaulated as a possible substitute for the C-97, calling attention to its great pay load, better range, and larger interior dimensions.[26]

Steps were taken during December and January 1945-1946 by the Air Technical Service Command (which became the Air Materiel Command on 6 March) to get the project under way. It was assigned to the Aircraft Projects Section of the Engineering Division, and by 17 January 1946 four officers had been cleared to receive information through action of Headquarters, AAF, and Manhattan District. Efforts were then made through the AMC liaison officer at Albuquerque, Major Robert L. Roark, to establish a working connection with the Manhattan representative at Oxnard Field (later Sandia Base) charged with responsibility for the project--Mr. Roger S. Warner. Apparently those charged with the project in the Engineering Division hoped to proceed in the same manner as for the SILVERPLATE modifications--through supplying a C-97 to Manhattan for study and general design of the necessary changes, which would then be applied to the other aircraft by the ATSC.

Major Roark, who had engineered the SILVERPLATE modification, explained that this procedure was impracticable, since the project, from the standpoint of Manhattan, had hardly advanced beyond the conception stage. He went on to say:

> The object of the subject program is to provide an aircraft which can on short notice transport, assemble, maintain and make available for loading in bombing aircraft atomic bombs as required for some specific mission to be staged from a base which is totally

unprepared to handle atomic bombs. All previous thinking has been done on the basis of prepared bases having shops, assembly equipment, and special hardstands available. The transport, assembly, and general handling procedures have been developed to fit such a situation, and consequently do not readily lend themselves to airborne equipment which may require handling of smaller components in different sequences. This means that in using airborne equipment, the end result is known, but the procedures are not known and the equipment itself is not known.

Roark went on to propose that Manhattan be supplied with basic drawings and other data on both the C-97 and C-74, so that it could proceed to carry out preliminary design of airborne equipment and the general arrangement of the aircraft interior, after first eliminating one of the types. Manhattan would then prepare specifications, requirements, and other data sufficient to enable the ATSC to perform detail design and finally actual modification.

Apparently little further was done on the project, which was given the code name HATCHERY (Cancelled) and numerical designation MX-886, until early in the fall, since CROSSROADS was absorbing nearly all AAF personnel qualified in atomic matters along with most of the strength of Manhattan. A visit to Sandia in August 1946 by Maj. R. S. Williams of AMC elicited the information that Manhattan was still interested in the concept, and the original plan of flying an XC-97 (the sole survivor of three built) to Kirtland for examination and possible modification was returned to. This was done early in September, and by 11 October it was agreed that this aircraft would be fully modified as a mock-up. Meanwhile, the two YC-97's originally allocated for the project were now approaching completion, and the allocation was confirmed after conferences at Sandia and in AAF Headquarters. It was also agreed that Manhattan would tell the AMC what modifications and special equipment would be needed, after which that command would carry them out. This would be the responsibility of Col. John R. Sutherland, who had just completed an assignment as bomb commander at CROSSROADS and was now designated Engineering Division Coordinating Officer for Manhattan District. He was assisted at the AMC by Major Roark, while Col. William A. Hatcher and Col. Leo V. Harman provided liaison at Kirtland-Sandia.[28]

By late November 1946 the general nature of the modification was taking shape. It was planned to use a monorail trolley with integral hoist, which had been designed by the AMC, to load and unload the bomb, and consideration was dropped of using a dolly hauled up the ramp or C-5 hoists mounted on an auxiliary A-frame in the tail. It was also planned to reenforce the floor of the fuselage under the assembly jacks by using a grid of longitudinal floor beams mated to I-beams at the side which would distribute the load into the structure. It was agreed that the atomic bomb might be carried in the C-97 on short flights, although this would not be required in long-range operations. This would necessitate the installation of a cradle and tie-down fittings.[29]

At this time a second concept began to enter the picture with the support of Manhattan--the use of a portable building for bomb assembly in the forward area, with the C-97 reduced to the role of transport for the specialized equipment. Although it might be briefly used as an assembly room, the equipment would be readily removable for transfer to the portable assembly building. This system was later designated Phase B and the older one Phase A. Great difficulty was to be experienced in developing a suitable portable building of reasonable weight which could be erected in a short time, however, and this had the effect of keeping Phase A, the original CHICKENPOX project, under way.[30]

Planning continued during late 1946 and into 1947, but more concrete progress was hampered by delays in the allocation of funds and the clearance of AMC and Boeing personnel to participate in the project, and in January 1947 Colonel Sutherland reported to AAF Headquarters:[31]

> This project has come to a halt through lack of funds. The MED funds, long promised, have never been received and judging by the past experience in trying to get the funds, it will be a good while longer in coming. In the meantime, the Equipment and Armament Labs have ceased work on the project due to lack of funds and the budget cut. Expenditure Orders have been returned for deletion of outside expenditures for which there are no funds. Efforts to contact Colonel Doubleday have met with no success.
>
> Clearances for the civilian and officer personnel have not yet been received and no satisfactory explanation has been made for the delay. Hq AAF blames MED and MED blames AAF for failure to get the clearances processed. In fact, with the exception of the Sandia people and this office, no one seems at all interested in the project.

The situation changed abruptly in mid-January 1947 when funds for CHICKENPOX and other atomic projects of the AMC became available by allocation from the AEC, amounting to $3,000,000. This caused an immediate upsurge of interest at Wright Field, previously somewhat indifferent to such undertakings because of the numerous complications involved, and Colonel Sutherland remarked of the changed situation:[32]

> The funds for this project have finally arrived along with a letter of instruction for its use. Heretofore little or no interest has been shown in the work being done by Major Roark and myself. Now that we have MONEY, we have become quite popular and everyone wants to get into the act. A great deal of thoughts seem to have been given to methods of hitching other people's broken down wagons (due to the budget cut) to our atomic star.

Nevertheless, the continued delay in clearances prevented full advantage being derived from this financial impetus.

Activity continued at Kirtland during early 1947, with the T&TLC, representatives of the Z Division at Sandia, and Major Roark of the AMC all engaged in efforts to develop a workable design and to adapt suitable items of equipment. An experimental assembly was performed in late January to test the drawing board design, utilizing a plywood mock-up of the overhead trolley. Besides this trolley loading system and the braced floor other features included the enlargement of the forward hatch to permit the passage of large pieces from the lower to the upper deck and the installation of storage bins, work benches, special lighting, air conditioning, heating, bomb supports, battery chargers, special hoists, a power hook-up, and a power trailer. To these were added arctic, tropical, and desert kits. The arctic kit was considered the most essential, and the AMC was asked to schedule a cold-weather test at Eglin Field for October 1947.[33]

Both the completion date for the first item and the priority assigned the CHICKENPOX project were changed during the first part of 1947. The original 1-C priority had been changed to 1-B, apparently some time during 1946. The original completion date assigned, 1 March 1948, was changed to 1 October 1947 by AAF Headquarters on 8 May 1947. In order to meet this date the AMC requested that the priority be raised to 1-A, and this was granted, along with an authorization of unlimited overtime, on 3 July. Air conditioning and tropicalization would also be postponed. Nevertheless, the 1 October date was not met, partly because of delays in the coordination of changes in the modification with the AEC.

The first CHICKENPOX YC-97 was delivered to Kirtland Field on 26 October 1947 by Colonel Sutherland and Major Roark, who instructed

Z Division personnel in the use of the equipment installed by the AMC. The modification was essentially complete except for the items to be installed by the AEC. It was planned for the Z Division to carry out its share of the modification and then subject it to service tests. These would supposedly be completed in January 1948, and the plane would then go to the Engineering Battalion, AFSWP, for training and the development of assembly procedures. It would then be assigned to the 1st Air Transport Unit, SAC. In the meantime, the AMC would be modifying another YC-97.

This schedule proved to be too optimistic. It was necessary to return the aircraft to Boeing for rework of the center section fuel cell to prevent collapse during pressurized flight and for modification of the heaters to reduce the fire hazard. When these changes were completed, the aircraft was scheduled to go to Eglin AFB for cold testing in March, but this was postponed by order of Headquarters, USAF, in order to have two planes available for possible emergency use during the international crisis which had arisen. Further difficulties developed during the spring with the two YC-97's which had been modified, involving particularly malfunction of the heaters and cracking of the special Nesa glass windshields. The Air Force also discovered in April that an essential item of equipment, the electronic simultaneity tester, was unavailable, apparently as a result of an AEC-AFSWP misunderstanding as to who was responsible for producing it. The continued modifications of course prevented the practice operations necessary to establish operational techniques and procedures. Altogether, the project could hardly be considered out of the experimental stage.

Incidentally, the AFSWP, which through its control of assembly teams began to figure increasingly in the picture, indicated that it did not regard the project very favorably, preferring portable buildings. These, however, also remained unavailable in practicable form.[34]

The CHICKENPOX Project was nevertheless considered sufficiently advanced by early 1948 to influence the GEM Program for the rapid build-up of atomic striking capability by the Air Force. The program, established in the spring of 1948 and based on requirements earlier outlined by the JCS, called for the CHICKENPOX modification of eight C-97's by 1 January 1949. As implemented by the Engineering Division, AMC, a Technical Instruction issued on 23 April 1948 directed the winterization and modification of the six remaining YC-97A's. The aircraft were to be prepared for global operation down to minus 65 degrees Fahrenheit, and the modifications were to proceed without delaying for more satisfactory equipment, with deadlines of two planes by 30 July, one by 30 August, and the remaining three by 15 December. The work was to be accomplished by the Boeing Aircraft Company, with Major Roark serving as project officer for the AMC.[35]

Although the above schedule appears to have been met as far as major modifications were concerned, a number of changes were made in the final CHICKENPOX configuration which appeared in the two development YC-97 aircraft (Nos. 588 and 589), which were undergoing further testing and evaluation. It was therefore necessary to arrange for the further modification of the other six YC-97's in February 1949. It was also planned to modify 10 additional YC-97A's from the 1949 production with delivery beginning in September. Another important development was the placing of an order for the development of a camouflage net with the Corps of Engineers, including the requirement that it be proof against detection by radar and that it be able to withstand a wind of 70 miles per hour. The Engineers estimated that a suitable net would weigh 45,000 pounds, and require six hours or more to erect.[36] Nevertheless, work on development of a net began and continued till the termination of the project.

During the latter part of 1948 and early 1949 practice operations were carried out by AFSWP personnel for the development of standard operating procedures and team proficiency. Although the AFSWP in general supported the Phase B type of operation, in which the C-97 was used primarily as a carrier for the specialized assembly equipment and a portable building, it had so far been unable to procure a suitable type of building and perforce had to utilize the C-97. Both the YC-97's, which had been assigned to the 1st Strategic Support Unit, SAC, were alternately used, together with the XC-97 (No. 470), which was moved from Eglin AFB to Kirtland as a ground trainer and mock-up vehicle. Operation COWBOY, in August 1948, was primarily intended for the test of forward assembly procedures, and CHICKENPOX aircraft was successfully employed to perform five consecutive assembly operations. Cold tests at Eglin AFB and first field tests at Kirtland had been completed in July. Despite this, neither of the CHICKENPOX aircraft was fully equipped, in that air conditioners for tropic operations and simultaneity firing testers, both of them considered integral items, were not available. The AFSWP, which held responsibility for providing an air transportable building, was able to secure the first type found suitable--

The PALMER HOUSE--in December 1948. Four were at once procured and four others ordered, so that the Phase B concept of CHICKENPOX would be completed. As a result the number of C-97's to be modified was revised downward to consist of the eight on which all or most of the work had been completed by January 1949.[37]

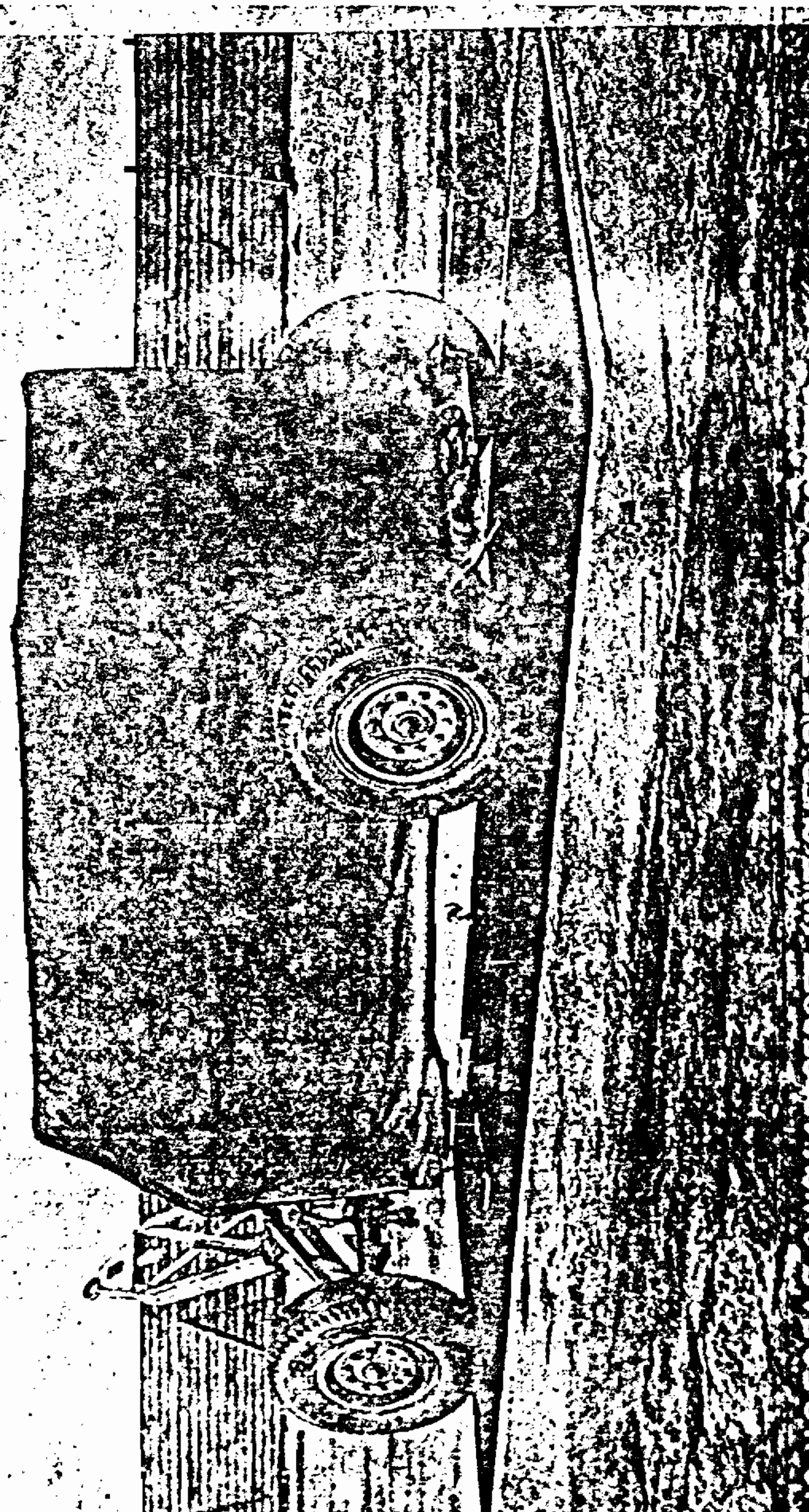
Actually only three of the eight CHICKENPOX aircraft ever became operational, since only three sets of assembly equipment (only one entirely complete) were procured for them by the AEC, this status being reached in June 1949. By this time the outlook for the entire CHICKENPOX assembly system, even the Phase B technique, had become decidedly confused because of the rapid replacement of the Mark III bomb models in the stockpile by the Mark IV, which would require much less extensive forward assembly. All Mark III, Modification O, bombs would be out of the stockpile by 1 July. Extensive forward servicing was much less necessary for the Mark III, Modifications 1 and 2, and the CHICKENPOX system would be correspondingly less useful. Further modifications would also be necessary to permit its use for these models. The Field Office for Atomic Energy by late 1948 had come to believe that a standard arctic tent shelter carried in a single cargo plane such as the C-54 and erected within two hours would suffice for the simple servicing required, if no local facilities were capable of conversion. This would dispense with the need for both the specially modified C-97 and the PALMER HOUSE. Although the CHICKENPOX C-97 could be used for this purpose, it could only be regarded as an expensive luxury.[38]

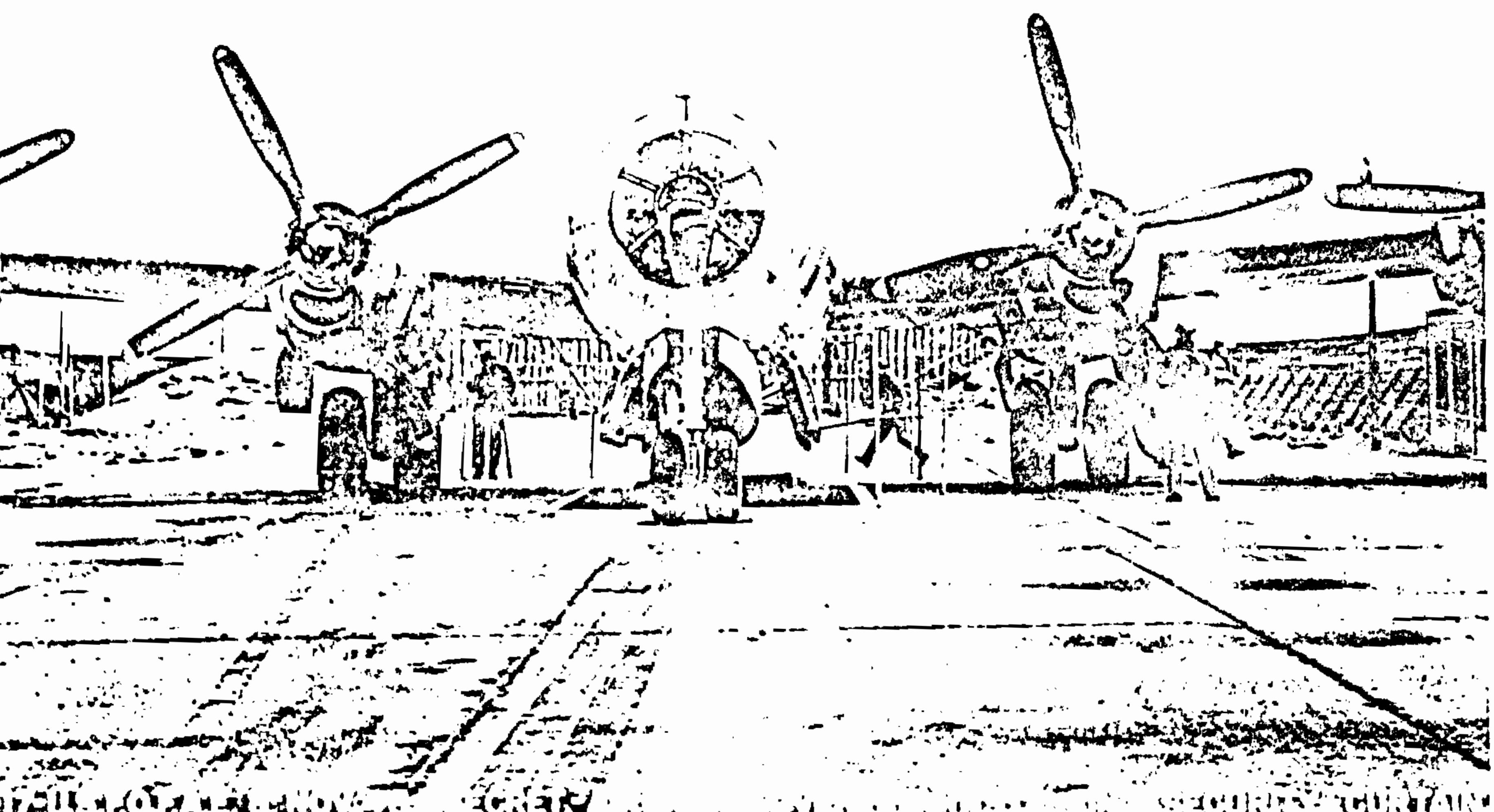
As a result of the above considerations, the end of Project CHICKENPOX came rather suddenly as compared to its protracted beginning.

On 23 May 1949 Brig. Gen. Howard G. Bunker, Chief of the Field Office for Atomic Energy at Kirtland AFB, concurred with a previous recommendation by General Montague of Sandia that CHICKENPOX be terminated as of 1 July. General Montague pointed out that the SAC was no longer planning to use CHICKENPOX facilities, except possibly for small-scale specialized missions. The AFSWP followed with a formal recommendation along the same line on 1 June, and as a result the project was formally terminated on 21 September. The final echo of CHICKENPOX came on 27 October, when a query from AFOAT to AMC as to whether it would be practicable to leave the modifications intact in existing planes for possible future emergency use elicited the information that destruction of the equipment had already begun and that immediate action would be needed in the form of a Headquarters, USAF, directive if this were to be saved. This was not forthcoming.[39]

Bomb Handling and Loading Equipment

As seen in Volume I, the unusual size, weight, and shape of the atomic bomb, particularly the FM, created handling problems which had to be met by the design and manufacture of special equipment. During World War II the Army Ordnance Department was responsible for developing and procuring such items as dollies and lifts for transporting and loading bombs on aircraft; however, like virtually all other matters pertaining to the development, manufacture, and delivery of the atomic bomb this problem was taken over by Manhattan District. In cooperation with the Air Materiel Command it designed, developed, and procured two principal items for this purpose--a stationary hydraulic hoist for lifting the bomb into the bomb bay and a dolly or trailer for moving the bomb from the assembly room to the hoist. These were successfully employed at Tinian in 1945 and a year later at Bikini.





During the spring and summer of 1946 the Army Air Forces was engaged in negotiations with Manhattan District looking to a larger degree of participation in atomic development activities and to a definite delineation of functions and responsibilities.* As a result of a conference on 9 May 1946 Manhattan representatives agreed to transfer responsibility for the development, programming, and supply of equipment for handling and transporting both service and practice models of atomic bombs to the AAF and the Ordnance Department. The respective responsibilities of the last two organizations were not, however, clearly defined, and correspondence between them and the Manhattan District continued into November. At this time the Ordnance Department withdrew entirely from the field, including responsibility for stockpiling and planning. War Department Circular 356 was completely revised to give the AAF "normal channel responsibility for the design, development, procurement, storage, and issue of dollies, hoists, or any combination thereof which is used in positioning a bomb in an aircraft." This was in accord with the new concept that the AAF would assume responsibility for the bomb when the completely assembled weapon was ready to leave the assembly building for loading.[40]

As a result of this agreement Manhattan transferred to the AAF certain loading pit equipment and bomb trailers, together with a Loading Pit Manual (LA-583), which it had prepared. Three completely equipped pit installations including necessary trailers were in place at the time (21 August 1946), these being located at Kwajalein (for Operation CROSSROADS), Sandia Base, and Roswell AAF (excluding two partially complete installations on Tinian and Iwo Jima, which were

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*See Chapter IV.

ly overlooked). These, however, were all claimed by Man- which agreed to transfer only three sets of pit equipment and ilers which were on order. All items involved were classified . Later, the AAF secured a concession to permit transfer of oswell equipment.[41].

Meanwhile, some months before this the Air Materiel Command had directed to initiate "a development program...for the purpose of eloping suitable carrying, releasing, and hoisting equipment for e A-Bomb, these equipments to be applicable for such aircraft as ill be required to carry this bomb." The directive further emphasized that every effort should be made to develop equipment which could be readily airborne and that if possible it should also be adaptable for other standard bombs. Accordingly the AMC issued technical instructions and initiated several development projects during the year.[42]

The hoist equipment consisted essentially of a turn-table hydraulic hoist, air-oil reservoir, and a gasoline-operated compressor, with necessary piping and valves. These items were mounted in a sub-surface concrete installation, and the whole was ordinarily referred to as a loading pit. The hoist itself was commercially manufactured as the Materialift by the Joyce-Cridland Company of Dayton, Ohio, and was basically similar to those employed in auto service stations. The bomb dolly or trailer was a four-wheeled towed vehicle with removable cradle. It had been designed by the Manhattan District and produced by the Utility Trailer Manufacturing Company of Los Angeles. The bomb was loaded on it within the assembly building and moved over the hoist, to which it was then transferred. The aircraft was then centered over the hoist with the aid of the turntable and the bomb apparently overlooked). These, however, were all claimed by Manhattan, which agreed to transfer only three sets of pit equipment and six trailers which were on order. All items involved were classified SECRET. Later, the AAF secured a concession to permit transfer of the Roswell equipment.[41]

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Not only was this delay objectionable, but the elaborate and expensive pit installation* both reduced operational flexibility and increased the vulnerability of existing bases. Accordingly there was an early demand from the AAF for improved equipment which eventually took two directions. One proposal was for a combination dolly and hoist which could be moved directly under the aircraft. A second was for an internal hoist which would lift the bomb into place after it had been wheeled under the plane. Either of these systems would require a nose jack also in the case of the B-29 if pits or ramps were to be dispensed with, since insufficient clearance existed. Another demand was for a portable dolly, so that the entire loading system could be air borne. These requirements were not easy to fill, because a replacement loading system had to equal the original in reliability.[43]

Despite the objections to the hydraulic pit loading system it was to continue in use for several years to come, and loading pits were constructed at a number of air bases and storage sites. By 28 March 1947 five additional ones had been constructed at various points, and action was being instituted in May 1948 to procure ten more sets of equipment for installations. Meanwhile, work had begun by the fall of 1946 at the AMC on a trailer-hoist. Although quickly developed, this was actually used only to position the bomb properly for raising into the aircraft by use of a chain hoist, after the nose

*The total cost was about $40,000, of which about $18,000 was for the equipment.

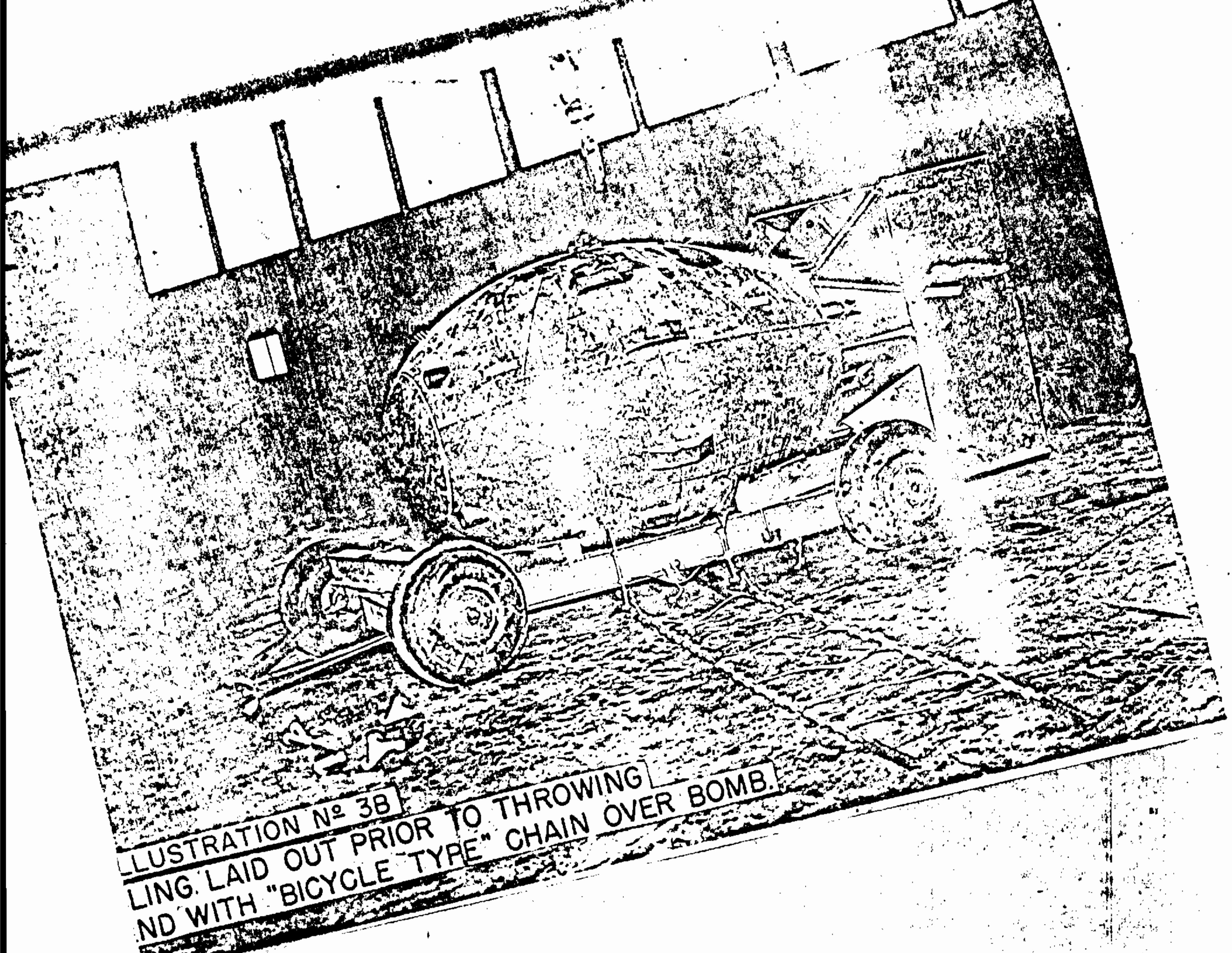
of the plane had been raised by a jack to secure the necessary clearance.[44] The up-forward movement provided by the trailer-hoist was unsuitable for the actual loading, a vertical movement being necessary because of space limitations. The lifting was to be accomplished by a sling and internal chain hoist, the A-6 and C-7 respectively. The A-6 was an existent sling which could be utilized for the purpose. The C-7 was an experimental 12,000 pound hoist ordered in late 1946 from the Steel Products Engineering Company, actually an adaptation of an existing design, the C-6, which was already in use on the B-29. Two were required for each aircraft. The total arrangement was regarded as an interim one of doubtful reliability.

Meanwhile, early in 1947 work also began on two other items--a "plain" low-bed dolly with lift to supplant the dolly in the above system and a much more elaborate combination dolly with a straight vertical lift capable of raising the bomb sufficiently to attach it to its rack within the aircraft. The purpose of the simplified dolly was to provide an item which could be readily transported by air. The combination trailer-lift would provide a heavy-duty all purpose item. The contract for producing the experimental prototype, capable of a 25,000 pound lift, was given to the W. L. Maxson Corporation of New York City by June 1947.[45]

All of the above projects, including the interim loading arrangement, progressed very slowly, apparently largely because of the severe restriction on release of information imposed by Manhattan District. The Maxson combination trailer-hoist turned out as a strictly long-term project, not resulting in an experimental article until May 1949, which then had to be turned back for extensive reworking. Development of a satisfactory internal hoist also turned out to be a considerable undertaking, although two available types, the C-6 and C-7, could be used in an emergency. The C-7 was selected over the C-6 because of its greater capacity, but was not altogether satisfactory, and the ultimate design, approved for incorporation in the GEM Program in June 1948, was the C-9. The requirement which proved particularly difficult to satisfy was that for a positive reverse locking feature. Essentially, the C-9 was the C-7 with irreversible gears. Meanwhile, both the C-6 and C-7 found limited use.* These hoists were mounted on the H frame within the bomb bay.[46]

Considerable difficulty also attended the development of the "plain" low-bed dolly, which was to replace the interim item with limited lift for use with the internal hoisting system. Drawings were completed by 1 June 1947 and the AMC engineering shops were directed to produce a hand-built prototype. By 10 June 1948 this had been tested by the AMC and 120 items ordered in connection with the GEM Program, through a production contract with Boeing. The threatening international situation during the spring of 1948 had apparently resulted in somewhat hasty action in this matter, since the dolly in question was still undergoing testing by the T&TLC at Kirtland, and a number of recommendations for modifications began to come in as a result. These, besides slowing production, created a design conflict in that the demands for such additional refinements as that the dolly be readily capable of being disassembled for transport and that it

*The C-6, with which the earlier modified planes were equipped, was used as late as Operation AJAX, in October 1948. Considerable risk attended its use, and the operation report urged that it not be employed again.

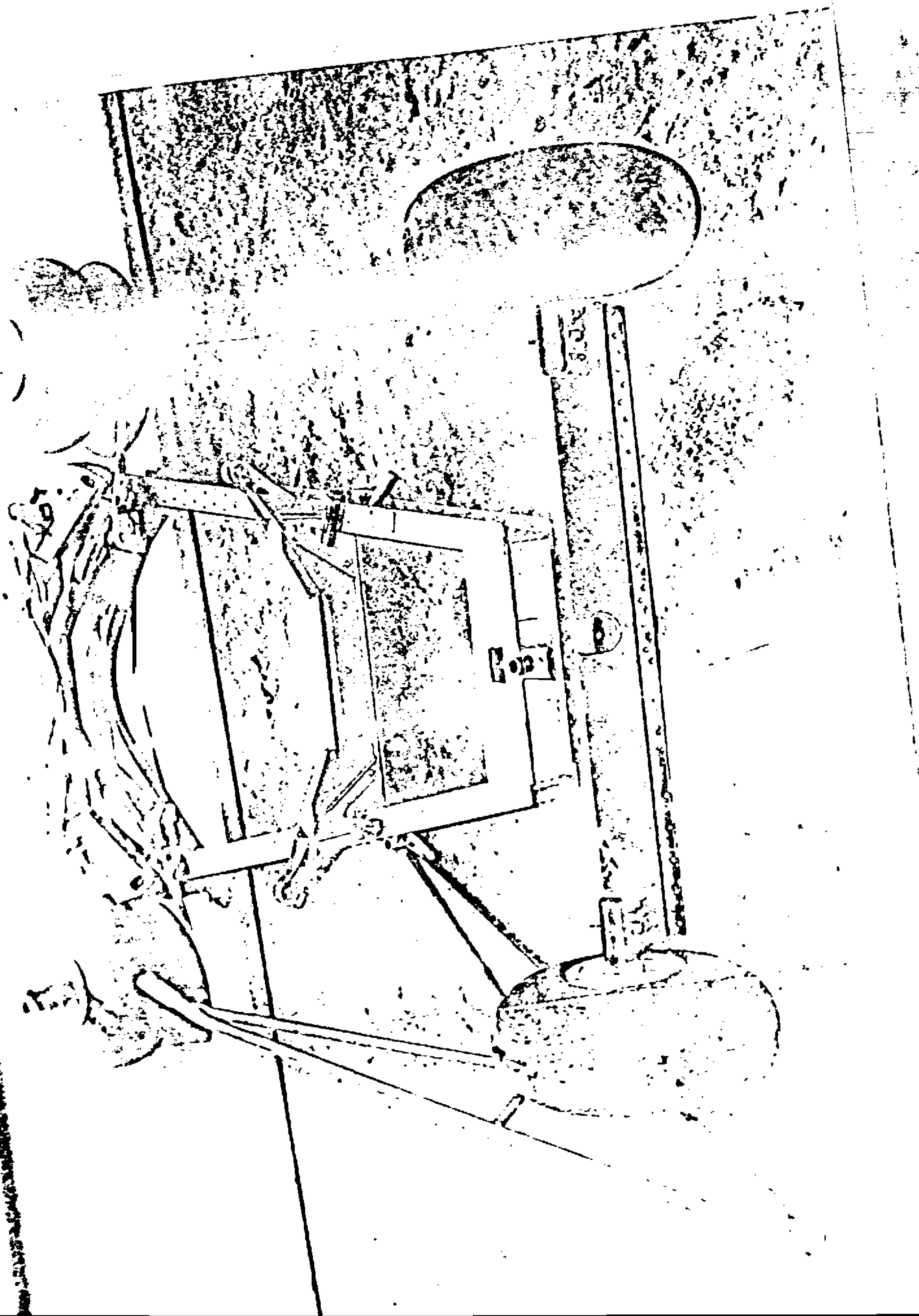


LLUSTRATION Nº 3B

LING. LAID OUT PRIOR TO THROWING

ND WITH "BICYCLE TYRE" CHAIN OVER BOMB.

CRET



RESTRICTED

ANHANDLING THE BOMB INTO POSITION
NDER THE BOMB BAY. NOTE IDLER SPROCKET
ND HOISTING CHAINS.

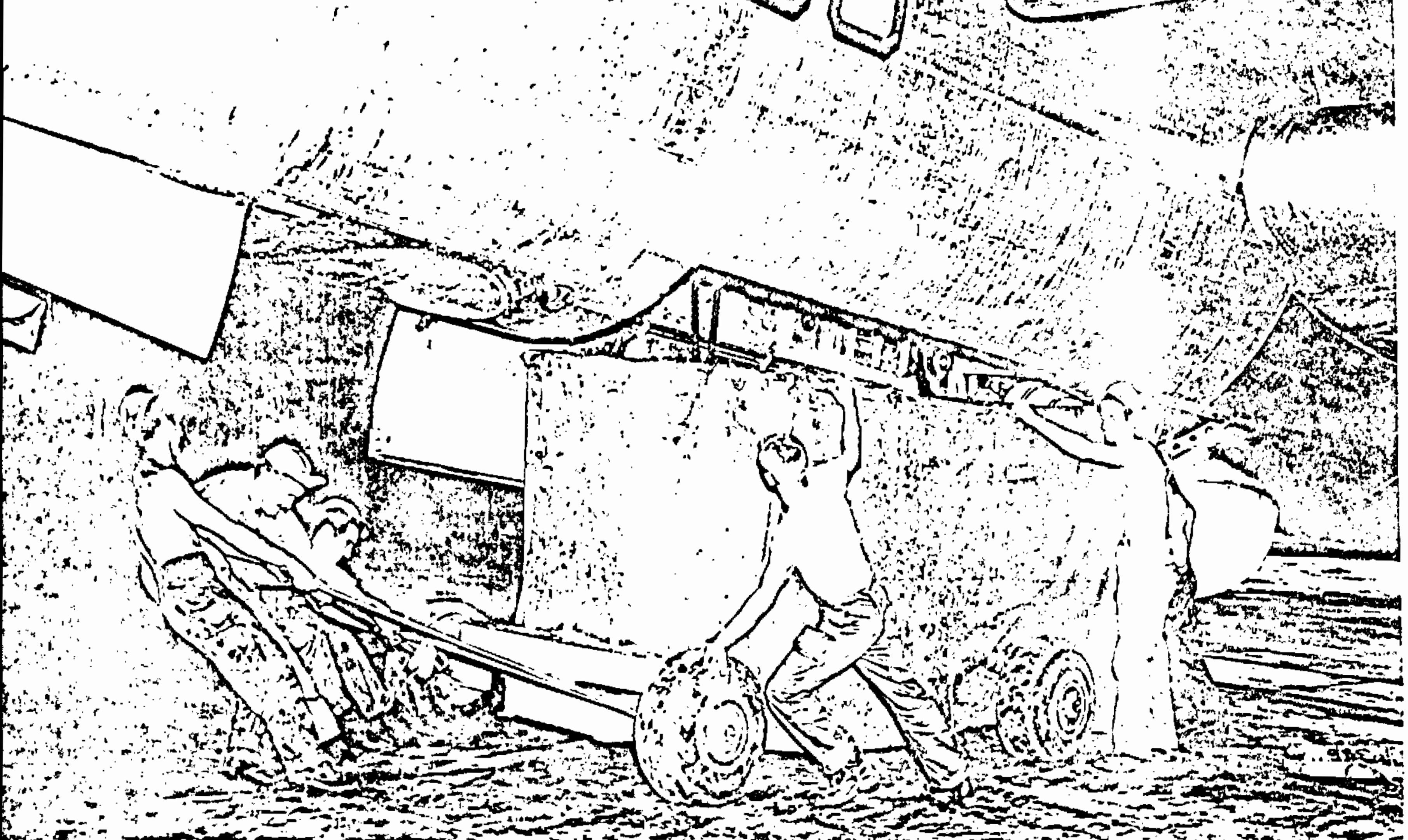


ILLUSTRATION Nº 10

RICTED

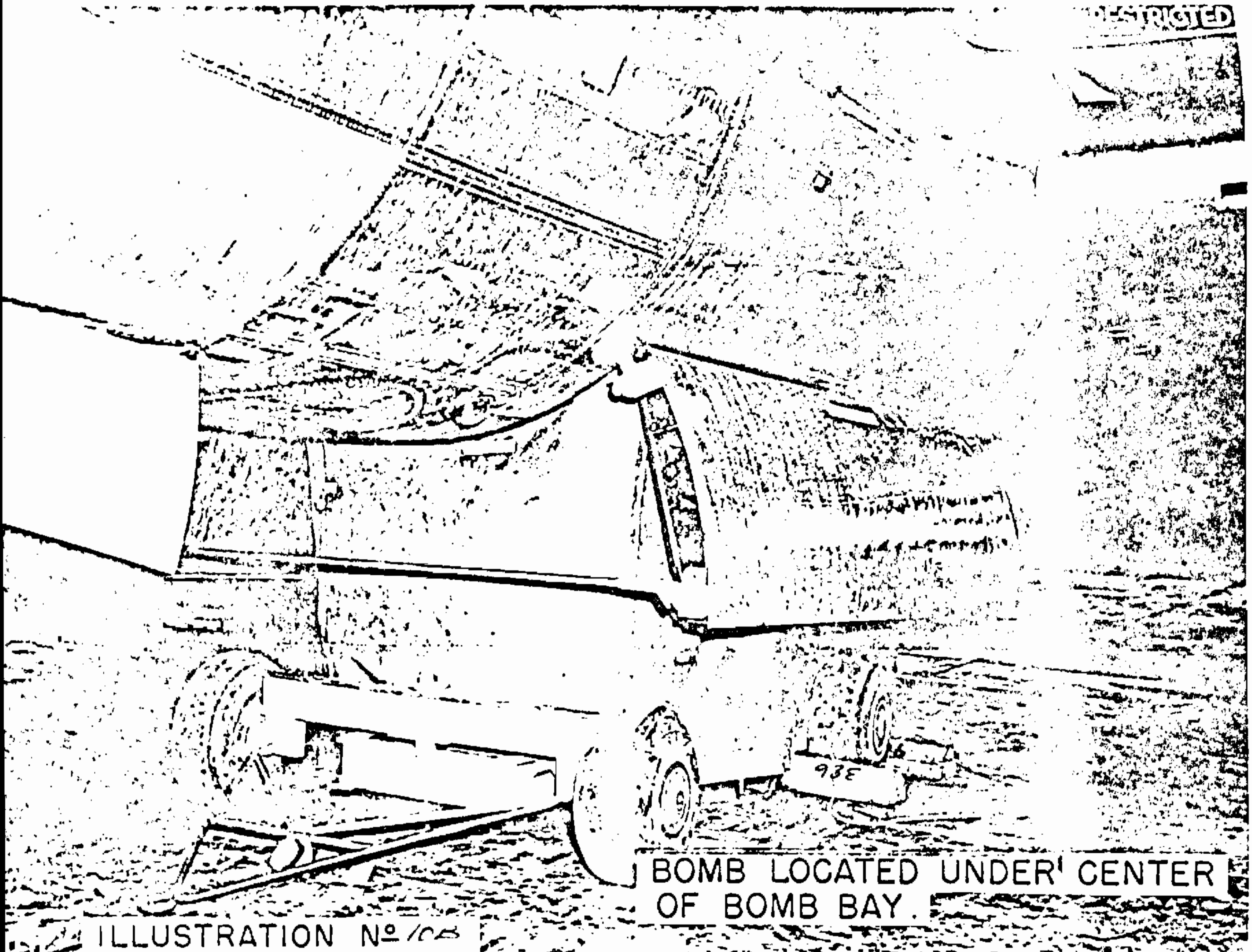


ILLUSTRATION Nº 108

mount a security curtain clashed increasingly with the requirement for roadability. As a result Colonel Sutherland of the AMS wrote to the T&ELC on 17 August 1948 to point this out and urge that further changes be kept to a minimum in order to prevent the N-1 from becoming "a conglomeration of hardware on wheels." Delivery of the N-1 apparently began in early 1949.[47]

Even with the low-bed dolly sufficient clearance would still not exist beneath the B-29 for loading, and this problem promised to become further complicated with the development of jet bombers, presumably with even less ground clearance. Four principal proposals were made to cope with this problem: use of a loading trench or wheel ramps, raising the fuselage by a jack, inflating the hydraulic elements in the wheel struts, and modification of the bomb bay doors. The first was subject to some of the same objections voiced against the loading pit and does not appear to have been too seriously considered.* Extensive study was made of the last three during late 1946 and 1947, and by early 1948 two standardized procedures had been evolved.

The first of these was based on the use of a Model V12-60 Malabar hydraulic jack to raise the nose of the aircraft, thus providing a clearance of approximately 71 inches under the fuselage just in front of the front bomb bay. A difficulty arose in that, since the dolly and bomb had to be wheeled in under the nose, use of the normal jacking point in the nose wheel well would result in blocking this ingress.

*A permanent ramp and pit arrangement was constructed at Muroc. It was also necessary to use a loading trench when the B-29's of the 509th were loaded by use of their C-6 internal hoists, since they did not have the special jacking arrangement of the later modification.

Accordingly a new jacking point was provided in the SADDLETREE modifications on the right side of the fuselage toward the nose. Since clearance was reduced to 64 inches under a forward lower gun turret in case the aircraft was fitted with one, a supplementary method provided for inflating the main wheel struts, which would provide a clearance of 72 inches under the turret. The second method of obtaining the necessary clearance was to inflate both the main landing gear struts and nose gear struts and then to remove either one or both bomb bay doors. The latter operation was simplified by replacing the existing bolt fasteners by pin bracket assemblies. Jacking required about eight minutes, and the doors could be removed in about one minute. The latter method also dispensed with the jack entirely; however, it did require a high pressure source of air (1200 pounds).[48]

As can be seen from the above, pit loading remained the main reliance of the Air Force until the end of 1948 because of the deficiencies of the interim system and the slow development of new equipment. Since only a few pit installations existed and only three sets of equipment were in stockpile, the onset of the international crisis in March 1948 resulted in much immediate activity in this area. On 9 April Headquarters, USAF, requested the Chief of Engineers, USA, to construct two pits on Okinawa, stating that the Air Force would supply the necessary equipment. It suggested, however, that the World War II pits on Tinian and Iwo Jima be first inspected to determine whether the equipment was not usable for at least one pit. In addition, the AFSWP on 29 April requested the Air Force to procure five sets of equipment, three of which would be installed at Sandia and Camp Campbell and two held in reserve. Meanwhile, a pit had just been completed at Fort Worth and one was under construction at Camp Hood. No loading pit existed in Alaska, and consideration was given at this time to the possibility of constructing one at Eilson Air Force Base.[49]

By July a requirement had been established for a total of 18 loading pits

At least one was already in place at each of these points with the exception of Camp Campbell and Limestone for a total of twelve operational. Three sets of equipment were in storage and ten on order, it being planned to maintain a stockpile of seven.[50]

Meanwhile, the 509th Bombardment Group, core of the Atomic Striking Force, which was on alert during part of the month of April, made plans to use the C-6 hoists as an emergency measure, since these were the only items readily available. However, the AMC was directed to procure 120 low-bed dollies and 250 sets of C-9 hoists as expeditiously as possible. It was estimated at this time that the C-9 hoist would not be ready before November in production quantities. The T&TLC accordingly requested the AMC to procure "up to a dozen steel cradles and adapters which could be used in connection with the C-6 hoist in case of emergency." Quantity production of C-9 hoists was not achieved until the first quarter of calendar 1949, when 463 were procured. These hoists, weighing 330 pounds per set of two, were carried as an integral part of the aircraft modification. At this time nose wheel jacks and N-1 dollies were being issued at the rate of four each per squadron of ten modified aircraft.[51]

Air-to-Air Refueling

During late 1947 and 1948 increasing emphasis was placed on the development of means of extending the range of atomic bombers. Although certain overseas bases were expected to be available in the event of war, it was felt to be wise to develop some means of intercontinental bombing. Neither the B-29 nor its successor the B-50 were capable of a flight from this continent to bomb Russian targets and return, the B-29 having a combat radius of 1500 nautical miles and the B-50C of 2600. Although the B-36B would increase this to about 3100, there were unanswered questions about its combat suitability, and its range would still be marginal. The outlook would become poorer rather than better with the development of the B-52, since the high speed provided by the turbo-jet engine would be attained at the expense of range. Some "artificial" means of range extension was therefore highly desirable over both the near and intermediate term, and air-to-air refueling seemed a logical answer. Besides the advantages of range extension, the dangers and difficulties attending take-off with a maximum fuel and bomb load would be greatly lessened.

Consideration of adopting a refueling system for the atomic striking force had begun in Headquarters, USAF, by the latter part of 1947. When the SAC urged the development of such a system in October, the Directorate of Requirements replied that an experimental program had already been approved. This provided for (1) modification of a prototype tanker and bomber-receiver (from 1948 funds) and assignment to the SAC for training; (2) modification of 100 B-29 tankers from fiscal 1949 funds; (3) modification of B-50B's for single point refueling as they came off the production line; (4) installation of single point refueling in production B-50C's. In November Headquarters, USAF, authorized AMC to expend $1,000,000 of fiscal 1948 funds to initiate the program immediately. In December the Directorate of Research and Development proposed extension of the program to include escort planes, particularly the P-80 and P-84. Early in 1948 the program was further approved by the Long Range Bombardment Board and assigned a 1-A priority.[52]

Although refueling in air had been carried out as early as 1923, the only company actually making the necessary equipment was Flight Refueling, Ltd., a British company which had been formed during the 1930's. Its most notable activity had been during 1944-1945, when it had installed its equipment in a number of Lancaster and Lincoln bombers in preparation for their proposed operation in the Pacific against Japan. The British system had also been given limited tests at Eglin Field during 1942. In view of the urgent need for a practicable system the AMC decided to employ the British system if practicable. During March 1948 a contract was made with Flight Refueling, Inc., to supply 40 complete sets of tanker-bomber refueling equipment, together with technical assistance by British engineers, necessary tools, and installation drawings, at a total cost of $1,250,000.[53]

First installation of this system, employing hose connections and gravity feed, was completed by 3 May 1948. Following flight tests certain modifications were made, and by 28 September 12 B-29 tankers and 12 B-29 receivers were modified and delivered to the SAC. The system employed permitted the transfer of 2600 gallons at a rate of 90 to 100 gallons per minute and was believed to allow the attainment of an increase of from 25 to 40 per cent in combat radius. This system was regarded as an interim one, to be supplanted by a force feed technique for increasing flow to 200 gallons a minute which the AMC hoped to complete development on by 1 January 1949. It was also expected to develop a new type system eliminating the hose and substituting a mechanical boom, on which Boeing-Wichita was engaged during the year.[54]

Under the GEM Program 40 B-29 tankers (designated SUPERMAN), 36 B-29 receivers (designated RURALIST), and 57 B-50A receivers were scheduled for modification by 15 December 1948. As previously seen, actual deliveries fell considerably short of this. Under the GEM Follow-On Program all B-50's were to be modified as receivers.[55]

Specialized Electronic Equipment

Other principal items of specialized electronic equipment connected with atomic operations for which the Air Force either had direct development and procurement responsibility or with which it became concerned through operational use included a phase inverter, flight test box, ring out box, and tester-calibration box. The inverter (Eclipse Pioneer Inverter No. 12130-1-B) became the cause of a serious bottleneck in the GEM Program during the rapid build-up of 1948. One inverter was used in each 1561 bomb, and another was used in the carrying aircraft to supply power for readying the bomb for the drop. The AEC also insisted that the aircraft carry a spare inverter. The Air Force was to secure the two external inverters per aircraft from the Bendix Aviation Corporation, which also manufactured the inverters for the bomb itself. Unfortunately, Bendix experienced some difficulty in meeting the specifications established by the AEC, and the inverters became a critical item in the GEM Program by June 1948. After fruitless efforts to secure inverters through lower level action, the Air Force in July brought pressure at the top level on the AEC, which had first priority, to release inverters. The AEC explained that it had already taken action to accelerate production, and agreed to meet Air Force requirements on an equal basis with its own, beginning in August. Nevertheless, inverters remained a short item for some time to come, and in October Headquarters authorized the AMC to release the modified bombers with necessary wiring, but without the inverters. It remained the Air Force viewpoint that the spare inverter was unnecessary.[56]

The flight test box was the control and monitoring instrument used in the aircraft cabin for testing the fuzing and firing circuits of the bomb prior to release. These instruments had been built by Manhattan District in limited number. All checking and calibration of the box had been done in the laboratory. With the expansion of the atomic program other methods of production and field calibration would become necessary. Under an agreement reached in March 1947 between Sandia Corporation and the AAF, the AMC would undertake the simplifying and procurement of the flight test boxes and turn them over to the Army Engineers for storage and third and fourth echelon maintenance. The agreement failed to hold after Colonel Dorland, Commanding Officer of Sandia Base, learned of it and convinced Z Division that the instrument should continue to be developed and procured by the AEC on the same basis as bomb components, then stored and maintained by the AFSWP, to be issued with the bomb itself. This arrangement was instituted; however, later in the year Z Division requested and secured the agreement of the AAF to check the components of the flight test box for possible substitution of standard Air Force items.[57]

Closely related to the flight test box was the Kilroy box and the calibration box. Intended respectively for testing and calibrating the complex circuits of the flight test box, their development was undertaken by Sandia Corporation during 1947. Later the two were combined into one item--the testing and calibration box. Also under development at this time was a trainer box, designed to replace the bomb for practicing with the flight test box. Another test item developed by Manhattan District early in the program was the ring out box, which tested the intricate wiring of the SILVERPLATE modification. This was greatly improved by Major Roark working with Manhattan personnel at Kwajalein during Operation CROSSROADS and further improved at Sacramento Air Depot when the SILVERPLATE installation was standardized late in 1946.[58]

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CHAPTER XII

DEVELOPMENT OF NEW ATOMIC BOMB CARRIERS

Although the B-29 had served as an admirable carrier for the early atomic bomb in both its versions, the weapons system thus created represented (at least in the case of the FM bomb) a fitting of the bomb to the aircraft. Over the longer term the revolutionary nature of the nuclear bomb appeared to dictate that future carriers would be designed around the bomb itself. Since the design, development, and production for operational use of the B-29 required approximately five years under war-time acceleration, it was obvious at the end of the war that an even longer period would elapse before an aircraft specifically designed as an atomic carrier would be available for operational use. The situation was further complicated by the appearance of the turbo-jet engine, which offered a tremendous gain in speed but had to be integrated into bomber design, and by the lack of fully developed information on atomic operations, including tactical procedures, target studies, and effects data. These all had to be carefully related to the best use of the potential stockpile, itself a highly uncertain item.

Adaptation of War-Time Heavy Bomber Designs

Meanwhile, the basic design of the B-29 could be further developed in the B-50, which had greater speed and range. Heavy and medium bombers already in process of development at the end of the war could also be considered for use as atomic carriers. At that time the XB-35 and XB-36 were already well advanced, and a number of medium jet bomber projects were also under way. These included the XB-45, 46, 47, and 48, as well as one attack bomber, the XA-43. Projects for all of these had been begun late in 1944.[1]

First action by Headquarters, AAF, to correlate the development of the new bombers to carriage of the atomic bomb appears to have been taken in April 1946, when AC/AS-4 requested the AMC to submit estimates on the prejudicial effect of carrying the atomic bomb on all experimental and production bombers subsequent to the B-29. He explained that the types and quantities of atomic bombers were to be based on Manhattan District's current estimates on the rate of stockpiling of fissionable material, a realistic production rate for bombs derived from this, and current estimates of the total possible production before the exhaustion of fissionable material.[2] In reply Brig. Gen. L. C. Craigie of the AMC reported that design studies, utilizing meager information on the dimensions of the bomb obtained from Manhattan District and based on a bomb 22 inches longer than the current one, showed that only the XB-36 and XB-47 could carry the FM bomb without penalty in speed or range (although the loss would be negligible in the case of the XB-45 and XB-46) and that only the XB-47 would require no modification.* The study also considered the XB-35, 48, and 50. Craigie pointed out that the latest military characteristics established for both heavy and medium bombers stated they should include provision for the

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* Apparently the study was limited to the consideration of penalties resulting from altered aerodynamic characteristics.

carriage of at least one atomic bomb.[3]

Of the above aircraft only the B-50 and B-36 were to become operational during the three year period following the war, and both were included in the GEM Program, which was aimed at the build-up of an enhanced striking capability during 1948 and thereafter. A principal change in the B-50 over the B-29 was the substitution of the much more powerful R-4360 Pratt and Whitney engine for the R-3350 Curtis-Wright engine, together with electrically controlled reversible pitch propellers, resulting in greater improved performance. The aircraft also incorporated a larger vertical stabilizer, and there was some rearrangement of the crew. The prototype first flew in June 1947, and was accepted in October for production. The early B-50's, numbering 80 and having fuselage and bomb bay identical with the B-29, were given SADDLETREE modifications after production, beginning in early 1948. It was planned that the eighty-first item, the first B-50B, would be the starting point for production line modification. It was also intended that later versions, beginning with the B-50C in late 1949, should incorporate a single and much longer bomb bay.[4] However, the B-50B designation for the early B-50's modified on the production line was later dropped, as was the single bomb bay proposal represented by the B-50C. The second group of B-50's to become operational--the B-50D's--differed little from the B-50A's except for boom in-flight refueling equipment, larger fuel capacity, crew of 10 instead of 11, improved radar, and a few other minor changes.[5]

Development of the B-36, the first postwar atomic bomb carrier of entirely new design, was begun in April 1941, when the Consolidated

Aircraft Company and the Boeing Aircraft Company were invited by the AAF to submit design studies for a long-range bomber with a speed of 450 miles per hour at 25,000 feet, range of 12,000 miles at an altitude of 25,000 feet, cruising speed of 275 miles per hour, service ceiling of 45,000 feet, and bomb load of 4,000 pounds at maximum range. The Consolidated proposal was accepted and a contract let for two experimental items in November 1941. Requirements were revised by late 1943 to provide for 10,000 pounds of bombs at 10,000 miles range and 72,000 pounds at 4,790 miles, with a maximum speed of 367 miles per hour and weight of 271,076 pounds. Delivery date for the first item, originally set for May 1944, was later postponed to October 1946, and the first flight was made on 8 August 1946.[6]

At this time it was estimated that the aircraft had a maximum speed of 323 miles per hour, a cruising speed of 225 miles per hour, and a maximum range of 9360 miles. Although this was not regarded by AMC development officers as too far from the planned performance, there was some disappointment at upper levels, especially when it was also reported that the aircraft showed numerous structural defects, resulting from faulty material and workmanship.[7] Nevertheless, despite some opposition within the Air Staff it was decided to continue the production schedule for 100 articles, of which 23 would be produced during 1947, beginning in June, 73 during 1948, and 4 in January 1949. It was planned in October 1946 to assign the first available items to the 58th Bombardment Wing, core of the atomic striking force, for equipping two groups at the rate of six planes per squadron and three squadrons per group. The only bases considered adequate for the B-36 were Fort Worth and Fairfield-Suisun, but a number of others had been recommended for modification.[8]

Nevertheless, many officers, including General George S. Kenney, Commanding General of the SAC, remained doubtful of the possibility of fitting the B-36 into the atomic striking force as an operational bomber. In late 1947 he proposed that the first 22 items (B-36A's) be utilized only as tankers in the refueling program being considered. However, the onset of the European crisis and the resulting great need for an operational bomber of greater range than the B-50 served to tip the scales in favor of the B-36. Accordingly, with General Kenney's agreement, provision was made in the GEM Program for the modification of 18 of the newer B-36B's as long-range atomic bombers, with delivery to operational groups to begin in September 1948.[9] The SAC actually received its first B-36 in June, and the plane was being regarded with more favor by October AFOAT reported:[10]

> The Air Force currently has one modified B-36 and is expecting to get four more this week. Unfortunately, these aircraft are not fully operational in view of parts lacking for the APQ 24 radar set. By 1 November the 8th Air Force is scheduled to get a total of seven B-36's. Under current plans, these aircraft will begin operations on D ≠ 15. Much effort will be required to get these airplanes operational within that time. However, an emergency may get those ships operational. SAC likes the airplane. They say it will climb to 35,000 feet on five engines. RAND also says it's a good ship. It will fly at 40,000 feet but bombing accuracy is poor at that altitude primarily because of proportionate error increase at higher altitude in bombing equipment.

Almost simultaneously with the XB-36 the XB-35 was also under way. This was a Northrop project for a long-range heavy bomber of radical design, based on the flying wing concept. Action was begun to authorize the development of this aircraft in July 1941. The preliminary design was submitted in November 1941 and the contract for a flying mock-up approved the same month. An engineering completion date of 1 March 1944 was later set for the prototype XB-35, but various problems delayed this until early 1946. The first flight was made 25 June 1946.[11]

The XB-35 was designed for a maximum bomb load of 32,000 pounds, of which 24,000 would be internal, or for a load of 10,000 pounds at a range of 7,600 miles. When the aircraft was considered by the AMC along with the XB-36 and the new jet bombers as a possible atomic carrier during early 1946, it was pointed out that the peculiar configuration of the plane, which resulted in a rather shallow bomb bay, would necessitate a semi-external, faired installation to carry the Mark III. This would result in a high speed loss of 6.5 per cent and a range loss of 9 per cent.[12]

Shortly after its first flight the XB-35 was flown to Muroc Lake for further testing, but thereafter it was virtually grounded for the following 18 months, a result of "continuing problems concerning the reduction gear and propeller operation." The design of this aircraft called for dual contra-rotating pusher propellers actuated by a two speed reduction gear, and since Northrop was unable to secure effectively functioning items of this type the development program for this aircraft in its propeller-driven version came to a virtual close.* Late in 1947 the program gained a second lease on life with the appearance of the jet version, the YB-49. In December, after two months of flight testing, Northrop claimed that a flying wing bomber was capable of 2,000 miles greater

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*These items were to be supplied by the AAF as government furnished equipment through a contract with United Aircraft.

range and 50 to 100 miles per hour greater speed than comparable conventional designs. The contractor also contended that the question of controlability and stability had been definitely answered.[13]

These claims came at a propitious time, since the project for the XB-52 had just been adversely evaluated by the Long-Range Bombardment Committee of the Aircraft and Weapons Board and the possibility of calling for new bids on the revised requirements was being considered rather than a change order contract with Boeing. Although Northrop gained a certain amount of support within Headquarters, USAF, its claims were strongly opposed by the AMC, which held that the necessity of adding a nacelle for military stores invalidated calculations showing a greater efficiency for the optimum all-wing plane. It also pointed out that the fewest unsolved problems in design lay in the fuselage plane, for which a wealth of data existed, and in contrast emphasized such questionable characteristics of the all-wing plane as its high speed stability and control, sensitivity to changes in loading, and lack of versatility in accommodating various types of bombs.[14] As a result of these and like objections, the contract competition for the XB-52 was not reopened, but change ordered in the light of the new military characteristics. This decision virtually eliminated the B-49 from the picture as a potential atomic carrier. Late in 1948 a reconnaissance program was being organized around the RB-49, under which 30 of these aircraft were to be procured at a cost of $128,647,600 for delivery during 1950. It was also proposed to modify the remaining nine YB-35's to RB-49's at a cost of $10,733,905.[15]

Early Jet Bomber Projects

Of the early jet bomber projects begun in late 1944--for the XB-45, XB-46, XB-47, XB-48, and XA-43--only the XB-45 and XB-47 were to reach the production stage. All were medium bomber designs* except that for the XA-43, an attack bomber, and all proposed to employ the General Electric TG-180 engine in groups of four or six.[16] The first of these to become available for evaluation was the XB-45, which first flew on 17 March 1947. Built by North American, it was essentially a conventional design to which jet engines had been adapted, and gave sound but not extremely high performance. In February 1948 it was described as having a maximum range of 2,780 nautical miles, maximum speed of 443 knots, gross take-off weight of 109,221 pounds, and bomb capacity of 10,000 pounds.[17]

As early as July 1946 the Chief, Research and Engineering Division, AC/AS-4 recommended the contracting for procurement of 96 B-45A's prior to the first flight of the experimental article. Comparing the new design to the other medium bomber projects under way, he stated:[18]

> The B-45 airplane is in competition with the B-46, B-47, and B-48 airplanes, all jet propelled. The performance of the B-46 is inferior to that of the B-45 and due to the shape of the fuselage it is extremely doubtful that all the required radar equipment can ever be satisfactorily installed. The B-47

*AAF bomber classifications were redefined in AAF Letter 65-71, 17 September 1947, which provided that all bombers having a tactical operating radius of over 2500 nautical miles at design gross weight and load should be classed as heavy bombers, those of 1000 to 2500 as medium, and those of less than 1000 as light. This placed all of the above in the category of light bombers. The same letter specifically designated the B-35 and B-36 as heavy, the B-29 and B-50 as medium, and the A-26 and B-45 as light bombers.

incorporates several experimental features such as the swept-back wing, underslung engine nacelles, and bicycle type landing gear. Though its performance characteristics will probably excell those of the B-45, it will undoubtedly require an extended period of development, and therefore, a tactical version will not be available for production for at least two and one half years. The B-48 airplane is somewhat more unconventional than the B-45 in that it has a 3-engine installation in each wing and also incorporates the bicycle type landing gear. Its performance characteristics are likely to exceed those of the B-45, but a tactical version of this airplane is still two and one half years away. The B-45, since it possesses the fewest unconventional components, can be made available in production in approximately one year. Such components as the wing section, wing and tail planforms, landing gear, etc. are of proven design on the B-45 airplane and should, therefore, present few development problems. Also the first XB-45 airplane will be a tactical version while the XB-46, XB-47, and XB-48 will be stripped. Because, as is noted above, the B-45 airplane departs in such slight degree from proven designs, it is the most logical one to start to produce prior to testing of the experimental model.

Although the early action proposed was not taken, a requirement was established by Headquarters, USAF, for 190 B-45's in July 1948, and contracts were let by the AMC with North American for 96 B-45A's and 94 B-45C's.[19] The 96 B-45A's were manufactured and delivered, but the contract for the B-45C's was subsequently cancelled.

Meanwhile, the B-45 was being considered during 1946 as a potential atomic bomb carrier. Col. J. R. Sutherland stated that an agreement was reached with Manhattan District in August 1946 that the B-45 design would be altered to incorporate the necessary space and load provisions to allow carriage of the atomic bomb. He later reported, however, in April 1947 that insufficient and erroneous information as to the size of the bomb had been supplied to the company and that as a result the plane would be unable to carry the FM bomb without major modification,* which had been disapproved by AAF headquarters.[20] Although the B-45 could carry the

* The principal difficulty was a large spar extending laterally across the bomb bay.

LB, the employment of this type of bomb was looked on as contrary to strategic policy and interest was lost in the design as an interim atomic bomber, although production in small quantity was ordered for conventional tactical use. Accordingly, the B-45 was not to be incorporated into the Air Force atomic program until late 1951, when about half of the slightly under 100 planes procured provided the basis for the FANDANGO Program to supply an interim tactical atomic capability for the United States Air Forces in Europe. At that time they were given the BACKBREAKER modification, enabling the carriage of the Mark V, VII, and VIII.

The second post-war jet bomber to enter production and the first of radically new design was the B-47. The design was initiated in late 1944 by the Boeing Aircraft Company at the invitation of the AAF in an attempt to meet military characteristics for a high speed, high altitude medium jet bomber issued by the Requirements Division, 17 November 1944. These called among other things for a bomber with a minimum high speed of 500 miles per hour, tactical altitude of 35,000 to 40,000 feet, range of 2,500 to 3,500 miles, and bomb load of sixteen 500 pound bombs or alternate loads of larger bombs up to 10,000 pounds if possible. The bomb load requirement was raised twice: in January 1945 to provide for a 12,000 pound bomb and in June 1947 to provide for a 22,000 pound bomb interchangeable with the atomic bomb. A letter contract authorizing Boeing to start immediately on the XB-47 project was issued 1 February 1945. However, the original relatively conventional design was to undergo drastic changes, particularly under influence of aerodynamic data on the swept wing captured from the

Germans. The first version had been somewhat similar to the B-45, with four jet engines mounted on the wings. These were first moved to the top of the fuselage in order to permit incorporation of a very thin and flexible wing. In the final version the engines, now increased to six, were underslung in pods beneath the wings, which were now swept back at a 35 degree angle.[21]

The first XB-47 was completed in November 1947 and made its maiden flight 17 December 1947. Two months before this an AMC officer had reported:[22]

> The XB-47 is the most promising of our jet-bomber projects. Its development prospects are far greater than any of the other Forty series jet bombers, and will offer improved performance with future engine development. The other bombers in this series due to their particular configurations, will not perform at materially higher speeds with increased thrust, to the extent that the B-47 configuration will lend itself . . . . In addition to lending itself to future improvements with improved engines and service requirements, it is favorable from the standpoints of maintenance, minimum hazards attending combat, and flexibility for service utility.

At this time, with 6 TG-190 engines, the following characteristics were envisaged: gross take-off weight- 130,300 pounds, landing weight--81,000 pounds, effective radius of action 1,400 miles, range--3,730 miles, high speed--630 miles per hour. Early flight evaluations confirmed the expected excellence of performance, and the AMC recommended immediate production. Comparative evaluation of all the new carriers in terms of technological advances and the latest strategic concepts resulted in a decision by Headquarters, USAF, in September 1948 to standardize on the B-36, B-50, and B-47 for the interim period, thus eliminating the B-45, 46, and 48. This decision was approved by Secretary Stuart Symington, who recommended cancellation of contracts for development of the B-54 (an improved and considerably altered B-50) and application of funds to the B-36 and B-47. The Air Force issued a letter contract on 22 November 1948 for the procurement of 10 B-47A's and a follow-on procurement of 3 B-47A's and 41 B-47B's, with deliveries scheduled for January 1950 through March 1951, at a figure of $28,500,000 for the first 10 planes. This contract was modified on 28 February 1949 for an increase to 55 B-47B's in follow-on procurement and a cancellation of the 3 B-47A's.

Meanwhile, an XB-47 arrived at Kirtland AFB for drop testing in January 1949. The contractor had faced almost the same difficulties in designing the bomb bay as in the case of the B-45, since information on size, weight, and shape had remained in the Top Secret-Restricted Data category and had not been released to contractors in detail. Nevertheless, Colonel Bunker reported: "Through good luck and heroic efforts by security handicapped AMC Project Officers, the dimensions of the first prototype B-47 are such that, with minor but undesirable modifications, the atomic bomb can be carried."[24] Modification, consisting of installing the H-frame and some alterations to the bomb bay doors, was readily completed, and by 2 February the plane had released two Mark IV facsimiles in trial runs at the Salton Sea bombing range. These were made at 35,000 feet and an indicated air speed of 232 miles per hour.[25]

Despite this promising beginning, the B-47 was not to become truly operational until late 1952. An attempt to accelerate the program by telescoping the development testing and operational suitability testing phases seemed only to create additional difficulties. As was to be expected in an airplane of radically new design, numerous changes were recommended which served to keep the airplanes which had been produced in a constant cycle of modification. Meantime, it did serve as a valuable pilot model for jet bombers of later design, particularly the B-52.

New Post-War Projects for Atomic Bombers

Post-war consideration of the development of . new medium and heavy bombers, with specific reference to the carriage of the atomic bomb, began during 1947. The military characteristics for future medium and heavy bombers, prepared by AC/AS-3 and submitted to AC/AS-4 on 23 June 1947, required a design "primarily to carry the atomic bomb internally, interchangeable with a combat load of 500 pounders up and including the

At this time planning was already going forward on the XB-51, a three-jet light bomber designed by the Glenn Martin Aircraft Corporation which was to make its first flight in October 1949, but of which only two items were to be built. More important, by early 1947 initial design work had begun on the XB-52, a proposed long-range heavy bomber employing turbo-propeller engines.

The original proposal was an attempt by Boeing to meet military characteristics for heavy bombardment aircraft dated 23 November 1945, requiring 5000 miles (4342 n.m.) radius, 400 miles per hour (347 k.) average speed, 450 miles per hour (391 k.) top speed, and bomb load of 10,000 pounds at extreme range. The Boeing proposal was for a 360,000 pound (later revised to 480,000 pound) aircraft, cruising at 420 miles per hour (365 k.), 5000 miles radius of action, with an extreme range of 12,400 miles

(10,769 n.m.). The Phase I study and mock-up proceeded during 1947 on this basis.[27] As early as April 1947 RAND raised questions regarding the basic requirements for the XB-52, doubting "the feasibility of designing an airplane, within reasonable weight limitations, of the range and cruising speed requirements called for in current heavy bomber characteristics." Though general in nature the study cast doubt on the ability of the XB-52 design to reach 5,000 miles radius of action with a 10,000 pound bomb load without an enormous increase in weight, pointing to a sharp rise in the weight-range curve as the design range was approached. RAND also favored a delta wing configuration as the most desirable for a long-range heavy bomber. As a result the Air Materiel Command was directed to consider the subject "by whatever means are considered most appropriate" and RAND was also directed to initiate discussions with Boeing.[28] Although the RAND figures were attacked as unsound by the AMC, the great weight and relatively low speed of the proposed bomber continued to arouse questions.

Further and even more definite exception was taken to the B-52 program in the fall of 1947 by a special Long Range Bombardment Committee of the USAF Aircraft and Weapons Board, a newly constituted group comprising the top command level of the Air Force. Concluding that the XB-52 in its present configuration did not present a practical solution to the long-range bombing problem, it recommended discontinuance of the current program and the establishment of new military characteristics for heavy bombers, with range reduced to 8,000 miles and cruising speed increased to 550 miles per hour (later lowered to 500) as the basis for a new project. At the same time it suggested adoption of inflight refueling as a means of achieving still greater range without going to an excessive weight. These recommendations, which were approved by the Aircraft and Weapons Board at its January 1948 meeting, became the basis for a reorientation of the XB-52 program, following extensive discussion continuing until June 1948. This hinged principally on two points: first, whether the new configuration should be developed through a change order with Boeing or thrown open to competitive bids from the aircraft industry; and second, the exact nature of the new military characteristics to be required.[29]

Headquarters, USAF, had first decided on a new competitive bids, but after protests by AMC emphasizing the loss of time and study data already accumulated by Boeing, this decision was withdrawn. However, a final decision remained in abeyance during early 1948 pending further consideration of the flying wing design favored by DCS/Operations. After strong opposition to this by the AMC and after a satisfactory new proposal by Boeing a final decision that Boeing should build the new B-52 was made in June 1948.[30] The new Boeing proposal was for an aircraft of 285,000 to 300,000 pounds gross weight, range of 8,000 miles (6956 n.m.)*, and minimum speed of 500 miles per hour (435 k.) for the last 2,000 miles into the target and first 2,000 miles out. These met the new military characteristics recommended by the Long Range Bombardment Committee, since the original speed requirement had been slightly reduced.

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* This could be further extended by one refueling.

Meanwhile, great difficulty was being experienced in arriving at requirements for the size of the bomb bay in the new atomic bomber and the weight of the bomb to be carried. Early in the design studies it had developed that the size of the bomb bay would constitute a critical design factor because of concurrent requirements for high speed and long-range. These made even small increases in drag and weight resulting from a larger fuselage of great moment. The Air Materiel Command was first directed to provide for carriage of an

However, by December 1947 the AMC had decided that these figures were impossible of attainment and secured the approval of Headquarters, USAF (over the protest of the Special Weapons Group), to a bomb size

This would provide for carriage of a bomb no larger in diameter than the Mark III, which was not an optimum figure but derived from the maximum dimensions of the B-29 bomb bay. Somewhat dissatisfied with these figures on the ground that they provided only for improved ballistics and not for a larger and more efficient bomb which might be strategically necessary, the Special Weapons Group attempted to secure information from the AEC as to the influence of a larger diameter on the efficiency of the bomb with a view to securing a modification of these requirements. Although the quick estimates secured from the AEC indicated an increased yield, this was not considered sufficient to justify the rapid increase in the weight of both the bomb and aircraft which would necessarily result.[31]

Design proposals were submitted by Boeing in April 1948, based on the figures recommended by the AMC, but the matter remained under consideration until October. In September AFOAT recommended a design to carry an atomic bomb

for a combat range of 6,947 nautical miles, or in lieu of this bomb a smaller atomic bomb

for a combat range increased by 4,000 pounds of fuel capacity. This corresponded in general to the characteristics adopted. At the same time AFOAT recommended a restudy of the B-55, a medium range high altitude bomber being considered simultaneously with the B-52, in the light of the prospective availability of both the B-47 and B-52. It suggested that if the design were retained it be reworked to provide for carriage only of a smaller atomic bomb of

or in lieu of this a substantially heavier but no larger load of conventional bombs. Although a specific development project for the revised B-52 was begun in October, 1948, the B-55 proposal was cancelled in the same month.* 32

Meanwhile, the B-52 configuration had continued to undergo changes. That presented by Boeing in April had envisaged a wing of conventional design and power plant consisting of four turbo-propeller engines, differing essentially from the two earlier versions in its lighter gross weight of 285,000 pounds. In October 1948 at the request of the AMC Boeing prepared a radically new

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* An important factor in the elimination of the B-55 appears to have been the concurrent appearance of a Navy design having greater speed and range and of about half the gross weight. These characteristics were achieved by close tailoring of the bomb bay to the Mark IV and omission of defensive armament and other heavy equipment. (Daily Diary, Materiel Branch, AFOAT, 30-31 August 1948).

design featuring swept wings and turbo-jet engines and bearing a close general resemblance to the XB-47. At the same time the gross weight estimates went up sharply, being placed between 330,000 and 390,000 pounds.[33] This configuration became the basis for the plane ultimately produced as the first post-war heavy bomber and the first Air Force plane specifically designed as an atomic carrier. The aircraft was not to fly until April 1952.

Guided Missiles as Atomic Carriers

The definite but limited success of the Germans in developing two operational types of guided missiles by 1944 and the appearance of the atomic bomb in the following year led some to believe that a quick "marriage" of the two would follow and that this would inaugurate a new era of "push-button warfare." Such estimates failed to evaluate properly the complexities which would necessarily attend the further development of each item and their possible combination into a new weapons system. They also failed to recognize the relatively "primitive" status of these two types of weapons, spectacular as they were. Each had been used under favorable conditions. The two German missiles had been fired at a target 30 miles in diameter not more than 200 miles away, carrying a warhead of less than one ton; even so, the V-1 had been successfully countered by the end of the war through the use of such other new devices as the proximity fuze and radar controlled guns. The atomic bombs had been dropped during daylight on two cities without any air defense of consequence and of extremely inflammable, flimsy construction. These drops had quickly induced the vacillating enemy to surrender, and simultaneously they had exhausted the existing stockpile. For some time to come risking precious fissionable material in carriers of uncertain reliability would be inconceivable.

Nevertheless, guided missiles, particularly those of the supersonic type, such as the V-2, opened new vistas in warfare—

both for offense and defense—and use of an atomic warhead, which was certainly a future possibility, would enormously increase the effect of a successful missile. Under the circumstances it is not surprising that the number of guided missile projects sponsored by the AAF greatly increased during the last year of the war and the immediate post-war period, with some of the later ones envisaging the carriage of an atomic warhead. It may be pointed out that the AAF and its predecessors had been experimenting with guided missiles of various types since the days of World War I (except the period 1932-1938) without any noteworthy success.

During World War II, with ample funds available, the types of missiles developed ranged from explosive carrying drone aircraft (both "war wearies" and specific missile designs), glide bombs, and high angle bombs such as AZON, RAZON, and TARZON. These employed a wide variety of control systems, including light or heat seeking, radar, radio, and television. A few types of missiles, including drone aircraft loaded with explosives and the AZON bomb, received limited operational use. In the last year of the war a group of missiles patterned after the German V-1 and powered by pulse jet engines were produced—including the JB-1, JB-2, and JB-10. The JB-2, a somewhat improved version of the V-1, actually went into production, but was not used operationally.[34]

The increased interest and number of projects in guided missiles which resulted from the unveiling of the German V weapons raised the question of the division of development responsibility within the Army for the first time. The initial effort to deal with this knotty problem, which was to become increasingly controversial after the war, was the directive issued on 2 October 1944 by Lt. Gen. Joseph T. McNarney, then serving as deputy chief of staff to Gen. George C. Marshall. This assigned the Army Air Forces "responsibility for the development of all guided or homing missiles launched from the ground which depend for sustenance primarily on the lift of aerodynamic forces." It assigned development responsibility for "guided or homing missiles which depend primarily upon their momentum for sustenance in flight" to the Army Service Forces, which of course included the Army Ordnance Department. The development of propulsion and control systems was left to the responsibility of the service sponsoring the missile, while warheads, fuzes, and non-integral launching devices were to be the responsibility of the appropriate technical service. The directive of course did not apply to the Navy.[35]

The AAF utilized this directive—which was later reenforced by a second directive of 7 October 1946 assigning "research and development activities pertaining to guided missiles" to the Commanding General, AAF—to establish some 26 active projects, with 9 others under consideration. Some of these were undertaken, however, for the Army Ground Forces. The Air Forces used this activity as a basis for requesting additional testing space at Wendover Field and increased wind tunnel facilities.[36] Nevertheless, Army Ordnance was no means idle in the still unsettled field, and there were complaints from the AAF that Ordnance was encroaching on its area of responsibility. AAF officers also protested that Ordnance had seized upon nearly all captured V-2's for its own use, even those earmarked for the AAF. For instance, General LeMay, Deputy Chief of Air Staff for Research and Development wrote in May 1946 to the Assistant Secretary of War for Air:[37]

> General Hughes gave the impression that full coordination obtains between the Ordnance Department and the Army Air Forces. Only to a certain extent is this true and by no means as perfect as outlined by General Hughes. The general situation of coordination between the Army Air Forces and Ordnance Department in guided missiles development is this: on technical information there is complete and adequate interchange; on military characteristics and basic requirements AAF has furnished AAF military characteristics to AGF and ASF, but this has not been freely returned; on contracts neither service formally coordinates with or asks the permission of the other before letting contracts considered essential to its own development program.

After detailing several examples of difficulties encountered in coordinating guided missile development with Ordnance, LeMay went on to complain about the handling of the captured German missiles:

> Much equipment was taken by AAF technical intelligence personnel in Europe which, after being turned over to the ASF shipping channels, never arrived at Wright Field. Typical of these items is the Wasserfall missile, which was finally traced to General Electric, Schenectady, and which the Ordnance Department has not yet agreed to release. Numerous models of air-launched and other missiles were traced to Aberdeen Proving Ground, but despite voluminous correspondence (on file, but not attached), AMC has yet to receive this equipment. One exception to this is the one damaged V-2 which AMC obtained and transported from Aberdeen to Wright Field. Surveys of undelivered enemy equipment have been made and accounting requested of Ordnance Department without satisfactory results.

In this situation the Air Staff considered it extremely desirable to give a demonstration of "the effectiveness of a missile fired at least one thousand miles by August 1946" in order "to impress upon the public mind the fact that the Army Air Forces have, and can use immediately, some form of guided missile."

The resulting project, designated BANSHEE (MX-767), was assigned to the Air Technical Service Command in January 1946. A B-29 was selected for modification and a control system based on SHORAN proposed, but a shortage of electronics experts resulting from demobilization continued to delay the project throughout 1946 and 1947. As a result the project gradually changed into a test program and was terminated without a demonstration in late 1949. Nevertheless, because of the atomic carrying capability of the B-29, which was doubtless intended to impress the public mind, this was in a sense the first guided missile project with atomic potential.[38]

Meanwhile, a number of other more advanced projects which were to begin to reach fruition beginning in 1952 were getting under way. The early post-war activity in guided missiles development reached a climax by the latter part of 1946, when the number of projects had increased to 28. Following the existing procedure in aircraft development these had been established through contracts, principally with aircraft companies, designed to produce either a prototype missile or at least the guidance, propulsion, or aeronautical data which would permit the construction of one. These were guided by statements of requirements issued during the summer and fall of 1945 to replace the original statement of requirements for guided missiles issued in 1938. As the result of a severe cut in December 1946 in the budget funds for guided missiles development for fiscal 1947, from $29,000,000 to about $13,000,000, it was found necessary to reduce the number of projects from 28 to 17, then to 12. These, however, still included projects in each of the four principal categories—air to air, air to ground, ground to air, and ground to ground. By June 1947 the AAF had also worked out a guided missiles philosophy and system of priorities, under which all missiles projects were placed within one of five priorities.

This history does not propose to examine in detail the guided missiles program, which has been dealt with in a separate study, but to review briefly those projects with a definite relationship to the atomic energy program. During the early postwar period very little attention was given to the problem of what was later to be termed the "marriage" of the guided missile with the atomic warhead for the reason that it was foreseen that despite the German V missile some time would elapse under the peacetime pace of development before an atomic carrying missile sufficiently reliable to warrant the risk of fissionable material would become available.* The problem was further complicated by the large size and complex nature of the FM bomb, which obviously called for much further development before application to a guided missile warhead. Although the LB bomb seemed much more adaptable for the purpose, the

* The problem was briefly considered by the JCS in the fall of 1945. The Chief of Naval Operations recommended the establishment of a joint War-Navy agency to replace the Guided Missiles Subcommittee of the JCS and correlate the development of the atomic bomb, guided missiles, and related devices. This was opposed by the Chief of Staff, U. S. Army, who recommended continuation of the Subcommittee and recognition of the newly constituted Military Advisory Board to the Officer-in-Charge of the Atomic Bomb Project as the agency to effect the correlation of atomic energy to other military weapons and equipment. (JCS 1559, 26 October 1945, and JCS 1559/2, 6 November 1945.)

loss of fissionable material through its lower efficiency made it also seem an undesirable choice, although possibly justifiable for certain targets in the lack of anything better.

Nevertheless, military characteristics for the air to ground missile, first stated 19 October 1945, provided: "The airframe for the missile shall be so constructed in size and shape that it will carry the required power plant and fuel plus a warhead

This obviously referred to the FM bomb. Minimum speed of 300 miles per hour, ground range of 300 miles, control either from 100 miles by parent aircraft or self control, 90 per cent reliability, and maximum range error of 5,000 feet were other requirements. In March 1946 AAF headquarters directed the AMC to procure an experimental missile from a contractor selected from the aircraft industry. Preparatory to circularizing Northrop, McDonnell, Bell, Republic, and other manufacturers for proposals, the AMC requested more detailed information on the physical characteristics of the warhead. Meanwhile, the project was given the code name of MASTIFF.[40]

AAF headquarters continued efforts throughout 1946 to obtain the desired information from Manhattan District, and this was finally promised in December; however, in March 1947 the project was listed as still held up by lack of information. Meanwhile, it was carried as a study by the Aircraft Laboratory of the AMC, which had prepared a preliminary analysis in March 1946. Bell, McDonnell, Northrop, and Fairchild had indicated interest and $330,000 had been allocated for fiscal 1947, but only $4918 had been expended by 31 December 1946. As a result the larger sum was reallocated and only $1,000 set aside in the fiscal 1948 budget.[41]

Nevertheless, in the reorganization of the guided missiles program finally concluded in mid-1947 the AMC recommended and AAF headquarters approved continuation of MASTIFF as one of 12 projects. It stated: "There is a requirement today, which will become mandatory by 1952, for supersonic air-to-surface guided missiles with ranges of at least 100 miles, which can carry both atomic and non-atomic warheads." On this premise AAF headquarters assigned air-to-surface missiles a first priority. The AMC proposed, however, to integrate MASTIFF into the over-all program by giving it to Bell as a longer range project to be preceded by the completion of a 100 miles supersonic missile of smaller size, SHRIKE, on which Bell had been engaged since 1945.[42]

Discussions on the proper coordination of the two air-to-surface missiles continued between the AMC and AAF headquarters during the latter part of 1947. As a result military characteristics for the air-to-surface missile were revised 22 October 1947 to provide for a speed of Mach 3.0, accuracy of within 1,500 feet radius for one of every two missiles launched, and other changes which served to somewhat generalize the previous requirements of 19 October 1945. No warhead weight or size was stated, only that it should be atomic

Meanwhile, the requirements for SHRIKE, which would serve as a pilot model, were somewhat lowered, the range being reduced from 100 to 50 miles

It was also expected that SHRIKE could serve as an interim tactical missile with conventional warhead. Meanwhile, it was proposed (with the exception of the guidance system) to suspend work on RASCAL, designation for the longer term supersonic missile to replace MASTIFF, until the completion of SHRIKE. With this program established, the Air Force began to make large sums available to Bell during 1946 to accelerate the SHRIKE-RASCAL project.[43]

Other missile projects of this period thought of as having atomic warhead potentialities or which later developed them were those for MATADOR (Martin), SNARK (Northrop), and Project MX-770 (North American). All of these were of the surface-to-surface category, the first two being directed toward subsonic interim missiles and the last being looked on as a long term project leading toward a supersonic long range missile, possibly employing nuclear propulsion Although there were also active air-to-air and surface-to-air projects, the use of atomic warheads does not appear to have been considered for these categories at this time. A study on guided missiles requirements prepared in June 1947 by the AMC, which became the basis for AAF planning and priorities, had taken a rather pessimistic view of the operational desirability of subsonid surface-to-surface missiles, and also had stressed the long term nature of the supersonic long range missiles, as follows:[44]

> 7. There is a requirement for the early perfection of high accuracy, supersonic surface-to-surface guided missiles, with ranges up to 1000 miles, for coast defense, and tactical and strategic land bombardment.
>
> 8. Although there is little likelihood that they will be operationally available prior to 1957, the potential advantages of the long range supersonic surface-to-surface guided missile and the necessity for attaining and maintaining weapon superiority over potential enemies, require that research on and development of this type proceed at the maximum rate. Ranges up to 10,000 miles are desired, with warheads in the non-atomic 500-5000 pounds class and with atomic warheads.
>
> 9. There is no operational requirement for subsonic surface-to-surface guided missiles, other than missile aircraft (drone) types. If, however, it is necessary to develop subsonic missiles as a step in attaining the supersonic, some of the former could be profitably employed for training, indoctrination, operational analysis and demonstration.

Despite these conclusions, the AMC recommended the continuation of MATADOR (Project MX-771) as an interim low-cost missile projects, having been initiated in August 1945 in an effort to meet military characteristics dated the nineteenth of that month. To enable its successful continuation the military characteristics for such a missile (500 mile subsonic) were lowered on 7 November 1947 as to the guidance system to provide for simultaneous control of 10 missiles rather than 200. Although the guidance system, a version of SHORAN, still remained somewhat unsettled, in December 1947 the AMC recommended the use of Project 180 funds (procurement of standard missiles) for fiscal 1948 for the procurement of 25 service test items at a cost of $3,500,000 as the earliest available operational missile. This was approved by Air Force headquarters and later increased to 50 items, to be procured from 180 funds for both fiscal 1948 and 1949.

Technical progress continued during 1948, and at the end of the year a MATADOR prototype was reported ready for launching under power. Early in 1949 it was being discussed as a possible atomic carrier along with SNARK and NAVAHO. At this time it was described as a turbo-jet powered missile 54 inches in diameter and 36 feet long capable of carrying a 3,000 pound warhead at a speed of 520 knots to a distance of 434 nautical miles, with a possible future extension to 868 nautical miles.[46]

Another subsonic missile project which survived the 1947 program reduction was a Northrop project, inaugurated early in 1946, aimed at filling military characteristics, dated 24 August 1945, for a long range (1,500 to 5,000 miles) surface-to-surface missile. A supersonic missile with speed of about Mach 1.6 was originally proposed, but this was to be preceded by a subsonic missile. After the AMC recommended in June 1947 elimination of the phase of the project calling for a subsonic missile, Northrop carried its fight against this to AAF headquarters, and a compromise was effected. It was agreed that the emphasis of the project would be shifted toward the development of an operational long-range subsonic missile, while the supersonic aspect would be reduced to a long-term study project. In recommending this change the Guided Missiles Branch argued that the revised program would provide an interim missile at relatively slight cost, since a similar effort would be needed in any case to provide the development information needed for the long term supersonic missile. The same guidance system, based on automatic celestial navigation, would be used for both missiles. This would constitute the major problem, although it was also estimated that a suitable turbo-jet propulsion system for the supersonic missile would require at least seven years to develop. Shortly afterward, it was estimated that the subsonic version could be available by late 1952.[47]

In January 1948 Maj. Gen. E. M. Powers, Assistant Deputy Chief of Staff for Materiel, stated that this project was "one of the most realistic developments in our guided missile program." The forecast at this time was for a range of from 4,000 to 5,000 miles, a speed of 600 miles per hour, and an accuracy of from 2 to 3 miles with 50 per cent hits. The total cost through the service test stage was estimated at $41,000,000.[48]

Meanwhile, military characteristics for the 1,500-5,000 mile surface-to-surface missile were revised on 7 November 1947. As in the case of air-to-surface missiles, requirements were made more general in nature. An important change was the assignment of first priority for payload to an atomic warhead and second priority to a substitute Although no specifications were given as to the size and weight of this, it was provided that "Special considerations dictated by the first priority warhead and its operation will be incorporated in the missile.[49] Despite the great favor with which the SNARK, designation of the Northrop subsonic missile, was regarded by Air Force headquarters, some delay was experienced in securing funds for the accelerated program, but this difficulty was overcome early in 1948. In September $3,500,000 in addition was secured from a supplemental 180 fund for fiscal 1948 to permit contracting for the procurement of 16 SNARK missiles.[50]

By early 1949 the design was solidifying, and SNARK was described as a turbo-jet missile with fuselage 58 inches in diameter and 55 feet in length. It was expected to have the capability of carrying a 5,000 pound warhead at 520 knots to a distance of up to 4,342 nautical miles. It was suggested that the missile might carry a bomb with a lowering of range to 3,500 nautical miles. It was scheduled for completion during 1953, and progress on the guidance system had been especially promising.[51]

The missile project most directly related to the atomic program, at least during the early post-war period, was MX-770. Undertaken by North American Aviation, Incorporated, under a letter contract dated 29 March 1946, it was extremely broad in scope and long range in aspect. Directed toward the ultimate development of a long-range supersonic surface-to-surface missile, it called for an extensive program of background research, including a comprehensive study of propulsion systems, among which was mentioned research and testing in "atomic power." The contract also referred to "study of structures, metallurgy, launching systems, and explosive warhead installations as required," and also stated that this enumeration was intended as a guide and not to limit the extent of the research to be conducted. The AMC was, however, enjoined to exercise constant supervision to avoid duplication of work by other organizations.

As explained elsewhere in this volume, North American first devoted itself to preparing an ambitious development proposal for a nuclear engine.* This was rejected because of the establishment of NEPA Project (MX-821) as the coordinated effort by the Air Force in nuclear propulsion. By the time of the AMC evaluation of the guided missiles program in May 1947 MX-770 had developed into a proposal for a three phase program, in which successive supersonic missiles of 500, 1,500 and 5,000 miles range would be produced. The first of these would be propelled by a rocket engine, the two latter by ramjets. The continuation of the three phase program was recommended by the AMC, and competing projects being conducted by Republic and Consolidated were eliminated. During 1948 the range requirement for the first phase missile, denominated as XSSM-A-2 or NAVAHO, was raised to 1000 miles, and it was planned to accelerate the program to bring the project to the fabrication stage by early 1951.

At this time NAVAHO had taken form as a missile of 6 feet diameter and 46 feet length, capable of carrying a 3,000 lb. warhead to a distance of

*See Chapter XV.

900 nautical miles. Completion was estimated for 1953.[52]

Despite the establishment of the above projects, some with specifically stated requirements for the carriage of atomic warheads, those charged with the direction of the Air Force atomic program apparently did not give a great deal of attention at this stage to the problem of directly relating atomic weapons to the development of guided missiles. This was probably principally because of the greater concern with gaining a foot in the door in atomic development for the Air Force and with building up an extensive operational capability, together with the post-war shortages of funds and specialized personnel. Another factor may well have been the separation of responsibility which followed the break-up of the Office of the Deputy Chief of the Air Staff for Research and Development in mid-1947. The Special Weapons Group was much more specialized in purely atomic matters, while other functions of the old office in the research and development field went to the newly created Directorate of Research and Development.

Toward the end of 1948 AFOAT began to show increased interest in the subject of both controlled bombs and guided missiles as atomic carriers. In October Lt. Col. L. D. Clay reported to Maj. Gen. D. M. Schlatter, the new head of the office:[53]

> At the present time there is no work underway dealing with the delivery of atomic weapons by controlled methods, i.e., air-to-surface guided missile, or surface-to-surface guided missile. It is true that Project MASTIFF, which is a project concerned with the development of an air-to-surface guided missile with an atomic warhead, has been thought of, but unfortunately no funds have been devoted to this project and the project has only been a planning project, so to speak.

Colonel Clay also investigated TARZON as a possible bombing system for atomic use, but reported that it was currently unsatisfactory because of the necessity for visual following of the tail fire, a requirement necessitating straight and level flight plus good weather. Reporting that the Guided Missiles Group, DCS/O, was currently initiating the requirement for a better system, he recommended that it be asked to investigate the application of bomb control systems to atomic weapons.

The problem also reached the T&TLC, and Col. Howard G. Bunker commented that the RAZON-TARZON system was unlikely to greatly improve accuracy over free drops, an opinion later to be confirmed in Korea. He concluded that at best it would be only an interim improvement and that what was really needed was an air-to-surface missile of much longer range than a controlled bomb.[54] A few weeks later Colonel Bunker proposed that since the first successful air-to surface missile might be developed within three years the time was appropriate for "a meeting of minds" between guided missile development personnel and those of the atomic bomb development program.* He suggested a conference at Kirtland attended by representatives of the Guided Missiles Group, DCS/O; the Guided Missiles Branch, DCS/M; the Guided Missiles Section, AMC; AFOAT; and the AEC.

The conference was held at Kirtland on 14 and 15 February 1949 with Air Force personnel only in attendance, and it was immediately realized that much must be done before even a beginning of a "marriage" program.

*Another factor in encouraging guided missiles activity was the prospective availability of both ELSIE and the smaller implosion bomb (TX-5). See Chapter XIII.

General Bunker reported that the Air Force guided missiles program was not sufficiently crystallized to warrant a meeting with AEC development personnel. He went on to state:[56]

> It was felt that prior to such a meeting with the AEC the Air Force should prepare an exhaustive study in which both the strategic problems as well as the weapon development program should be thoroughly studies and a probable year-to-year phasing of our operational techniques and weapon availability established. Since this involves the agencies of the Air Staff, and perhaps assistance from the Rand Corporation, which is engaged in a study of methods of waging warfare, it was concluded that the answer to this type of problem could only be determined after many months and full coordination throughout the Air Staff.

(Memorandum Report: Atomic Warhead-Guided Missile Meeting, FOFAE, 14-15 Feb. 1949, by Chief, FOFAE.) This problem of correlating the two programs will be considered in a subsequent volume.

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CHAPTER XIII

THE NEED FOR IMPROVED BOMBS

At the end of the war there were two distinct types of atomic bombs--each with serious defects. Although development of an improved weapon began almost immediately, these remained, with very slight changes, the only operational bombs for almost four years to come. The Nagasaki bomb, a duplicate of which had been fired at TRINITY (Unclassified), was variously designated the FAT MAN (Restricted), FM, 1561, and Mark III, Modification 0. It began to pass into stockpile during the fall of 1945 and constituted the bulk of the stored weapons until 1950. It was replaced in production by the Mark III, Modification 1, during 1948 and by the Mark IV during 1949. The weapon dropped at Hiroshima, the LITTLE BOY (Restricted) or LB, was not stockpiled in quantity, despite its smaller size and superior ballistics, because of its great inefficiency in the use of fissionable material.[1]

Defects of the Mark III

The deficiencies and limiting inconvenience of the Mark III as an operational weapon were immediately recognized by the AAF officers who had to deal with it. Most of these centered around its great size and weight, awkward shape, complexity of fuzing and firing mechanism, poor ballistics, the complex and lengthy assembly procedures required, and the serious aeronautical and structural weakness of the empennage. The maximum dimensions of the bomb, were dictated by the size of the forward bomb-bay of the B-29 while its minimum dimensions were dictated by the general design of the bomb, particularly the large amount of explosive arranged in a sphere, the need for detonating this from points simultaneously, and the elaborate fuzing system, aimed to achieve maximum reliability (estimated at 1:10,000) in an air burst.

The poor ballistic coefficient* of the bomb, approximately 1.2, coupled with weaknesses in the design and structure of the empennage, made necessary an extensive training program for bomber crews utilizing the weapon. The accuracy of the results achieved at Nagasaki temporarily distracted attention from this problem, but the gross inaccuracy of the drop at CROSSROADS (unclassified) strongly focussed attention on the need for improvement. Although an extensive competitive training program had been used to select the crew, the results were so bad that they caused serious embarrassment to the AAF and demonstrated that only changes in the bomb itself would correct the situation.[2] Since the B-29 was the only aircraft immediately available to carry the bomb, a change in the fineness ratio to attain an improved ballistic coefficient was impracticable, and attention was therefore directed to other aerodynamic factors, particularly the tail structure.

A second weakness centered around the limited duration of the prepared state of the bomb and the difficulty in the assembly and arming procedures. The life span of the batteries, once charged

*This term is defined by the Tripartite Glossary as "the measure of the ability of a missile to overcome air resistance." It is computed in terms of a ballistical unit by consideration of the mass, diameter, and form factor, the latter being derived by actual testing.

and installed, was nine days, during which period they had to be recharged twice. Furthermore, the accumulation of heat around the nuclear capsule required its removal after 10 days. Neither operation could be performed without a complete disassembly and reassembly of the bomb, a process requiring about 16 hours.[3]

A third problem lay in the use of a fuzing and firing system so complex that a special aircrew member, the weaponeer, was required to monitor the condition of the bomb during flight and to arm it prior to release. The basic element in the fuzing was the AR-9A1 fighter-plane tail-warning radar unit, specially modified to transmit a firing signal at a predetermined altitude

For greater certainty four of these units, generally referred to as Archies, were employed. As safeguards against a premature firing signal resulting from such causes as radar reflections from the aircraft, the Archies were prevented from operating for a time after leaving the aircraft--for 15 seconds by clock switches and until a predetermined altitude

by barometric switches. The firing system provided for applying a high voltage obtained from lead-acid batteries coupled to a phase inverter and step-up transformer simultaneously to detonators distributed over the sphere of explosive. Nearly all main items in the fuzing and firing systems appeared in duplicate or quadruplicate, so interconnected as to avoid either failure to operate or premature operation.

Other difficulties and hazards arose from the great weight and diameter of the bomb, which made the operation of placing it under and raising it into the bomb bay a matter of serious moment requiring the use of elaborate equipment; the necessity for the aircraft taking off with the nuclear capsule in place, which might result in a catastrophic explosion with at least partial nuclear participation in the event of a take-off accident; the use of nose detonators of mercury fulminate to insure destruction of the bomb in the event of failure of the electrical fuzing and firing system; and the impossibility of changing fuze settings after assembly.[4]

Most of the deficiencies in the Mark III were sufficiently obvious from the beginning. Since several were the result of hasty designing to meet war-time deadlines, the first major post-war mission of the Z Division of Manhattan District was to re-engineer the bomb with the particular aims of simplifying production and assembly and of improving ballistics. This project apparently made very slow progress during 1946 and 1947, probably because of the loss of technical personnel, the demands of Operation CROSSROADS, and the organizational difficulties attending the dissolution of the Manhattan District and formation of the AEC and AFSWP. It should be noted that the AAF was given no responsibility and played only the most indirect role in the design of the original bomb, nor was it able to influence directly the reworking of the design until late 1947, when it secured representation on the MLC and participation in the AFSWP. During this early post-war period the efforts of the AAF in the development phase of atomic warfare were almost entirely confined to the modification of aircraft, such as the C-97, for transporting and assembling the bomb, and the development of improved handling equipment.[5] These were areas of activity conceded by Manhattan and the AEC.

One result of this situation was that the AAF's explanation of the bombing error at Bikini was received with skepticism by other agencies within the military departments.[6] Instead of directing attention to the very poor ballistics and structural weakness of the bomb the principal result of CROSSROADS was to overemphasize the destructive potentialities of an underwater burst and set off the consequent clamor for a penetrating weapon. This permitted Project ELSIE (Restricted) to be inaugurated despite the opposition of the AAF, considerably ahead of a program for the development of improved weapons. Under the circumstances it is not surprising that the development of the Mark IV also went forward slowly or that when it at length appeared, though ballistically improved, it failed to incorporate other features much desired by the Air Force.

Establishing Requirements for the Mark IV

The AAF report on the bombing error at CROSSROADS certainly implied the need for correction of its cause, but the AAF took no official action, possibly because of awareness that the report was already available to the responsible officials within Joint Task Force One, including Manhattan District representatives.[7] The first official recommendations by the AAF appear to have been those proposed by the Tactical and Technical Liaison Committee on 15 August 1947, more than a year after the Bikini tests. These called for relatively minor modifications, apparently gleaned from the operational experiences of bomb commanders and weaponeers: (1) increased battery life, (2) in-flight setting for height of burst, (3) replacement of the radar fuzing system by a time and/or barometric system, (4) development of a bomb parachute or drogue for emergency jettisoning or harbor mining. The first and fourth of these recommendations were also approved by Colonel J.R. Sutherland of the AMC, who pointed out that the development of in-flight setting was already being carried out for the AEC as a special secret project by the Air Materiel Command and that the Command was also working on an improved radar fuzing system on the same basis. He also suggested that a study on improving the ballistics of the bomb be undertaken. The recommendations were passed for comment to the AFSWP, which agreed only with those concerning extending battery life and the development of a jettisoning parachute or drogue.[8]

Meanwhile, on 18 August 1947 the Military Liaison Committee had recommended that the Armed Forces Special Weapons Project prepare a paper for the Joint Chiefs of Staff setting forth the development problem for all conceivable methods of delivery of the atomic bomb. It was proposed that this serve as the basis for a JCS directive to the Atomic Energy Commission and the AFSWP delineating the entire development program for atomic weapons, including a statement of relative priorities.[9] The AFSWP immediately asked the services for statements of proposed military characteristics of atomic weapons and respective priorities. Such a statement was prepared for the Air Force within the Special Weapons Group and transmitted to the AFSWP on 18 December 1947, though without assignment of priorities.[10] It covered four areas--the atomic bomb, atomic warhead, surface-to-surface guided missiles, and air-to-surface guided missiles--specifically excluding for later consideration radiological warfare, surface-to-air missiles, and aircraft. The military characteristics thus assembled were quite general in nature, and apparently were without any immediate influence on bomb development other than to stimulate thought. The AFSWP also found the study assigned to it by the JCS extremely unwieldy, and it did not appear until the summer of 1948. The results of this will be later discussed.

Of much greater immediate significance in influencing bomb development was a conference on 23 December 1947 at Los Alamos attended by Colonel Bunker of the T&TLC; Colonel Sutherland of the AMC; Colonel Canterbury, Captain Hayward, and Commander Schaffer of the AFSWP; and Dr. Bradbury of the AEC. This apparently represented the first "break-through" by the Air Force to direct contact with those responsible for bomb development, and a number of problems connected with the bomb were discussed. The need for in-flight insertion to improve disaster control was made clear by the Air Force representatives; however, Dr. Bradbury stated that such a characteristic would require at least two years to develop, and would lead to complication of both weapon and aircraft. He agreed that in the case of the Mark IV there was a good chance that the capsule might be removed during flight, and plans were made to test this procedure. It was brought out that the nose fuzes had been deleted from the Mark IV, a modification also much desired by the Air Force. However, Dr. Bradbury stated that there was "no present intention to improve the ballistics of the FM or Mark IV for the purpose of improving bombing accuracy, which is considered adequate in view of the large destructive radius." Some attention was being given to improving the aerodynamics of the bomb. Apparently this referred to "cleaning of the exterior and somewhat improving the shape of the casing, little was done on the tail structure until the summer of 1948.[11]

Work on the Mark IV went forward steadily but slowly throughout the first half of 1948, with the AFSWP becoming more active in this through the work of its new Development Division, headed by Col. William M. Canterbury, a USAF officer. The Air Force participated ...ally on a somewhat informal basis through the activity of the ... and Project W-47. On 29 March an unrehearsed test of nuclear ...ction and insertion was carried out in a grounded B-29 at Kirt... Field. This required 31 minutes, about one third of predicted ..., although no specially designed tools were employed. As a result the AFSWP proposed formally through the MLC that the AEC undertake a study of the redesign of the Mark IV to facilitate in-flight insertion. The AEC agreed to the modification on 17 June. On the recommendation of Colonel Canterbury, Lt. Col. W. N. D'Ettore, ..., was ordered to Sandia to work out the procedures and tools for ...ation.[12]

Meanwhile, the MLC had voted at its meeting of 27 April 1948 to inform the AEC that production and stockpiling of the Mark IV bomb would be expedited. By this time the design of the Mark IV was nearly complete except for the provision of inflight insertion and the revised aerodynamic features, particularly the improved empennage. To deal with this unsettled problem Colonel Canterbury persuaded the AEC to call in expert aid from the aircraft industry. A small ... of aerodynamicists headed by Mr. J. K. Northrop was recommended ... Air Force and assembled for a conference at Sandia Laboratory ...-27 May 1948. The meeting was also attended by representatives of the T&TLC, AMC, and AFSWP. A test program involving drop and wind tunnel testing, carried out under the supervision of the Development Division, AFSWP, resulted from this, and a tail configuration employing wedge type fins and a perforated drag plate was evolved. This gave considerable improvement in yaw, pitch, and roll over the box-type tail previously employed, particularly in the high-Mach-number phase of the trajectory. The same group of aerodynamicists also suggested at a subsequent conference on 2-3 September the substitution

for the current one employed in both the Mark III and IV, indicating a probable saving of from 2000 to 2400 pounds. This was too late for the Mark IV, but was to be incorporated in the Mark VI [13]

Up to the summer of 1948 the desires of the Air Force relative to the military characteristics of new types of atomic bombs, including the Mark IV, had been expressed informally by the T&TLC, generally through AFSWP. The Air Force Office for Atomic Energy now suggested to the Field Office for Atomic Energy* that the time had arrived to present the AEC, through the MLC, with a formal statement of "its desires for improvements or modifications to the Mark IV bomb or to bombs of the Mark IV basic diameter." In reply Colonel [illegible] pointed out that the Mark IV was now practically a complete item, and that any major changes proposed at this time would mean a great delay in its mass production and stockpiling. He therefore

* This was the new designation (without essential change in function) of the T&TLC, effective 6 August 1948. The Special Weapons Group had become the Air Force Office for Atomic Energy five days earlier.

...gested that any requests made to the AEC be confined essentially ...changes already under consideration, particularly the following: (1) predictable and reproducible ballistic characteristics, (2) in-...ertion and extraction of nuclear components, and (3) development and stockpiling of different high explosive charges adaptable to designs. For longer term consideration he pro-...ed that the AEC be requested to investigate the following subjects ...possible development: (1) the safety factors surrounding core ...ing within the assembled bomb, (2) extension of battery life to ...mit a longer assembly period, (3) in-flight adjustment of aeros ...d archies. (4) greater reliability and accuracy in the fuzing and ...firing assembly, (5) smaller diameter and less ...ght but without serious reduction of nuclear efficiency, (6) a bomb of greater fineness ratio to exploit the longer bomb-...s of the proposed B-52 and B-55.[14]

This exchange of correspondence became the basis for the prepara-...n of a detailed statement by the Air Force on the military character-...istics of FM type atomic weapons. This was prepared by AFOAT with the assistance of FOPAE and coordinated with other sections of the Air Staff during the fall of 1948. Several months were then spent ...ordinating the statement with the other services, the MLC and the AEC so that it would represent the viewpoint of the National Military Establishment and "be an effective departure for an intense and sympathetic R&D program in the AEC." It was finally transmitted ...the AEC formally on 18 May 1949.[15]

Meanwhile, the development of the Mark IV continued with the principal guidance coming from Field Office for Atomic Energy and the Development Division, AFSWP. The final design of the Mark IV was completed during the early part of 1949 and the new bombs began to go into stockpile during the summer of 1949. Although the bomb did not incorporate the lightweight case or any basic change in the fusing system, which remained the clock-baro-Archie combination it did contain a number of modifications which made it very acceptable to the Air Force. Assembly and servicing of the most vital elements of the bomb were greatly simplified so that forward assembly was now reduced to one hour.

The Penetrating Weapon Project

Although the development of the Mark IV was the major project in

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* The principal change was the substitution of a single circuit spark coil and condenser for the much more elaborate phase inverter and [illegible] transformer combination.

** The ballistic coefficient was raised from about 1.2 to about 2.5.

the field of atomic weapons development during the three years immediately following the war,

These were later designated respectively the TX-8 and TX-10 Work on this project began at Los Alamos in September 1946 on the personal directive of General Groves, according to a later statement by him. The spectacular result of the underwater burst at CROSSROADS was undoubtedly the immediate motivating factor. Although this represented the explosion of an FM bomb, it was obvious that this type because of its fragility could not be readily adapted for an unretarded underwater detonation after a free air drop.* The LB on the other hand was relatively simple and rugged. Also, its smaller size made it suitable for carriage in smaller aircraft. Unfortunately, its low nuclear efficiency made it extremely wasteful of fissionable material. This, however, appeared less important prior to SANDSTONE than afterward,

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After the establishment of the AEC, work on the penetrating weapon appears to have gone forward slowly, if at all, although in January 1948 General Groves stated that he knew of no order rescinding his directive initiating the project. The development of the weapon was, however, to become almost entirely a project of the

* The AAF later proposed the development of a technique for dropping with a drogue parachute, but this failed to make immediate headway.

Navy's Bureau of Ordnance, which had produced the LB. The Navy, with the strong support of the newly organized Committee on Atomic Energy of the Research and Development Board, moved to revive the penetrating weapon project from its dormant status during the summer of 1947. During the following months the Air Force fought a losing battle against the proposed project, which it considered an ill-advised and backward step, until shortly before its final approval the following spring, when the Air Force reluctantly concurred.

The adaptation

appears to have been first officially discussed at the inter-service level at a meeting of the CAE in July 1947, when it was mentioned as a means of radiological contamination. At the ninth meeting of the CAE on 2 October the subject was again raised by Admiral Parsons, and as a result the CAE recommended the development of the weapon to the JRDB with the further suggestion that the AEC permit the development work to be performed by the Bureau of Ordnance. When the JRDB requested the opinion of the chiefs of the military services the Navy expressed approval, as did the Army subject to certain reservations. The Air Force, however, expressed disapproval on five different grounds: (1) lack of integration of the proposal with an overall atomic weapons development program, (2) inherent technical and economic inefficiencies of the weapon, (3) conflict with and possible delay of more urgent programs of the AEC, (4) the fact that the project, if justifiable, should be under the control of the AFSWP, (5) the fact that the suitability of the penetrating weapon in an over-all weapons development program had not been determined by the Armed Forces. As a substitute for the

...e recommendation it proposed that the JRDB inform the JCS of ...e estimated technical performance and estimated time schedules ...f current and proposed atomic weapons systems" for an appraisal ...f their strategic value and that if a project for a penetrating ...eapon were approved as part of the over-all program the AFSWP be ...ployed as the agency for correlating and implementing the project, ... upon the facilities of the Armed Forces as needed.[18]

Referred to the CAE by the JRDB, the Air Force objections were ...ruled, the CAE pointing out that later consideration by the ...S was not precluded. General Groves unexpectedly failed to support the Air Force position, denying that the AFSWP had an interest in the development. The CAE decision was approved by the JRDB at its ...ting of 25 March 1948 and passed on to the MLC for transmission to the AEC. Meanwhile, the AEC had concurred with a preliminary ...uiry from the MLC that an optimum [redacted] weapon was the most promising line of attack on the problem from a short-range point of view and that the Bureau of Ordnance might undertake the mechanical phases of the development after specifications for the nuclear aspects were supplied by the AEC.[20]

Although the issue was now essentially settled, the MLC again asked for the opinion of the services prior to the transmission of its request to the AEC. Secretary Symington, replying on 9 April for the Air Force, bowed to the inevitable by concurring in the ...sirability of research and development on the penetrating weapon ...d offered the aid of the Air Force in considering such phases as ...dynamic properties, circuitry, monitoring, releasing, bombing ...tems, and methods of delivery. He also suggested that the project be closely monitored in the light of the objections voiced by the Air Force, proposing (1) that the AEC initiate the program without delay providing there was no conflict with the rest of the weapon development program, (2) that "appropriate joint agencies immediately scrutinize the technical possibilities and strategic and tactical implications" of the penetrating weapon and other LB weapons, (3) that a thorough evaluation of the military worth of the weapon in relation to the stockpile of fissionable material be maintained by joint agencies, (4) that any research and development on weapons which might interfere with other atomic development or use of critical materials be based on this review, and (5) that any Armed Forces participation in an atomic weapons project be under the surveillance of the AFSWP.[20]

The Navy seized this final review as an opportunity to propose that the scope of the project be extended to include an airburst weapon of considerably lighter weight than the penetrating weapon, stating that this development could proceed concurrently. The MLC informed the AEC on 9 April that it considered the decision of the JCS to represent the wishes of the NME and followed this with another letter on 13 May summarizing the opinions of the military services and pointing out the capability of the AFSWP. The AEC requested the Chief, Bureau of Ordnance, on 27 April to undertake the non-nuclear phases, suggesting the code name MINNIE (Restricted) for the project. This was later changed to ELSIE, and the weapon given the numerical designation TX-8 The Navy lost little time in pushing ahead with the project, and by 3 September 1948 was able to outline it in some detail, setting forth the size, shape, and weight of the proposed TX-8 the time schedule; and the cost.

The manufacture of the prototype was expected by January 1951. The cost was estimated at $3,127,600.[21]

There is no doubt that a number of high Air Force officers in the atomic program felt that the inauguration of the penetrating weapon program by the Navy represented a signal set-back for the Air Force in its struggle for a larger hand in research and development on atomic weapons. Col. John M. Armstrong later stated that many behind-the-scenes maneuvers took place which did not appear in the above recorded decisions and events. He contended that the position of the Air Force in opposing an immediate initiation of the ELSIE Project was soundly based on two main grounds: (1) it would jeopardize the requirement for a maximum stockpile of FM type weapons, and (2) there was little or no requirement for the United States to have penetrating weapons. He also pointed out that the procedures by which the project had been established violated the concept of relationships between the JRDB and the JCS in the selection of new weapons systems for development. There appears also to have been the feeling within the Air Force that the penetrating weapon project would serve largely as a cover for the development of a

Establishing Requirements for the Mark V

The question of developing an implosion bomb of smaller size than the Mark III and IV came under consideration at about the same time as the proposal for a penetrating weapon, but for various reasons it made slower progress. The resources of Los Alamos and its Sandia extension were principally taken up with the development of the Mark IV, and the influence of the Air Force was placed behind its early production and stockpiling. Preparation for Operation SANDSTONE, which would test the new types of nuclear pits, was also a considerable burden during 1947 and 1948, and much further development would hinge on the answers obtained there. It was also recognized that a reduction in size would necessarily lead to a reduced efficiency in the use of the scarce and expensive metal plutonium, the only fissionable material certainly known to work in an implosion bomb. From the standpoint of the Air Force it may also be pointed out that it had in 1945 an aircraft which could easily carry the current bomb and had under development an aircraft, the B-36, which could carry two such bombs at once. Its strategic concept also favored larger bombs rather than smaller. The principal gain for it in a smaller bomb would be in range extension, a factor which became of increasing importance with the high speed turbojet bombers under development. However, this gain could not be fully achieved unless the aircraft was designed from the beginning for the smaller bomb.

The MLC recommendation that the AFSWP prepare a broad study on the development problems surrounding the future methods of delivery of atomic weapons, made in July 1947, included an opinion that additional types of delivery vehicles should be available to provide operational flexibility and that this goal was attainable only through the development of smaller and lighter weapons.[23] The subject was further discussed at a joint meeting of the MLC and CAE on 20 October at which the CAE concluded.

> As a result of its discussions, the Committee finds that the military requirements for atomic weapons to be delivered by aircraft or guided missiles are such that the present Nagasaki type atomic bomb does not lend itself to wide and flexible employment. It is the view of this Committee that a weapon which is both lighter and smaller in overall size than the present type will be of considerable military importance.

The CAE advised the MLC that it considered it untimely to make specific recommendations to Los Alamos because of the burden of the forthcoming atomic tests, but it did suggest that the MLC advise the AEC of the importance of the lighter weapon problem and that it should be further considered after the tests. In reply the AEC promised that a vigorous program of development in this would be initiated.[24]

Nothing further appears to have been done in regard to this subject until August 1948, when the AEC informally notified the Air Force that it was ready to proceed on FM bombs of reduced size and weight and asked "what the USAF desires in weight and size, what NT equivalents would be acceptable, how important such developments would be to deliverability of bombs, what reductions in efficiency and in possible total damage area within limits of available fissionable material would be acceptable." It further indicated "that if no guidance is obtained in this matter, they will propose a research project based on their own intuitive guess as to what the military could use."[25] As a result AFOAT, working with FCFAE, assembled a proposed comprehensive statement of Air Force requirements for implosion type weapons development which it coordinated with other sections of the Air Staff for possible presentation to the C.S. This would have assigned fourth priority (after three desired modifications to the Mark IV)

These figures had been suggested at a conference at Los Alamos on 2-3 September 1948 attended by a group of aeronautical experts called to advise the AEC on the ergonnage of the Mark IV and by representatives of the Air Force, Navy, AFSWP, and AEC.[26]

Meanwhile, after informal concurrences with the Air Force through the Field Office, the AEC had proceeded to establish a development program for the smaller FM weapon, without very definite design parameters, though it was believed that a bomb

could be produced with little reduction in efficiency. At this point the Navy began to press for the establishment of more definite characteristics, proposing through Admiral Parsons that the Air Force join with it

apparently because it wished to proceed with the design of a carrier-based atomic bomber around these figures. The Air Force, however, was unwilling to establish such definite requirements so early in the development program for three principal reasons: first, the preliminary design of both the B-52 and B-55 were well established with provision for carrying a bomb

a capability which the B-47 would also have, and the Air Force was more interested in greater efficiency from the larger bomb than the development of a smaller; second, it believed that the efficiency of the smaller bomb would be jeopardized by too early a fix on a definite size; third, as in the case of the penetration weapon it contended that the smaller bomb should only be considered against a complete background of atomic weapons systems as a whole and that this must await further extensive studies on desired yields as related to specific target and delivery systems. During the fall of 1948 it accordingly developed greater and greater reluctance to participate in the establishment of definite design parameters for the smaller weapon which would be immediately reflected in a development project. Instead it pressed for a broad analysis of atomic weapons systems and the assignment of relative priorities within this.[27]

On 4 October the AEC suggested to the MLC that the services prepare studies on deliverability as a function of bomb weight and size in order to provide guidance for Los Alamos.

The Navy study, prepared by the Bureau of Aeronautics, concluded after indicating various improvements in performance to be expected from carrier-based attack planes with reduced bomb load:[28]

> Unless available information indicates that the decrease in bomb effectiveness with reduced weight and size is so powerful a consideration as to cancel completely any gains likely to be realized through reduction of attrition rates attributable to increased aircraft performance, it recommended that effective steps be taken to design and produce bombs of reduced size and weight as expeditiously as possible. To produce tactically significant improvement in aerial delivery, it is important that the reduction in diameter and weight proceed at least to, and preferably much below, combination indicated.

Recognizing the extreme complexity of the problem, which was based on a large number of variables already under analysis, the Air Force did not present a reply, but continued to work on the over-all statement on FM weapons previously mentioned. Nevertheless, the MLC continued to emphasize the importance of the development of the weapon. On 2 December 1948 it stated in commenting on the Los Alamos program for 1949:[29]

> Although quantitative data are not yet available, it is clear that any reduction in weight will result in improved combat performance of carrying airplanes. This improvement is an urgent military requirement, and the development and engineering of a smaller and lighter implosion weapon should proceed accordingly.

It also suggested that development go forward on a schedule to produce a completed weapon for testing by early 1951 and a "substantial conversion" of the stockpile by January 1952. Later that month, in response to questions from the AEC as to acceptable yields for such a weapon, it replied that for planning purposes yields in the range of would be acceptable.

Meanwhile the Air Force completed and turned over to the MLC its over-all statement on characteristics of implosion weapons, and on 21 December 1948 the MLC forwarded this to the AEC for comment. This paper, entitled "Desired Military and Technical Characteristics of FM Weapons," included the statement of a requirement for a smaller FM bomb [30]

Upon decision on the exact size of the explosive sphere and the concurrent diameter and weight of the entire bomb, scheduled to be decided on by August 1949, the development of two cases was to be embarked on.

respectively and in that order of priority. Except for the special characteristics that the bomb should not require in-flight monitoring, it should otherwise conform with the desired future characteristics of the Mark IV. Testing was to be possible by early 1951 and stockpiling by 1 January 1952.

However, the smaller bomb, which the AEC had already designated the CX-5 was assigned second priority behind a group of five selected improvements for the Mark IV. These, which had been reduced in number and generalized in order to secure coordination from the Navy, were as follows: (1) "predictable and reproducible ballistic characteristics and . . . acceptable high altitude and high speed ejection characteristics," (2) "technique and tools for insertion and extraction of the nuclear components of the bomb during flight," (3) "a lightweight casing for the bomb," (4) "a dependable internal power supply which requires a minimum of testing and servicing during operations," and (5) "improvement of the bomb firing system so as to offer, with dependable operation, the least practicable chance of being pre-triggered or jammed."

The statement also listed in third priority some 16 additional desired but less urgent characteristics for FM atomic bombs of the current diameter. In fourth priority was placed the development of bomb configuration and tail assemblies around improved Mark IV components which would take full advantage of new bomb bay dimensions for improving high speed and high altitude ejection and ballistic characteristics. It was made clear that this referred in particular to the B-47 and B-52, both of which would be capable of carrying a bomb of

Important excisions during the course of revision included the drogue requirement, water penetration characteristics, and specific kiloton yields.

This statement, which was to be accepted by the AEC without drastic change, was the first important, fully coordinated, and official statement of characteristics for atomic bombs of the implosion type. In preparing it the Air Force appeared to be acting reluctantly because of doubt as to the tactical utility of the proposed TX-5, the loss of fissionable material which would necessarily result from its lower efficiency, possible interference with the Mark IV program, and the prior design of new bombers like the B-47 and B-52 around the bomb. Several factors, however, forced the Air Force to act prior to the over-all study of targets and atomic delivery systems which it had argued was essential while resisting the penetration weapon program. Los Alamos was restive under a program based only on the cleaning up of the Mark III and wished to push into new and challenging weapons problems "to sustain morale." The Navy was eager for the smaller weapon and wished to design a carrier-based bomber around it. Under the circumstances the Air Force had to coordinate the TX- with the implosion weapon development program to preserve a position of leadership and to protect its interest in the Mark IV. Otherwise, the TX- might have been established as an independent project similar to ELSIE.[31]

Consideration of Larger Diameter Bombs

The above program of research and development made no provision for an [illegible] bomb of greater size or for bombs employing thermonuclear reactions, although the possible future need for both was considered to some extent by the Air Force during this period. The subject of larger FM bombs arose in connection with the design of the B-52 and B-55, the first heavy bombers of post-war design. Military characteristics for these aircraft, both of which were under way in late 1947, provided for a bomb bay capable of carrying a bomb   Somewhat tardily, in December 1947, the Special Weapons Group queried the AEC through the MLC as to the desirability of a bomb of greater diameter. Dr. Bradbury stated that Los Alamos had never been approached on this subject, but was anxious to investigate it since a substantial saving of fissionable material or larger blasts for equal material could be achieved. This reply of course reflected the fact that the bomb grew out of a shaping of the design to the capacity of the B-29 bomb bay rather than fixing on an optimum size.

At the instance of the SWG the Chief of Staff, USAF, requested the AEC to carry out an analysis of the effects of increasing the lateral dimensions of the FM bomb, to be completed by 15 January 1948. This close date resulted from the fact that the design proposals for the B-55 were expected by April from the aircraft industry, this date being critical for budgetary reasons. The SWG also pointed out the desirability of "a comprehensive study of strategic requirements for numbers, sizes, and types of atomic bomb bursts." Even after both of these studies there would remain the complex and perhaps insoluble problem of correlating the larger bomb bay with the 13 other variables already considered by the AMC in the design of the aircraft in the effort to retain a tactically advanced design.[32]

The subject of a larger FM bomb does not appear to have been further pursued at this time, probably because of the smaller than expected percentage of gain, uncertainty of available figures, and adverse effect of an increase in size on the critically important deliverability factors of speed and range. Colonel Armstrong of the SWC stated in August 1948 that the bomb bay capacity of the B-52 was fixed

but pointed out that "this fortuitous decision" was supported by the results of SANDSTONE, which indicated that there was a series of possibilities available without going to a bomb larger

Consideration of Thermonuclear Bombs

Another important phase of bomb development which was under consideration by Manhattan District and the AEC during the period from 1946 to 1948 centered around the application of the thermonuclear-fusion principle to the atomic bomb, either as a means of constructing a super bomb with a new order of explosive power or as a means of attaining a better utilization of fissionable material within a fission bomb. During the war Manhattan had begun study of a fusion bomb under the designation ALARM CLOCK. After some progress this was dropped in favor of complete concentration on the fission bomb, which was recognized as a stage which must precede the development of a fusion bomb, since only temperatures and pressures of the order of those resulting from a nuclear explosion could initiate a fusion reaction.

Thermonuclear bombs were again considered by Manhattan District in 1946. A "hydrogen weapon conference" was held at Los Alamos on 12 June attended by 31 top scientists (including Klaus Fuchs of Great Britain). A report was prepared which stated two important conclusions: that it was "likely that a super bomb can be constructed and will work" and that the detailed design submitted was "judged on the whole workable." It was also estimated that testing of a thermonuclear bomb could take place within one or two years. Nevertheless, work on such a weapon apparently did not progress beyond the study phase during 1947 and 1948, possibly because no requirement was stated by the National Military Establishment, and in 1948 the General Advisory Committee to the AEC unanimously recommended against "a major attempt to build a hydrogen bomb."[35]

The AFSWP study of August 1948 on atomic weapons mentioned two proposed designs: SUPER (Restricted and ALARM CLOCK (Restricted 36

SUPER would be a large bomb with a yield computed in multiples of one megaton of TNT;

Since there was no critical mass for either of these substances, there was no theoretical limit to the size of the bomb, although this would of course be restricted by the size of the carrier. A critical factor affecting the potential number of bombs appeared, however, in the available supply

although the exact proportion was not known. The technical problem of bomb design also appeared formidable.

ALARM CLOCK, the original name for the thermonuclear bomb proposal during the war, was now applied to a less ambitious proposal to utilize small quantities

These isotopes, it was believed, would undergo a fusion reaction and thus produce large quantities of neutrons which in turn would increase the efficiency of the fission reaction, including that within the

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* Deuterium was extracted from ordinary water by electrolytic means.

natural uranium of the tamper. In this case the technical problems were much less imposing

While recommending that further study be given to both of these proposals, the AFSWP indicated that it considered ALARM CLOCK the more promising of the two. In the case of SUPER it doubted the military utility of such a powerful weapon and also emphasized the difficulties attending the technical design of the bomb and producing the quantity of tritium required. Earlier than this, on 10 June 1948, the AFSWP had suggested to the MLC that the JCS determine at an early date the "approximate upper limit to the TNT equivalent yield for which there is a conceivable military requirement" as guidance on the development of a super bomb based on the thermonuclear principle. In the same letter the AFSWP had suggested that study of thermonuclear bombs proceed in fifth priority in the weapons development program. Although the Air Force did not include thermonuclear weapons in its own statement of desired military and technical characteristics of atomic bombs, prepared later in the year for presentation to the AEC, it did indicate concurrence with the AFSWP point of view as stated in its letter of 10 June.[37] No decision had been reached by the end of 1948 regarding the establishment of a military requirement for these weapons.

The question of thermonuclear bombs was also considered in the Report of the CAE Panel on Long Range Military Objectives in Atomic Energy in August 1948.

the Panel recommended tt

regard to the SUPER it pointed out serious technical problems and oth-[38]
er objections to an immediate all-out effort, concluding:

> The Panel recognizes the importance of work directed toward the development of this thermonuclear weapon, but in view of the magnitude and complexity of the problem, the special personnel requirements, and the uncertainties as to the characteristics of a feasible weapon, it believes that this long-range objective cannot and will not be attacked at this time with the extensive scientific and industrial effort which characterized the wartime Manhattan District developments.

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2. See Vol. I, Chap. XIV and XIX.

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CHAPTER XIV

SPECIAL LOGISTICAL PROBLEMS

The development, production, and use of the atomic bomb created new and unusual logistical problems with which the Air Forces, as the principal using agency, was compelled to deal from the start. These at first related principally to the transportation, assembly, and handling of the complex new weapon, operations which were shared with Manhattan District and the Navy. Manhattan District, of course, entirely handled production, even of practice bombs. Storage did not constitute a problem during the war, since only two bombs were available for combat use, but it was to become an important function as the stockpile mounted. During the early post-war period the AAF and USAF became increasingly involved in the logistics of the bomb. Although production remained the exclusive prerogative of Manhattan District and its successor, the AEC, the Air Force gained a hand in fixing the technical requirements for the weapons produced and played an increasingly important role in the other logistical areas. As its operational buildup progressed it was necessary in particular for it to deal with difficult problems involving rapid transport and assembly. It was also necessary to consider other basic matters such as disaster procedures and the possible need for developing new base plans to provide for safe and expeditious handling of atomic weapons. The situation was further complicated by the operational concept which developed of maintaining constant readiness for an overwhelming mass strategic strike.

Storage of Atomic Weapons

At the end of the war it was obvious that the atomic stockpile of the United States would ultimately constitute its most previous material reserve—the key to its national security. Steps were taken to design and construct three secure storage sites by Manhattan District during 1946, and some contracts had been let by the end of the year. These sites—designated A, B, and C—were located respectively at

With the establishment of the AEC, both the construction and control of the sites passed under the control of the AFSWP, and construction continued throughout 1947 and 1948, though none of the sites was entirely completed.* During this period the physical possession of the slowly increasing atomic stockpile was held by the AFSWP,

Technical custody was transferred to the AEC in the fall of 1947, but no change was made in the location of the weapons, and the AFSWP remained responsible for their physical protection. Meanwhile the question of custody as a matter of policy remained

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*See Chapter III.

a moot point between the military services and the AEC, to be finally clarified by a decision of the President in July 1948.[1]

Unfortunately, the AAF was not consulted in the design or location of these storage sites, apparently because Manhattan District considered them wholly within its sphere of activity. Though admirably located from the standpoint of security, they left much to be desired as to accessibility from operational bases of the SAC.

The AFSWP proceeded with the construction of these strips during early 1947 with very little AAF concurrence or collaboration. The exact plans of the AFSWP for operating these strips are not clear from correspondence in Air Force files; however, it apparently intended at first to maintain jurisdication over them.[2]

On 23 July 1947 the AFSWP formally notified the AAF of the work on the air strip and asked it to provide a list of necessary equipment for its operation and a statement of manning requirements. This information was supplied on 17 October. Later, on 26 November, the AFSWP asked for additional information, including plans for loading pits and security fencing. At the same time it informed the Air Force that it proposed to ask it to man the strip on a standby basis. Control of the base would remain, however, with the AFSWP. A similar proposal for the airstrip was made on 11 December. The

AFSWP stated that the strip was nearly complete and that it was ready to install the auxiliary equipment, control tower, operations office, field and boundary lights, gasoline storage facilities, and loading pits as soon as it received a list of equipment and installations desired, together with detailed specifications and plans. It also asked what equipment the Air Force would be willing to supply and requested that the Air Force be prepared to man the strip on a standby basis by 15 May 1948.[3]

On the recommendation of the Special Weapons Group, the Air Force accepted the proposals for both airstrips and established a requirement for their manning and operation. Meanwhile, the AFSWP suggested that "the care and custody" should be assumed by the Air Force, offering to contribute limited funds, including cost of operation for the first year. It also suggested that the Camp Hood strip be placed on a minimum standby basis until 10 February 1948 and that it become fully operational by 1 July. At this time the strip was expected to become operational on a standby basis sometime after 1 July. As a result the SAC was directed to man the strip on a minimum basis as soon as possible, to survey the metes and bounds of the real estate necessary for transfer, and to prepare a layout plan for construction and installation of facilitties including estimated costs for both minimum and full operation. Minimum operational status was defined as control tower, servicing, and flight clearance facilities functional from 0800 to 1700 daily except Saturday and Sunday, with a duty officer on 24 hour basis. Full-time operations would involve the servicing and handling of approximately six B-29 aircraft daily, plus a limited number of administrative aircraft. B-36's would be handled without fuel servicing.[4]

Similar action to assign the Camp Campbell airstrip to the SAC and activate it was taken by Headquarters, USAF, following the receipt of an AFSWP request on 1 March 1948.[5] Nevertheless, progress was extremely slow during 1948 in achieving any high degree of operational capability, apparently because of a severe shortage of funds, coupled with a disagreement within the Air Staff as to the source from which the construction funds would be obtained. Lt. Gen. Curtis E. LeMay, Commanding General of the Strategic Air Command, after a visit to the airstrips in November, wrote in protest to the Chief of Staff:[6]

> I am shocked to find that both places are without even primitive operational facilities such as suitable control towers, radio aids, night lighting, crash and fire fighting equipment, etc. As we are responsible for dropping the atomic bomb, I maintain that to be unable to dispatch aircraft into and out of these fields at night during marginal weather is ridiculous. We must get top priority in filling the gaps in our atomic program. The essential requirements have been submitted to your HQ and have been agreed upon by your air installations people. It would appear that this project must be handled on an emergency status to be followed up with more permanent construction that will of necessity have to be provided.

The SAC had submitted plans and estimates for construction in two phases. Phase I would include runway lighting, a control tower, an operations building, and essential power, water, road, and maintenance facilities. Most buildings would be of pre-fab or interim construction. Phase II would consist of permanent quarters and offices to be erected at an estimated cost of $7,000,000.[7]

Quick action to provide minimum operational facilities followed General LeMay's letter, and construction continued throughout 1949. However, the airstrips, now designated respectively Gray and Campbell AFB were still not regarded as entirely capable of supporting SAC Operations Order No. 30-49 (deployment in event of emergency) in February 1950.[8] Two months later Brig. Gen. Howard G. Bunker stated, "None of the sites, with the possible exception of Site Able, is properly equipped as to all weather flight facilities, weather service, or adequate fuel supply, for handling large number of aircraft." He went on to point out that these bases were inherently uneconomical, in that they did not receive a high peace-time utilization, and dangerous, in that their small number made them liable to a successful attack and in that up to thirty-six hours might be lost while aircraft were flown into them and loaded. He urged that they be reduced to reserve status and supplanted by a much more numerous net of storage sites directly attached to operational group bases.[9]

At the end of 1948 the Air Force was giving increasing attention to the desirability of storage of non-nuclear weapon components at forward bases in order to provide earlier delivery capability. Construction of storage facilities , was considered early in 1948. Planning and design requirements were secured from the AFSWP, and during the summer the Army Engineers carried out a survey for a storage and assembly area located some five miles from the runways. The Air Staff rejected this survey on the ground that it would entail great operational inconvenience and would probably become unnecessary with the Mark IV bomb. AFOAT, however, requested the Directorate of Installations to proceed with planning for the construction of storage facilities for the non-nuclear components of 30 bombs.[10] However, the entire matter of storage at operational air bases was ultimately to be referred later to a Joint Working Group of the Department of Defense and the AEC for high level decision, which came late in 1949.

Development of a Specialized Base System and Disaster Procedures

The need for specialized bases for atomic operations was dictated by the complexity of the weapon itself and the power of the blast from it. The bomb required assembly, testing, and loading procedures which were markedly different from those of other weapons. The security requirement was also considerably more rigid than normal. The possibility of an accidental atomic blast which might either destroy the entire base or render it unusable through radiological contamination also had to be considered, at least until the development of a means of in-flight insertion. Some of these problems were recognized as early as the operations from Tinian in 1945. Special assembly buildings and loading facilities were constructed there, unusual security procedures enforced, and the initial take-off of the Enola Gay made with a bomb which was assembled into a live weapon only after the plane was airborne. The precaution against a nuclear explosion in the event of a take-off accident was not possible in the case of Bock's Car, which delivered an FM bomb on Nagasaki three days later.

Several complex factors, which it was impossible to accurately evaluate, doubtless delayed the establishment of any very firm specialized requirements for bases for atomic bombers. The AAF did not control either the storage or assembly of atomic bombs, and would presumably have to pick them up at a Manhattan (or later an AEC-AFSWP) storage site, selected for physical security rather than operational suitability. Furthermore, the Spaatz Board Report and other early operational studies laid considerable emphasis on the desirability of maintaining a balanced and flexible Air Force, whose aircraft would be capable of alternating as needed the delivery of conventional and atomic weapons. As a result great emphasis was placed during 1946, 1947, and 1948 on the development of portable assembly and handling equipment, which would presumably make possible the use of almost any base for atomic strikes, thus increasing operational flexibility and diminishing vulnerability. Nevertheless, certain installations at forward bases were either still essential or would greatly facilitate operations, and it was also necessary to consider the dangers attending the handling of the Mark III bomb as well as those attending take-offs and possible return landings with it in a live condition, a necessity until the stockpiling of the Mark IV beginning in mid-1949. During 1948 the delay in the development of portable loading equipment and the sudden heightening of international tension also created a demand for hydraulic loading pits, and a number were built at various points.*

One of the first studies to consider the requirements for atomic bases in a general way was that prepared by Col. Leo V. Harman of the T&TLC in February 1947 concerning the preparation of a logistics manual on the use of the atomic bomb. The study pointed out:[11]

> No doubt there would have to be several airfields, two or more supply depots, numerous communications installations, service installations, etc., all supported by a chain of intermediate bases, extending back to the zone of the interior. To get an idea of the complexity of the installation, consider carrying out the Tinian operation without the support of the Pacific Theater bases which were operating at that time. The installations which we are concerned with in this discussion are those required to maintain the heavy bombardment groups, the transport unit, and the engineer special battalion. What will be the nature of the airfield installations required? How much housing, warehouse storage, shop space, hospitalization, etc., would be required? What operational installations are needed by the engineer special battalion to handle the atomic bomb itself? What storage installations would be needed for storing components of additional bombs? What communications installations are needed for such a fast-moving operation?
>
> Information is available at Sandia Engineer Base on the installations required by the engineer special battalion. Specifically, these installations would include assembly buildings with proper air-conditioning and heating units, storage area installations, and housing for the engineer special battalion personnel. The installations for the transport unit and the heavy bombardment groups would be very similar to those used in past operations. However, special consideration should be given to the fact that operations may be

*See Chapter XI

carried on in extreme climatic conditions of heat or cold. Much research and development is required in providing suitable installations for such operations.

A later study prepared by the T&TLC in the fall of the same year on the sequence of operational events (as a basis for war planning) added little to the above, stating simply:[12]

> Since status of forward bases is unknown, the following requirement is stated. The forward base chosen for final assembly and loading must have available, prior to the alert order, a loading pit, suitable assembly building, and air-conditioning equipment for the assembly building to insure low humidity during the final assembly process. The construction of these minimum special facilities is estimated to require 10 days, after the arrival at the forward base of the required materiel and construction crews.

It did, however, provide specifications for assembly buildings, set forth a requirement for certain hard-surface connecting roads, and stated that a minimum distance of two miles must be maintained between assembled bombs, with the total on the base at once limited to three. These requirements were completely subsidiary to the main subject, and it was made clear that the longer range plan provided for portable assembly buildings as soon as developed.

The question of the acquisition of land drew attention in the Special Weapons Group to the need for planning criteria for both a specialized base system and individual bases. Col. Arthur A. Fickel of the Special Weapons Group proposed that these be derived from the operational plans for the strategic air offensive, the operational sequences imposed by the bomb, and the technical requirements of the bomb. The SWG accordingly requested the T&TLC to prepare a new study on operational sequences together with a separate study on air base requirements. Lt. Col. Frank J. Drittler and Lt. Col. Merrill E. DeLonge of the Directorate of Air Installations were sent to Kirtland to assist with this.[13]

The resulting study, appearing in May 1948, proposed the development of a network of bases, intermediate and forward, and stated: "The primary requisite in establishing air base requirements is that of site-planning with special emphasis on safety features to prevent accidents and attendant problems in atomic operation." Based on "scientific theory and prediction," a radius of 10,000 feet from a low order detonation was established as the danger zone for possible fatal results from blast and radiological effects, and this was used throughout the study in establishing minimum distances between assembled bombs and between assembled bombs and other vital installations. The design criteria were based entirely on the characteristics of the Mark III bomb.

Intermediate bases were assigned no special facilities apart from those normal for the support of very heavy bombers, although a loading pit was mentioned as possibly desirable for sustained operations. The study presented two possible plans for a forward base, each adapted for the operation of both standard bombers and atomic carriers. The first plan provided for a consolidated operation from one air base of three runways joined by an extensive system of taxiways. Capacity would be quite limited, since only one bomb could be assembled or loaded at the same time and only one loaded atomic bomber could take off at one time, although four loaded aircraft and one assembled bomb could be accumulated. The second plan provided for a normal air base installation as the service center for all aircraft, both standard and atomic carriers. The latter, however, would fly for loading and take-off to satellite strips parallel to the main runway but at distances of at least 10,000 feet. Each satellite strip would have its own assembly and loading facilities. In addition to the tactical advantage of simultaneous take-offs, this removed the possibility of inactivating the main runway and delaying the mission through the crash of one atomic carrier.

The study also included the complete plan for a standard assembly area, with characteristics of the six buildings—assembly building, offices, warehouses, shops, etc.—in each area. These would provide facilities for one assembly team each, and they would be duplicated for each additional team. Loading pits (after the first) were to be constructed at the rate of two to each six teams. Another important recommendation was for take-off over water or from a 200 to 500 foot elevation if possible. Failing either of these, a requirement was stated for a 3,000 foot graded extension of the runway or strip.[14] This study provided guidance for Air Installations in its planning for the bases at both of which it was decided to employ the satellite system. However, its adoption as a fixed requirement appears to have been postponed because of several uncertain factors which it was impossible to evaluate, such as the availability of the Mark IV with in-flight insertion, lack of a complete disaster plan, and the choice of processing system. For example, if a forward assembly procedure were decided on, it would also be necessary to plan for bomb storage areas.[15]

Despite the existence of this study, which served as a general guide, little was done toward the construction of specialized atomic operating bases during 1948 other than the building of additional hydraulic loading pits at various air bases. The building of a system of satellite strips was considered early in the year

two satellite strips at were being definitely planned, together with assembly, loading, and possibly storage areas, but these projects were dropped later in the year. Two important factors in the latter action were prospective availability of the Mark IV (with in-flight insertion) and uncertainty as to the exact type of atomic assembly and striking operation which would become standard. Although extensive surveys were carried out at Limestone, there was apparently increasing question regarding the extreme dispersion required by the strip system.[16]

In August a memorandum from AFOAT stated in reference to

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*Rapid City was selected as an atomic bomber (VH) base by agreement between Lt. Gen. Ira C. Eaker and Maj. Gen. L. R. Groves. This was confirmed by Lt. Gen. Hoyt S. Vandenberg in October 1947, and digging for a command post began under AFSWP direction soon after.

Limestone AFB, where the most extensive surveys had been undertaken:

> 2. The decision is made not to continue at this time with any further surveys, land acquisition, or construction of this area, for the following reasons:
>
> a. The precise function of this Base with respect to atomic operations has not been fully determined,
>
> b. The possibility of air-insertion of nuclear components of atomic bombs may invalidate the extreme safety distances heretofore considered necessary at any vital atomic operational air base.
>
> c. The continued build-up of the surveyed area will be extremely costly at this time, is operationally very awkward from an Air Force point of view, and also will involve a dislocation of civilians which might not be acceptably supported by our present peacetime requirements.

Instead, it was suggested "that the layout plans at incorporate more practicable facilities, which should meet equally well any operational role of this base as foreseen in the next few years."[17] By December it was clear that specialized base plans for atomic operations would have to be completely revised, and it was also becoming clear that all bases would have to be tied together in an over-all operational plan which would determine the exact requirements at each base.[18]

During early 1949 work went forward in the Directorate of Armament on "an atomic operating facility," which the SAC approved for construction at Limestone on 6 April. AFOAT suggested only:[19]

> 3. This proposed facility should be established at some AF installation so that the AF will have at least one airbase set up like a forward base for atomic operations. This should be done for the purpose of determining the merit of this proposed atomic energy facility. The airbase selected to be this

atomic energy operations proving ground could be

or any other AF base suitable as a simulated forward base. The important consideration is that the AF determine as early as possible that it has a planned layout for atomic operations which is suitable in every way. Plans for forward base design should be definite, complete and tested as early as possible. The early establishment of such a facility is the quickest way of developing a suitable future airbase design for atomic operations.

Meanwhile, the principal actual construction work going forward in specialized base facilities during 1948 was an increase in the number of hydraulic loading pits. On 1 June the Air Force had pits already installed.

Pit construction was slowed down in the latter half of the year, however, as the result of a SAC recommendation, based on prospective early availability of the C-9 hoist, that pit construction be discontinued at SAC bases except for those already underway. This was approved by Headquarters, USAF, although it was pointed out that the two pits planned at Sites A, B, and C would be completed.[20]

Closely related to the development of base requirements was the development of standardized procedures designed to prevent an atomic disaster resulting from an accidental detonation, particularly one which would incapacitate a base, and to insure the taking of proper measures if such a disaster occurred. These were regarded as of especially great importance as long as the Mark III bomb, which made necessary a take-off and possible return after an abortive mission with nuclear core in place, was in use. This project, which overlapped to a certain degree the preparation of a standard operating procedure, got its initial impetus early in 1947, when both the T&TLC and the AFSWP began to consider the problem. Because of the lack of technically qualified personnel little progress was made, however, and in June 1947 at the request of Colonel Bunker, the Deputy Chief of Air Staff for Research and Development took steps to assign four specialists from various staff agencies and commands (Air Safety, SAC, AMC, and Air Surgeon) to prepare the initial plan within 90 days.[21]

Brig. Gen. D. L. Putt, of the Engineering Division, AMC, pointed out, however, that emergency procedures were still based principally on theory and recommended that a series of tests be carried out to derive factual data prior to the preparation of standardized procedures. He suggested that these include tests with drone B-29's and atomic bombs complete except for nuclear cores. This recommendation became the basis for the preparation of a test program, but meanwhile the preparation of a tentative disaster plan also went forward. Both projects were carried out by a sub-committee of the T&TLC. By December 1947 the disaster plan was complete in its first draft form and was being reviewed, and in March 1948 it was forwarded to the Chief, SWG, with recommendations for reproduction and distribution.[22] Bearing the title of USAF Disaster Plan (Tentative), it consisted of three parts: I. Preventive Measures, II. Safety Regulations, and III. Disaster Procedures. Coverage was broad, particularly for Part I, which dealt with such topics as site planning, personnel training and proficiency, operating limitations of B-29 aircraft, altitude-airspeed zones for jettisoning, requirements as to service condition of principal aircraft components, action to deal with fire in the aircraft, other aircraft operational emergencies. Parts II and III dealt principally with the duties and responsibilities of individuals and groups on the base during normal operations and during a disaster. A special disaster section consisting of a specially trained group of four teams and equipped with special clothing and radiation detection instruments was provided for, with the duty of controlling activities within the disaster area, as well as a special radiological section of the medical detachment to give first aid.

The 10,000 foot safety zone was followed generally in planning for distribution of facilities and personnel. Gamma radiation rates affecting individuals were stated as follows: daily tolerance--.1 roentgen; casualty--50 roentgens; fatality (50 percent)--600 roentgens. Tolerance rate for beta radiation was described as approximately 5 times the gamma rate, while for alpha radiation complete skin coverage and masks were to be required if the number of counts exceeded 500 per 100 square centimeters.

This study was circulated through the Air Staff and the field commands for criticism during 1948. Its final revision, however, had to await the proposed field tests. The T&TLC had prepared a program for these and submitted them to the AFSWP for coordination in January 1948. This was designed to provide answers to such questions as the following: the maximum impact velocity without detonation of the bomb when jettisoned "safe," the type and size of a parachute which would achieve lower velocity than this figure, the yield of a nuclear explosion resulting from an impact detonation, the time lag between a gasoline fire in a grounded aircraft and detonation of an FM bomb in its bomb bay, the difference in the results of impact and heat detonation, the bounce or skip action of the bomb when jettisoned at low altitudes, the behavior of the bomb during a crash, the reaction to various types of combat damage.[23]

Since the methods proposed for producing the experimental data involved the expenditure of FM bombs less their nuclear components and since much of the information collected would be Restricted Data, it was necessary to secure AEC concurrence. The Air Force submitted the program to the AEC for review in March 1948, but the Operation SANDSTONE apparently delayed an early analysis and also failed to provide much helpful data bearing on the problem. After consideration by Los Alamos the AEC indicated through the MLC in November that it agreed as to the desirability of the tests, but that it lacked statistical resources to properly evaluate them. It proposed that the AFSWP conduct the tests with the aide of the Navy Bureau of Ordnance and the Army Department of Ordnance. The sensitivity test program was still being considered by the MLC ast the end of 1948.[24]

Bomb Assembly and Forward Transport

A very important logistic factor which influenced atomic delivery capability during 1946, 1947, and 1948 was the number of assembly teams available and the rate at which they could assemble the stockpile bombs. Although an AAF team, the First Ordnance Squadron, was trained for the operations from Tinian in 1945, it participated only to a limited degree and was thereafter allowed to wither on the vine as it was denied further access to the bomb by Manhattan District and the AFSWP.* No additional Air Force teams

*See also Chapter X.

were trained until 1948, when the AFSWP agreed to train teams each composed of personnel from one service. The AFSWP sought to retain operational control over these teams on the ground that their activity represented a "service" function, but was overcome by opposition from both the Air Force and Navy. The first two Air Force teams completed their training late in 1948 and were added to one Navy and three Army teams, all of whom would be available to support atomic operations. It was agreed, however, that the first four Air Force teams would remain under AFSWP control in order to meet the needs of Sites B and C. Thereafter, new teams would go under the operational control of the SAC, but remain under the technical supervision of the AFSWP. During 1946, 1947, and most of 1948 the assembly capability resided in a special engineering battalion at Sandia Base which had been organized by Manhattan District and taken over by the AFSWP. Authorized a strength originally of 500 men and 80 officers, it was reported at various times during the period to include from one to four assembly teams.

The work of assembly was seriously complicated by the complex nature of the Mark III bomb and the difficulty of performing servicing operations on it. Furthermore, the ready state of the bomb was considered to be limited by two time factors. First, the batteries were not accessible from the outside of the bomb, and disassembly and replacement were required if the bomb was not used within eight days, since their effective life did not exceed this. Second, it was believed that the nuclear capsule, because of its output of heat, should be removed from the bomb within approximately 10 days, which likewise required complete disassembly of the bomb.[25]

Since the three first storage sites were deep within the continental United States, considerable time would also be lost in flying the bombs to a staging base within striking distance of the target. The dangers of taking off, flying over the United States, and landing with a live bomb also had to be considered. At the same time there was continually increased emphasis on the desirability of an early mass strike in the event of war. All these factors militated for assembly at the final take-off point, but at the same time there was objection to the storage of large numbers of bombs at vulnerable forward bases, at least as long as the stockpile remained small.

As a result, during 1947 and 1948, as the rapid early delivery problem was given increasing attention, the tendency was toward the development of a highly flexiblerear-forward assembly technique. Under this procedure the bomb was given the first part of its assembly at the storage site and then flown to the forward base, where the final assembly including installation of the nuclear capsule, detonators, and batteries was carried out. Assembly teams were therefore divided into two parts, a rear and a forward unit, the latter being flown to the forward base while the first bomb was being assembled. In order to gain flexibility in the choice of forward bases, it was proposed also to employ a portable forward assembly room, in the form of either a specially modified C-97 transport aircraft (CHICKENPOX) or a specially designed "knock-down" building which could be set up quickly at the selected point. Until the Mark IV bomb began to become available in mid-1949 this system, the number of ready bombs, therefore hinged largely on the number and assembly capacity of the assembly teams. Since the number of teams did not exceed six prior to the end of 1948, a mass delivery was impossible even if the planes and bombs for one had been available.

By early 1947 it was becoming obvious that speedy operational delivery of the atomic bomb against an enemy would involve a rather complicated series of coordinated procedures, in which three agencies--the AAF, AFSWP, and AEC-- would participate. By this time the AAF had organized the Strategic Air Command as its atomic striking force, although its capability was limited to fewer than 30 planes in the 509th Bombardment Group of the Eighth Air Force. The assembly capability resided in the 38th Special Engineer Battalion, under the operational control of the AFSWP. The AEC held theoretical, but the AFSWP practical custody of the weapons--both nuclear and non-nuclear components. No war plan contemplating an organized and coordinated use of the atomic bomb existed.

Initial action within the AAF toward the preparation of a suitable logistics manual for atomic bomb operations was taken by Col. Leo V. Harman of the T&TLC in February 1947. He submitted a study to Headquarters, AAF, recommending that a board of three or more officers be designated to prepare the manual without delay with a principal aim of supplying information for staff planners. He proposed that the manual, which he outlined, have sections on organization, transportation, supply, installations, communications, intelligence, personnel, and operations. A somewhat less ambitious proposal came in April from the Eighth Air Force for the establishment of a Standard Operating Procedure for coordinating AAF and AFSWP transport and loading. Like the T&TLC study, it assumed the establishment of a task force of three units: the "Silver Plate Group" (509th), the

First Air Transport Unit (just assigned to the SAC), and the Engineer Special Battalion. After listing the functions and responsibilities of each, the study described a typical rear-forward assembly and movement. The Air Transport Unit would dispatch eight C-54's to Kirtland. The first would carry the forward assembly team to the forward base, while the others would move the 40,000 pounds of special equipment needed. The partially assembled bombs would be picked up and carried forward as rapidly as assembled by the modified B-29's of the Silver Plate Group. Neither study attempted to establish a time schedule except that the latter provided for take-off from Kirtland of the advanced echelon of the Engineer Battalion within 24 hours.[26]

After concurrence from interested sections of the Air Staff, particularly the War Plans Division of AC/AS-5, the Deputy Chief of Air Staff for Research and Development directed the T&TIC on 30 July 1947 to proceed with the preparation of the proposed manual, cautioning it to confine the treatment to logistics and employment factors without digressing into war planning. The start of the project was temporarily delayed by the fact that AFSWP had not yet recognized the T&TIC, which thus could not secure the necessary information, but the AFSWP at length agreed to cooperate on the manual. The work on it went forward during the remainder of the year and the first half of 1948 under Lt. Col. William N. D'Ettore, and was apparently incorporated into the Tentative SOP for Atomic Operations, a somewhat broader outline completed in August 1948.[27]

Meanwhile, General LeMay's office had also directed the T&TIC to undertake two other studies which somewhat overlapped the proposed manual and were apparently intended to supply early information which could be used to establish a short range war plan. This followed discussions between Maj. Gen. Otto P. Weyland, AC/AS-5, and Lt. Gen. Lewis H. Brereton, Chairman of the MLC, regarding the implementation of War Department directives of 29 April and 18 June 1947 concerning plans for the immediate initiation of atomic warfare. The first study would be a statement of "the minimum special personnel, equipment, and facilities which would be required to achieve an atomic bomb processing rate from storage to loaded combat aircraft of (1) 10 and (2) 25 atomic bombs within 24 hours of an alert." Operational capabilities in transport were to be assumed, with trained personnel and special facilities and equipment to be the limiting factors. The second study was to be a statement of the maximum U.S. capability of processing from storage to loaded transport or combat aircraft, with the same limiting factors.[28]

The two studies were completed on 1 October and represented the most detailed statement up to that time of both the specialized logistic requirements for an atomic attack and the current assembly capabilities. The 38th Engineer Battalion was described as having two skeleton assembly teams, either of which was capable of producing an assembled bomb in 54 hours. Thereafter, it could produce one bomb every 36 hours for 2 weeks, after which fatigue would probably severely cut the output, or by using the teams alternately the 36 hour rate could be maintained indefinitely. Only one assembly room and one loading pit was available at the rear base. Loading was estimated to require two hours.[29]

Actually the rear assembly method was considered impracticable for reasons already described, and a second method of loading .

pre-assembled but incomplete bombs for flight to a forward base and final assembly there was outlined. Under this procedure one team would be moved forward 12 hours after the alert with its equipment of 40,000 pounds. Since no portable assembly building was available, a suitable building would have to be provided (with air conditioning) at the forward base, together with a loading pit. Rear assembly--consiting of putting together the high explosive assembly, the firing assembly, the fuzing assembly, the ellipsoids, and tail--would require 32 to 48 hours. Forward assembly--consisting of installing the nuclear capsule, detonators, and batteries-- would require 24 to 28 hours. It was estimated that the first bomb could be loaded into the aircraft at the forward base within 60 hours plus ferry time after the receipt of the alert. Additional bombs could be loaded at the rate of 1 each 28 hours for 2 weeks, after which a decrease in the rate by one-half (because of fatigue) would occur. The pre-assembled bomb would have been loaded into the B-29 for ferrying 32 hours after the alert order. Only one forward assembly kit was available.

Relating assembly operations to the 11 available fully qualified combat aircrews, it was estimated that each could be supplied with one bomb by the end of 9 days, 20 hours, using the rear assembly technique, and by the end of 14 days, 4 hours plus ferry time using the rear-forward time. The first figure could not be sustained, since it would be attained by concurrent use of the two skeleton teams under conditions of extreme emergency, and a more realistic figure would be 17 days, 6 hours, based on alternate use of the teams. No final table of organization or list of equipment was yet available for assembly teams, although the strength had been set at 39.

In regard to the attainment of 24 hour capability for 10 and 25 bombs, the studies pointed out that this was not then possible because of the time required for activating and cycling the batteries (42 hours), shortage of assembly personnel, and lack of tools and facilities. Because of the time lag, 24 hour capability was not considered attainable for the rear-forward assembly method. It was, however, considered practicable for forward base assembly, provided these bases were provided with all atomic bomb components, full strength assembly teams, and complete equipment and facilities. A critical requirement would be the necessity of having fully cycled batteries constantly available, which would require a heavy expenditure of batteries or development of a new type. Other principal requirements for 24 hour capability were listed as follows:

	1 bomb	10 bombs	25 bombs
Assembly team personnel	39	390	975
Equipment (kits)	1	10	25
Weight (pounds)	40,000	400,000	1,000,000
Cubage	3,800	38,000	94,000
Cargo A/C (C-54's)	9	90	225
Airdromes	1	4	9
Assembly Bldgs.	1	10	25
Tactical A/C and Crews	1	10	25

Airdrome requirements were based on the limiting of each one to the presence of three assembled bombs. These were also to be kept at a distance from each other of two miles. The studies, which enclosed general characteristics and plans for assembly buildings, in which only one bomb was to be processed at a time, were also important in calling attention to the specialized characteristics of a forward atomic air base.

Shortly after the preparation of these studies Operation AJAX, the first tactical atomic maneuver, was executed by Task Force Eight during the period 15 to 25 November 1947. Following the organizational plan already outlined, the Task Force consisted of three units--the 509th Bombardment Group, the First Air Transport Unit, and the 38th Special Engineer Battalion. The operation was established to assemble six FM bombs and deliver one of them (less fissionable material) plus five practice bombs on three operational strikes. The rear-forward assembly procedure was employed, with

Wendover Field, Utah, as the forward base. A tentative Standard Operating Procedure was prepared for the operation by the T&TLC in coordination with the Eighth Air Force and the 38th Engineer Battalion, and one of the principal aims was to provide a critique on this SOP.

Forward assembly was carried out in a portable building which was airborne to Wendover with the assembly team and erected there in 13 hours. Although planned schedules were met, the assembly teams were physically exhausted after assembly of the six bombs, and this revealed that the estimates of delivery capability in the 1 October study were overly optimistic. The results of the operation proved useful in revising the Tentative SOP for Atomic Operations, which was completed in July 1948. Meanwhile, no additional maneuvers were held in July 1948 because of the demands of Operation SANDSTONE.[30]

In March 1948 the SWG directed the T&TLC to revise its previous studies on the sequence of operational events and air base requirements for handling of atomic bombs as a basis for the development of strategical doctrine and war plans. These studies, submitted on

21 May, were essentially a revision of those prepared the preceding fall, and gave a good picture of current assembly capability. This, however, had not undergone any marked change, being still severely limited by continued reliance on the Mark III bomb, delay in the training of additional assembly teams, and a continued shortage of equipment and assembly facilities.

The operational sequence study again outlined the three methods currently under consideration for processing bombs for delivery: (1) the two-stage operation using rear and forward bases (Fat-Rat), (2) the complete fly-away U.S. (Cat-Rear), the complete assembly at forward base (Cat-Forward). Although presented in somewhat greater detail, the procedures remained basically unchanged. The rear-forward technique now envisaged use of either a portable assembly building or the CHICKENPOX aircraft at the forward base, with emergency loading by the C-6 internal aircraft hoist if no hydraulic loading pit was available. Rear and forward phases of the assembly were expected to require 24 hours each. Including preparation of batteries, which would require 42 hours, and loading, the first bomb would be in the aircraft ready for delivery in 92 hours plus ferry time. Thereafter one bomb per assembly team could be ready each 24 hours.

Using the rear assembly technique, which would presuppose permission to fly with a live bomb over sections of the continental United States, each team could ready and load its first bomb 56 hours after the alert and additional ones each 24 hours. The forward assembly technique, which would presuppose storage of all components at the forward base, would provide the same capability, less the necessary ferry time and thus the earliest possible means of delivery. Neither the rear or forward technique would impose the logistic burden of the rear-forward method, which required the movement of a forward assembly team (now increased to 109 men) and 40,000 pounds of equipment. The latter would include the portable assembly building, and use of the CHICKENPOX aircraft would reduce the figure by one-half.

The 38th Engineer Battalion was now described as having three assembly teams available. This, however, did not provide the same number of assembly lines, as only one permanent assembly building was available, although it was thought that an additional one might be improvised (if some risks were accepted). Two partially complete portable assembly buildings (less air conditioning and heating units) were also available. The two existing CHICKENPOX aircraft were still undergoing modification and test. It was considered that the best usage of assembly personnel would be achieved through use of the rear-forward method.

Delivery capability still was limited to the 509th Bombardment Group, which now contained 32 modified aircraft but only 12 fully qualified crews. The planning factors for early capability were therefore based on the delivery of 12 bombs. Assembly and loading of these was estimated to require nine days and zero hours plus ferry time   using the favored rear-forward procedure. Transport requirements were eased by the fact that the bomb itself would be moved by the bombers to the forward base, and all 32 aircraft could be utilized for this. Safe ferry range so loaded was estimated at 3,500 nautical miles, and non-refueling radius of ection as 2,000 nautical miles. Ready state of the bomb was still limited to 9 days, 8 hours by the effective life of the batteries, and the factor of nuclear core heat was also thought to limit the period of complete assembly to 10 days. This factor forbade the accumulation of any large number of ready bombs of current type except by a multiplying of assembly teams and facilities.

For transport support of atomic operations the First Air Transport Unit had available ten C-54 aircraft with a similar number of crews. These were considered to have a safe range of 2,100 nautical miles with load of 8,000 pounds or 1,800 nautical miles with 10,000 pounds. A principal function of this unit would be the movement of the forward assembly teams, their equipment, and certain components, such as batteries, which would be serviced and ready for installation on arrival of the bomb. Loading of the bomb into the carrying or delivery aircraft would be carried out by Air Force armament personnel.

The study continued to prescribe rigid procedures for forward bases because of the possibility of take-off crashes with detonation of the high explosive and partial nuclear participation. Attention was also drawn to the necessity that intermediate bases also meet certain requirements. At this time no definite requirements for construction of new atomic bases had been established by the Air Force, although these were under study in connection with the proposed new bases at Limestone and Eielson.[31]

During the latter half of 1948, with Operation SANDSTONE out of the way, a number of Air Force-AFSWP field maneuvers were held, these including

Increasing attention was given to the forward assembly technique, and at WHIPPORWILL held in October, it was determined that assembly time per team, without allowance for battery preparation, could be reduced to 16 hours. Considerable difficulty was experienced in bomb loading because of the continued shortage of hydraulic pit hoists and nonavailability of the new C-9 internal hoist. It was necessary to rely on the C-6 hoist very largely, and this was uncertain as well as dangerous.

By the end of 1948 the requirement for assembly teams was increased to 20 from the 10 provided for in JCS 1745/5. However, it had become apparent that the training of such a number of teams, because of a shortage of technically qualified personnel and the length of the course, would be a long-term matter, and that the earliest possibility of greatly improving assembly capability would develop with the appearance of the Mark IV bomb. This weapon, which began to go into stockpile in mid-1949, made it possible to nearly double assembly capability.

The above discussed factors obviously provided only for the conduct of a limited operation--the assembly and forward movement of about one dozen bombs. For more extended operations it would obviously be uneconomical and limiting to depend on transport of the bombs by combat aircraft alone. The SAC Mobility Plan, which was also being developed in the latter part of 1948, also called for the utilization of all space in the bomb group aircraft for the transportation of necessary operational equipment. Although the B-29's themselves might be assigned to a transport function when they were replaced by later types, it was meantime desirable to consider the possibility of using transport aircraft for this function.

Study of the possibility of using various types of transport aircraft--including the C-47, C-54, C-74, C-82, C-97 and C-124--began in the late summer of 1948 under the supervision of the AFSWP. As a result it was determined that with the exception of the C-47 all of these could carry even the major components in disassembled form, although only the C-74, C-97, and C-124 could carry the complete components for one bomb in one load. At the end of the year Sandia Corporation was working on a special cradle for carrying the assembled bomb in a transport aircraft. It was later determined that this procedure would only be practicable in the C-97 or C-124. The limited number of these aircraft again drew attention to the possibilities of adapting the surplus B-29's for transport, but decision on this was to be delayed.

It may be noted that the presidential decision in July 1948 that custody of atomic weapons would remain in the hands of the Atomic Energy Commission until a specific order for their transfer after the development of an emergency somewhat complicated the assembly problem and made necessary the working out of procedures for the necessary exchange of components from Sandia Corporation, charged with storage responsibility, to the AFSWP, which would carry out the assembly. The first operational maneuver in the exchange procedure was SAFE SWAP held by AFSWP and the AEC in December 1948. Slightly over two hours was required to effectuate the exchange of four nuclear capsules after the exercise was initiated by the transmission of the code word from Washington.*

*See Chapter III.

Another important development during 1948 was the working out of a mobile supply plan which would enable the Strategic Air Command, with the support of the AMC, to move its units within 72 hours to any forward base in the world and there carry out sustained operations. In order to achieve this, each combat squadron was to be equipped with flyaway kits consisting of an air transportable assembly of aircraft spare parts and supplies designed to provide support for 30 days. Each was also to be equipped with essential unit equipment designed to meet the minimum requirements for carrying out initial operations for 30 days. Both categories of these items were to be moved in unit aircraft and organic air transport.

A readiness reserve was also to be established at certain designated depots, this to consist of TO&E equipment (less unit essential equipment), plus an additional 30 day quantity of aircraft spare parts and supplies, commonly referred to as Table II. This was divided into two categories--that to be airlifted and that to be moved by water. It was packed and marked so as to insure prompt shipment and arrival within 30 days to supplement the equipment and supplies which had moved with the units. The AMC was charged with the assembly and maintenance in storage of the necessary wing TO&E property and the aircraft supply tables. It was also to be responsible for the determination of quantitative requirements for the replacement of materiel and the preparation of the budget to support the logistic aspects of the emergency war plan. It was also to organize and train the Air Depot Wings which would provide the depot level logistic support to the tactical units included in the war plan. These procedures were to be extensively tested during early

1949, and by May the plan was being put into effect.[33]

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32. Ltr., Chief, FOFME, to Asst. for AE, sub.: Planning Requirements for Transportation of Bombs, 27 Aug. 1948; ltr., C/S AFSWP to C/S USAF, sub.: Interim Report on Transport Capacity of Cargo Aircraft, 27 Oct. 1948; Note for Record by Col. Ralph Rhudy, AFOAT, no sub., 28 Feb. 1949.

33. USAF and Atomic Warfare, pp. 195-197.

CHAPTER XV

SPECIALIZED RESEARCH

New Research Policy

One of the most important effects of World War II on military science was to emphasize the astounding results in the form of weapons systems and countermeasures which could be achieved by the application of recent scientific discoveries to warfare, particularly through the coordinated effort of scientists themselves. These results had appeared in such forms as radar, the proximity fuze, the German V-1 and V-2 guided missiles, and most spectacular of all—the atomic bomb. The last could serve as a classic example of the carrying of an idea through the research, development and production stages into a finished weapon within a limited time through intensive, large scale, coordinated effort. Nevertheless, this effort, successfully telescoped as it was, had required nearly six years from the time of Dr. Einstein's letter to President Roosevelt to the drop on Hiroshima, and only three bombs had been produced. Although their cataclysmic effect made additional ones unnecessary, this at the same time meant that a similar period of preparation would not again be available in the future.

The above situation was clearly recognized by the Spaatz Board, which emphasized as a major point the necessity for a greatly enlarged research and development program in order to maintain a first line air force in being, capable of warding off a sudden atomic attack. Later studies suggested that such an attack might be impossible to ward off and that the only defense lay in the deterrent of an immediate capability of delivering an overwhelming retaliation. In either case the cushion of space and time heretofore enjoyed by the United States had disappeared before the advance of the new weapons.

Army Air Corps activity in background or basic research during the pre-war period was limited almost entirely to its co-sponsorship of the National Advisory Council on Aeronautics. Its need for more advanced types of aircraft was satisfied through development contracts made after competitive bidding among aircraft companies in an effort to meet military characteristics which it specified. The Army Ordnance Department in somewhat similar fashion met its need for bombs and guns. Any necessary background research in aeronautics was accomplished by the contracting companies or the NACA. The onset of the war, the resulting expansion, and the achievement of semi-autonomous status by the Army Air Forces did not greatly alter this situation. Wright Field, for instance, remained essentially a center for coordinating production and procurement, receiving and testing new equipment, and accomplishing modifications.

The direct gearing of research and development which produced the V missiles and the atomic bomb made clear that the older system was now obsolete, as the Spaatz Board recognized, and the establishment of the Office of the Deputy Chief of Staff for Research and Development in December 1945 represented the first step toward a reorganized approach. Despite the obvious interest of the AAF in the new prospects opened by the unlocking of atomic energy, it was severely handicapped in entering effectively into either research or development within the field because of three principal factors: it was organizationally in a subordinate position, Manhattan District was maintaining a tight grip on all atomic information and activity, and there were few AAF officers who had any knowledge whatever of atomic matters. Only a handful had had any direct contact with the technology of the atomic bomb, and this had been decidedly limited—almost entirely to the field of operational logistics. The first objective of the AAF was therefore to secure entrance into Manhattan Project for a few AAF officers of suitable technical background, and this was achieved during early 1946. Later a program of training a small group of carefully selected officers in nuclear physics was also instituted. Results of these programs would necessarily be of slow growth.

Although the AAF was hardly in a position to sponsor an extensive program of research in view of the above circumstances, coupled with the rapid post-war mobilization, it could turn to the aircraft companies with which it had been long cooperating for technical assistance. The ability of these companies to deal with specific development problems had been repeatedly demonstrated. It was therefore logical to attempt to utilize this technological competence in the new field which was now opening. Accordingly, the AAF entered into three broad research contracts during early 1946 which had direct or indirect connections with the utilization of atomic energy. Two of these--NEPA, with a group of aircraft companies led by Fairchild, and Project MX-770, with North American--called for research into the possibilities of applying nuclear energy to the propulsion of aircraft. The third--Rand, with the Douglas Aircraft Company--was much broader in scope, calling for feasibility studies of the entire subject of intercontinental warfare by air; however, it was obvious that this would concentrate principally on the use of atomic weapons. The immediate problem, in order to make these projects truly operative, was to gain for them access to classified information concerning atomic energy, and the struggle to achieve this was to be almost constant for more than two years to come.

Definite results of the new policy as applied to the atomic field were visible by the end of 1948. As the outcome of a Rand study, accompanied by effective staff action by the Air Force, a coordinated program to develop techniques of radiological warfare had got under way in the National Military Establishment. Agreement was also near on a coordinated program to develop a means of applying nuclear propulsion to aircraft. The Air Force had also successfully discharged its responsibility for conducting a broad study of long range detection techniques, utilizing the resources of many governmental agencies. The degree of scientific-military collaboration achieved in these ventures forecast a further expansion of such coordinated measures. Two of these programs--nuclear propulsion and radiological warfare--will be reviewed in this chapter, while the third, long range detection, has already been treated as an effort in technical intelligence.* A brief summary will also be given of the organization and early activities of Rand, which became an increasingly vital factor in directing the course of technical research and development as applied to atomic warfare.

Project Rand

Project Rand, established early in 1946, was to play a considerable role in Air Force atomic research and development, particularly through feasibility studies which indicated the general direction to be followed in various development and planning areas, such as the development of nuclear engines for aircraft, the development of strategic bombing systems, and radiological warfare. The project was of course by no means limited to the atomic area, and in fact had some difficulty in gaining entry into it. Basically, its establishment appeared to be a reflection of the great prestige acquired by science during the course of World War II, coupled with the realization that a broader and better organized approach to the problem of military research and development was necessary in order to more fully

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*See Chapter VIII.

exploit its possibilities.

Rand was organized by the Douglas Aircraft Company as a contract project MX 791 of the Army Air Forces. Initiated by a letter contract dated 1 March 1946, the project was later given a definitive contract, No. W 33-038 ac-14105, dated 24 June 1946. These contracts were broad in terms, stating as the general objective: "The contractor will perform a program of study and research on the broad subject of inter-continental warfare, other than surface, with the object of recommending to the Army Air Forces preferred techniques and instrumentalities for this purpose." Constant technical supervision was to be exercised by the newly established Deputy Chief of the Air Staff for Research and Development.[1] The organization was broadened in 1947 to include representatives of three other aircraft companies—Boeing, North American, and Northrop—on an advisory council, and on 14 May 1948 Rand was reorganized as a non-profit corporation.[2] Air Force policy toward Rand was officially defined in AFL 80-10, 21 July 1948,[3] which after restating the original mission of the project went on to emphasize that Rand was essentially a "background research project—not a development project."

The project proposed to operate principally by assigning sub-contracts for research within specialized fields to existing research institutions throughout the country. Recourse would also be had to the services of consultants, these being recognized authorities in various fields throughout the country. A relatively small central organization would be established. The project was thus essentially a means of organizing the available research talent of the country for application to future military problems of technical nature confronting the post-war AAF. By January 1948 Rand's atomic activities were organized under three main headings: Systems Analysis, Air Defense,* and Weapons Analysis. Nuclear energy information was required in all these areas.[3]

Rand attempted no specific studies in the atomic energy field during 1946 or early 1947, because of the close control on the dissemination of technical information being maintained by Manhattan District and the AEC. In December 1946 the AAF began the effort, to be very protracted, to obtain a sufficiently broad access to atomic data for Rand to enable it to function effectively.** In a letter to Maj. Gen. Leslie R. Groves, Maj. Gen C. E. LeMay elaborated at length on the proposed functions of Rand and its relationship to the AAF:[4]

> For many years the AAF has utilized a typical Army procedure to obtain new and improved weapons for the conduct of aerial warfare. This procedure relied upon the technical skill and ability of AAF personnel to conceive and state in the form of general characteristics the requirements for aerial weapons. The picture today has changed in that scientific and technological developments have advanced to such a point that the AAF cannot be expected to have, within its ranks, personnel whose scientific knowledge parallels or exceeds that of civilian scientists and technicians. During the

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* See Chapter IX.

**Manhattan had granted Rand access to the NEPA quarterly reports in November.

war a very close relationship was developed between the military and scientific world. As a consequence, the scientists for the first time were able to study military problems beyond the normal confines of stated military characteristics. Mutual understanding between the military and civilian scientists advanced to such a point that the results are apparent to all. These intimate contacts will be continued and increased by encouraging the scientist to exercise his imagination and talent in developing new weapons for the military.

The above facts were well understood by General H. H. Arnold, and before he relinquished command of the AAF, methods were conceived whereby civilian scientists could be placed in a position of recommending to the AAF better ways and better equipment for conducting aerial warfare. One of these methods consists of contracting with one of the most reputable aircraft companies in far broader terms than had ever been conceived to date. It was thought, and time has proved this thought conclusively, that a very broad contract which stated in general that the problem of inter-continental warfare, other than by surface means, should be studied in its entirety, would attract some of the best scientific minds in this country. The awarding of such a contract to Douglas Aircraft has already attracted talent far beyond what was originally conceived to be possible.

LeMay emphasized that one essential was complete exchange of information between the AAF and Rand, and stated that Rand personnel had been given a complete briefing by the Air Staff, including an intelligence estimate and war plans. He went on to explain:

It is not intended, nor will Rand be permitted to participate in any detailed study or analysis which is adequately covered by another contracting agency of the AAF. It is expected, however, that Rand will, by virtue of general knowledge of all AAF research and development activities, be able to integrate all information with their own studies in the development of new aerial weapons....

It is felt that Rand, by the very nature of their AAF contract, will be in an excellent position to translate the application of atomic power to rockets, satellites, etc. It follows that Rand will be able to assist NEPA in establishing some of the overall characteristics such as weight, size, and dimensions of the end products which NEPA may eventually conceive and prove practical....

> The new problem which falls within the scope of the Rand contractor is the integration, in general terms, of the characteristics now and in the foreseeable future, of atomic explosives which undoubtedly will be a part of the intercontinental missiles evolved as a result of Rand studies. Here again it is considered essential that Rand be provided with general information, namely weight, size, dimensions, and general characteristics of this all important part of the final product in order that Rand studies may be complete and comprehensive....

LeMay specifically requested the clearance of one Rand representative for general information by Manhattan, or more if compartmentation were desired.

The above statement apparently failed to gain the desired access, as LeMay renewed the request in a letter to the AEC in May 1947. He proposed that the AEC grant general clearances for a limited number of top personnel, in order to permit proper direction of the project, and administrative clearances for visits to appropriate AEC facilities by scientific and technical personnel; and also that it make provision for the transmittal of such AEC reports as might be required to assist Rand in its function. Asking for an opportunity to brief top AEC personnel on Rand, he explained:[5]

> More broadly, the objective of this project was to face squarely one of our greatest weaknesses, namely the fact that in the past our research programs have in general borne little relation to basic or strategic plans, and our planning has borne little resemblance to research programs. We cannot do long range planning without taking fully into account intelligent estimates of strategic advances in science and technology; conversely if we expect research and technology in this country to give the greatest support to national security, we must bring leadership in these fields into our confidence, familiarizing a select group with our estimates of future military problems.

After further negotiation, including a conference among [illegible], MLC, and AAF representatives on 17 July 1947, the AEC agreed to grant clearances to a few top Rand personnel for broad information and to give Restricted Data concerning reactor design and power production to persons in Rand who in the opinion of the AAF required it. It also agreed to review Rand studies for validity of assumptions as to availability of raw materials, present and projected rates of production of fissionable material, and progress of reactor development. It, however, disapproved participation by AEC personnel in a summer symposium on nuclear power aircraft planned by Rand and declined to monitor it for security.[6] Although these represented decidedly limited concessions, since the channel of access would be at a formal top level and the area strictly delimited, it did permit Rand to aid NEPA, which was having rough going, by undertaking several nuclear power studies.

Another [illegible] area of activity for Rand in the atomic [illegible] during [illegible], [illegible] was radiological warfare. In this case, it undertook at the suggestion of Gen. George S. Kenney, Commanding General of the SAC, but on its own responsibility, a preliminary feasibility study of radiological warfare, using only publicly available information, such as that contained in the Smyth Report. The result presented the subject in such a new and favorable light that the Air Force, by effective staff action, was able to initiate a joint NME-AEC effort in this new system of warfare. Rand representatives participated actively in the joint effort.

Rand was able to expand its atomic activities in still other areas during 1948. In its report to the MLC on atomic activities as of 31 December 1947 the Air Force indicated that RAND was expected to become active in the following areas in addition to the two already mentioned: the effect of the characteristics of atomic weapons on the operational requirements, design, performance, and cost of the carrier vehicles; target studies on the number of atomic weapons required to perform a given task; comparisons of the relative importance of atomic weapons and those of other types; future possibilities of atomic bombs.[8]

Entry into the first of the above fields came about during 1948 as the result of difficulties experienced by the AFSWP in fulfilling a request from the MLC. In August 1947 the latter had asked for a study delineating the technical considerations concerning the development of atomic weapons suitable for any means of delivery. This was to be submitted by the MLC to the

JCS as a foundation for the establishment of a coordinated program of weapons development to which the JCS and RDB could assign priorities consistent with both technical possibilities and military requirements. After asking the services for statements of the desired military characteristics for atomic weapons, the AFSWP began the study, now further broadened, but by the spring of 1948 was finding increased difficulty in making progress. At the suggestion of Col. W. M. Canterbury, Chief of the Development Division, the AFSWP asked for the aid of Rand in carrying out the proposed study. The request was approved by the Air Force, and the AFSWP accordingly asked the AEC to approve an exchange of information among Rand, Sandia, and Los Alamos.

Meanwhile, on 2 July the Air Force directed Rand to support the comprehensive study of atomic weapon development as related to atomic warfare which had been undertaken by the AFSWP. The scope of the proposed program may be summarized as follows:

a. The relative military effectiveness of various types and methods of employment of atomic bombs and warheads.

b. The effect on nuclear efficiency and military utility of variations in the size and power of present and future types of atomic bombs.

c. The technical and economic feasibility of the weapons and methods of employment analyzed as above.

d. The development problems inherent in various possible means of delivery.

e. The analysis and study of new proposals or developments in the field of military utilization of atomic weapons.

f. Any other considerations pertinent to the over-all problem.

Accomplishment of this assignment would obviously require access to a very wide range of Restricted Data.[9]

As a preliminary step, the Air Force conducted a briefing in July 1948 at Kirtland AFB for Sandia Corporation-Los Alamos personnel on the scope and nature of the preparation of the Air Force for atomic warfare. After a favorable reaction to this, the Air Force, which had for some time been trying to secure unrestricted collaboration between its agencies and the appropriate laboratories of the AEC, asked for AEC approval for direct collaboration between Los Alamos and Rand. On receiving the Air Force request, the Military Applications Division, AEC, referred the entire matter of coordination to the MLC with the suggestion that it prepare a complete, non-overlapping program of NME projects requiring such collaboration. It also stated that the AEC agreed as to the desirability of direct collaboration at the working level. The MLC referred the suggestion to the AFSWP, which dealt with it by scheduling a conference of the interested agencies for 1 September 1948.

The AFSWP wished to limit the discussion to the local level, regarding the question of collaboration with RAND as the immediate problem and viewing the over-all problem as too broad. At the resulting conference, Dr. Norman Bradbury of Los Alamos took immediate exception to the request by Rand for generalized information on the atomic bomb and freedom of discussion with Los Alamos. He agreed finally to transmit information in certain specific areas (bomb modifications, external ballistics, and terminal ballistics) through the AEC and MLC in Washington. In the opinion of Col. John G. Armstrong, the Air Force representative at the meeting, this substantially defeated the purpose of the meeting, since it continued the Manhattan District policy of providing information only in response to specific requests. It may be noted that this conflicted with previous assurances given by the Division of Military Application.[10]

Nevertheless, using the information thus acquired, Rand was able to widen considerably the scope of its atomic studies. Although nearly all its atomic studies during 1948 and 1949 continued to be related to radiological warfare and nuclear engines, it began to publish studies on the use of the atomic bomb early in 1950. Meanwhile, many of its target and vehicular studies were directly related to atomic warfare, as was its broad air defense study.*

Establishing a Research Program for Atomic Propulsion

The proposal for an AAF research project aimed at accumulating a sufficient background of data to make possible the development of an aircraft propelled by nuclear energy appears to have originated in the Office of the Assistant Chief of the Air Staff-4 (Materiel) in the fall of 1945. As early as 18 October AC/AS-4 wrote to the Air Technical Service Command

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*For a list of items containing Restricted Data, see Rand Publications Index, AEC RD Supplement, August 1952.

relative to the stablishment of a broad program to study the effect of atomic energy on future AAF weapons and equipment, describing efforts being made to obtain a formal channel by which AAF engineering activities could obtain access to technical data on nuclear energy.[11]

On 7 December 1945 Brig. Gen. Alden R. Crawford, Acting AC/AS-4, notified the ATSC of the establishment of the Military Advisory Board to the Commanding General, Manhattan District, of which one duty would be to advise Manhattan of the needs of the services. General Crawford stated that the AAF member, Maj. Gen. Curtis E. LeMay, would serve as the necessary channel for requests for and the dissemination of information, and suggested that the ATSC proceed to prepare a resume of the information desired for both current and future AAF programs in aircraft, missiles, electronics, propulsion, and accessories.[12] Following further communications between the AC/AS-4 and the ATSC this was limited to a review, in the form of a draft letter to Manhattan District, of the present status of AAF research and development activities in the propulsion field, the anticipated advantages offered by nuclear propulsion, the speculative characteristics of future aircraft so propelled, and the proposals of contractors. General Crawford suggested that action might be undertaken by Manhattan District or by contractors selected by the AAF and functioning under the joint cognizance of the AAF and Manhattan.

The draft letter requested was submitted on [illegible] March 1946 by the Engineering Division of AMC, to which it had been passed by the ATSC. After a review of the propulsion field, it suggested several methods by which nuclear energy might be utilized. Of these it recommended steam power, the gas turbine, and the turbo-jet as the most immediately promising. The Air Materiel Command had meantime budgeted one million dollars for research and development into atomic energy power plants for fiscal 1946, and proposals for development work had been received from the M. W. Kellogg Co., the Fairchild Engine and Airplane Corp., and B. M. Giannini and Co.[14]

Meanwhile, staff conversations were proceeding with Manhattan, and General Spaatz, Commanding General of the AAF, proposed to General Groves on 22 March that the AAF enter into contracts with certain industrial firms for studies on atomic energy propulsion for aircraft and related experimental work. The plan called for the establishment of a general atomic energy power research project at Oak Ridge by the Monsanto Chemical Company. Aircraft companies accepted as contractors by the AAF and approved by Manhattan would furnish technicians to work on the general project under the control of Monsanto, while the AAF itself supplied project officers to monitor each contract and provide liaison between the Air Materiel Command and the Manhattan District. The AAF would deal with Monsanto on the details of the work to be undertaken.[15] Manhattan agreed to the AAF proposal on four conditions: (1) all work would be undertaken under the cognizance of one contractor agency; (2) a special security system, approved by Manhattan, would be established; (3) there would be no proselyting of Manhattan Project scientists or hiring of specialists formerly employed by it without prior approval; (4) the contract and all later work done under it involving Manhattan District information would be approved by it. The AAF was then invited to send observers to a Manhattan District meeting in New York City which was held to discuss the proposed organization of a group to undertake the development of the Daniels pile. Manhattan planned to place this group under the direction of the Monsanto Chemical Company, contractual operator of the Clinton Laboratories at Oak Ridge, Tennessee.[16]

The AAF dispatched invitations to the aircraft engine companies selected for participation for an organizational meeting to be held at the Pentagon on 23 April 1946. The companies selected were those which had built or which held a contract for a tactical aircraft engine, a criterion which excluded two companies, M. W. Kellogg Co. and G. M. Gianni & Co., which had presented nuclear development proposals. Twelve companies were represented as follows: the Allison Division, General Motors Corp.; the Continental Aviation and Engine Corp.; (Continental Motors, Inc.); the Fairchild Engine and Airplane Corp.; Frederic Flader, Inc.; the General Electric Co.; the Lycoming Division, Aviation Corp.; the Menasco Manufacturing Co.; Northrop Aircraft, Inc.; the Pratt and Whitney Engine Co.

(United Aircraft Corp.); the Packard Motor Car Company; the Wright Aeronautical Corp. (Curtis-Wright Corp.); and the Westinghouse Electric and Manufacturing Co. The Manhattan District, the Monsanto Chemical Co., the National Advisory Council on Aeronautics, and the Navy Bureau of Aeronautics were also represented. The NACA was invited by the AAF to join in full participation and the Navy Bureau of Aeronautics as an observer. In accord with its agreement with Manhattan, the AAF plan presented provided for one "vehicle", or monitoring company which would hold the AAF contract and main responsibility, though equal participation would be allowed all the other companies. Because of the more advanced state of its planning, Fairchild was designated the "vehicle" company, with the agreement of the others present, all of which agreed to participate with the exception of Packard.[17]

By drawing into the project such an extensive section of the aircraft industry, the AAF expected to achieve two desirable results. First, a selection of technical and engineering personnel of extensive practical experience, otherwise unavailable, would be applied to a specific problem of great difficulty, and these would be supported by the industrial facilities of their companies. Second, the participating individuals would carry back with them at the conclusion of the project knowledge in a new area which could then be used to educate the entire aeronautical industry.

Dr. McCullough, representing [illegible] meeting, explained that the first object of the main project would be to develop a working ground power unit of the Daniels pile, for which a sound theoretical basis had already been laid by the Manhattan District. He proposed to set up three working groups. The first would deal with the immediate planning of piles, control and handling, boiler details, blower details, and chemical processes. The second would be concerned with long-range planning. The third would deal with the selection of the power plant. Monsanto proposed to recruit 15 individuals from industry for Group I and 6 to 8 for Group II, while it provided those for Group III from its own organization. It would also draw on industry for 30 part-time consultants of the top rank. The AAF phase of the project would parallel the activities of Monsanto and would be staffed by the aeronautical companies under the leadership of Fairchild. These personnel would have equal access to all information and would return with their acquired knowledge to their companies at the conclusion of the project, which was expected to extend for approximately 18 months.[18]

A letter of intent in the amount of $1,300,000 was signed by the AAF and Fairchild on 23 May 1946, and a second organizational meeting was held on the 28th of the same month. NEPA Project began to function at once, directed by Mr. Dean C. Smith of Fairchild from the company's offices in New York City, and during the summer of 1946 were mainly concerned with organization, recruiting of personnel, negotiations with Manhattan over facilities and housing at Oak Ridge, preparation of a [illegible] contract, and planning for the training and research programs to be put into effect. It was also quickly seen that an extensive training program would be essential in order to quickly acquaint engineers and technicians with the status of current advance in the field of nuclear energy. Transfer of the project's offices to Oak Ridge took place in September.

A cost-reimbursement, non-profit contract was prepared in preliminary form by October. Direct costs and administrative expenses were to be payable monthly, subject to redetermination every six months beginning 30 June 1947. For fiscal year 1947 and 1948 the estimated cost was $3,300,000, including $312,000 for administrative expenses and a $300,000 special fund.[19] Ratification of the contract was delayed, however, by various factors and did not come until 8 May 1947. Including the $1,300,000 covered by the Letter of intent, it amounted to $3,300,000 (from 1946 and 1947 fiscal year AAF research and development fund resources). In addition to the prime contractor, the Fairchild Company, it provided for participation by the member companies and for a Board of Consultants drawn from them.[20]

An outline of the proposed research and development program was ready by 30 August 1946. In addition to the work performed at Clinton Laboratories, it was proposed to subcontract for projects in specific areas with private institutions and the Massachusetts Institute of Technology and with aeronautical companies.[21] After this outline had been circulated among the Board of Consultants, a meeting was held by it on 8 October, together with representatives of the Military Liaison Committee, the Army Air Forces, the Navy, and the Monsanto Chemical Company, which was the principal Oak Ridge contractor. In addition to giving favorable consideration to the proposed research and development program, the meeting considered the proposed educational program, all technical proposals received, and miscellaneous matters, including the possible effect on the project of the establishment of the Joint Research and Development Board and the Atomic Energy Commission. As a result the AAF prepared and forwarded to Manhattan District in late October 1946 a review of the proposed research and development program, together with comments on operational methods and sub-contracting procedures, and these received general approval.[22]

Meanwhile, two other research efforts in nuclear propulsion for aircraft had got under way under the leadership of North American Aviation, Inc., and Rand Corporation, and it now became obvious that these would have to be coordinated with NEPA so that their activities would harmonize rather than clash with those of the principal project, particularly in utilizing the limited national research facilities in the nuclear field.* It was also obvious that Manhattan District would not sanction more than one large effort by the AAF in the field of nuclear propulsion.

Project MX-770, assigned to North American Aviation, Inc., and approved by letter contract of 29 March 1946, slightly antedated the NEPA Project and was given a directive which was apparently broad enough to permit entrance into the same field of research. The definitive contract, approved 9 December 1946 as Contract W 33-038 ac-11291, called for the contractor "to conduct experimental investigations and engage in a study and research program for a period of one (1) year ending 22 April 1946;" however, this was later extended. The contract was aimed toward providing the necessary basis for a long-range surface-to-surface guided missile system, comprising within its scope studies of structures and metallurgy, guidance systems, and propulsion systems, "including... atomic power." It was further stated, "The study and research outlined... is intended as a guide and does not limit the extent of the research work to be conducted;" however, the contract did provide for "constant supervision... by the Air Materiel Command in order to avoid duplication of work being done by other organizations."[23]

North American, operating under the above very broad provisions, assembled 260 engineers and scientists at its Aerophysics Laboratory at Inglewood, California, and began studies toward a nuclear propulsion system, at the same time asking for recognition as a participating part of the NEPA. Although this request was rejected by the AAF, the project was invited to submit further ideas for consideration. It thereupon proceeded to prepare an extensive report--NA 47-15--in February 1947. Greatly advanced over the earlier proposal, it requested authority to undertake background research on and the development of nuclear reactors together with associated rocket and ram-jet engines as an integrated phase of its work under Project MX-770 toward the development of a long-range surface-to-surface missile. It specifically proposed the development of a high temperature reactor as the first step toward an open cycle nuclear engine employing either the turbo-jet or ram-jet principle.[24]

After consultations with representatives of NEPA, the AEC, Monsanto Chemical Company (contract operators of the Clinton Laboratories for general nuclear research at Oak Ridge), and Rand, culminating in a conference at Oak Ridge on 28 April 1947, the AAF concluded that despite the many interesting aspects of the report it reflected a time lag in the latest information on nuclear development and that this seriously detracted from its soundness. The North American proposal was therefore rejected in favor of the continuation of a single coordinated project under the leadership of Fairchild, and North American was asked to permit its nuclear scientists to transfer to NEPA. MX-770 was continued, however, as a guided missile project.[25]

A second independent research proposal was sponsored by the Douglas Aircraft Company through its Rand contract. A Nuclear Physics Section had been set up within Rand under Dr. David T. Griggs. Though concerned with all nuclear processes having a bearing on intercontinental warfare, it at first concentrated on nuclear propulsion. Late in 1946 Rand submitted a plan to pursue applied research at the Battelle Memorial Institute in nuclear rocket propulsion, aimed ultimately at the construction of a "percolator type" reactor, utilizing a drilled, porous aggregate block impregnated with a uranium oxide. Extremely high energy density and volumetric efficiency were claimed for this arrangement, and it was forecast that a combined heat exchanger and pile developing [illegible]0,000 pounds of thrust might be contained within a volume of less than two cubic feet. After some correspondence and a conference in January 1947 attended by representatives of Rand, NEPA, and Battelle, the AAF decided that the Douglas proposal would overlap the work of NEPA. Since the conferees agreed that the proposal merited investigation, however, it was agreed that it would be taken over by NEPA through a suitable contract with Battelle. Rand also was to continue its studies in nuclear propulsion through a general evaluation of future potentialities of various proposed systems without entering into detailed design or construction problems. These would be integrated into an over-all study of various propulsion systems, including chemically fueled aircraft.[26]

Meanwhile, the NEPA Project Staff, which had been operating from the Fairchild offices in New York City, was moved to Oak Ridge in September 1946. Here were to be centered administration, planning, training, and certain types of research in convenient proximity to the Clinton Laboratories, where work preliminary to the development of the Daniels pile had begun. A site identified as the S-50 Area was assigned by Manhattan Project, various types of housekeeping services were arranged for, and a housing program for NEPA personnel got under way. Salary and wage scales as well as job titles employed by Monsanto were used as patterns in order to conform harmoniously with the local situation. A health and accident insurance program was also established.

By 27 January 1947 approximately 200 contractor personnel and 75 military had received clearance, and work was well under way on the collation of data and the preparation of handbooks on nuclear physics, pile design, thermodynamic factors, and shielding. A nuclear physics training program was being conducted, and a breakdown of the program into definitive projects was being prepared.

Three basic types of propulsion were being considered: open-cycle (including turbo-jet, turbo-propeller, ram-jet, and pulse-jet), rocket systems, and closed cycle (including steam and mercury vapor turbines). The main problems appeared to center around reactor and moderator combinations, pile geometry, shielding provisions, control features, physiological considerations, working fluids, and heat-resistant materials. Although no definite estimate of time was considered possible because of the many intangible factors, it was believed that a crude laboratory-type engine could be completed within three years, with essential refinements requiring three to five additional years.[31]

The Air Force Fight for NEPA Project

The future status of NEPA was brought into question in early 1947 by the realignment of atomic energy activities by the Atomic Energy Act of 1946 and of research and development functions in the War and Navy Departments incident to the establishment of the Joint Research and Development Board. Manhattan District's share in the control of NEPA passed to the Atomic Energy Commission on 31 December 1946 under Executive Order 9816 (Par. 1 (a) and (b)). Chairman Lilienthal, however, agreed to issue an order under the provisions of Section 3 (a) of the Atomic Energy Act to leave undisturbed the administration and supervision of any War and Navy Department contracts and facilities for research and development which had been transferred, pending a thorough study, and then make mutually satisfactory arrangements concerning the future status of such contracts and facilities.[32] The AEC, however, showed no immediate intention of pressing for an early decision on NEPA, though it [illegible] allotted no funds for its support.

The NEPA Project came under the consideration of the JRDB in February 1947 in connection with its examination of the various atomic energy programs of the National Military Establishment. It was particularly concerned that these programs be so coordinated as to reflect the best usage of the limited amount of fissionable material available and the likewise limited quantity of scientific manpower. The question of the continuance of NEPA became specifically the concern of the newly created Committee on Atomic Energy of the JRDB, which apparently considered it at two meetings during March and April 1947 after having been briefed on the history, aims, and organization of the NEPA Project on 10 March by its representatives.[33] At the request of C. H. Greenewalt of the CAE, Maj. Gen. Alden R. Crawford and Admiral Stevens also made statements for the AAF and Navy respectively on the program. In general, they supported the thesis that chemically fueled aircraft could not achieve sufficient speed and range to carry out successfully the strategic offensive against Russia and therefore urged the continuation of the project.[34] On 9 April Dr. J. B. Conant, Chairman, reported to Dr. Vannevar Bush, Chairman of the JRDB, that it was the opinion of the Committee that it would require a minimum of ten years to develop a nuclear propulsion unit for aircraft and that an all-out effort in this direction would seriously interfere with the program to develop new reactors for the manufacture of fissionable material, resulting in a diminished bomb output. Stating that testimony received from Army, Air Forces, and Navy officers present had been conflicting, he asked for guidance as to the tactical necessity of atomic bomb delivery by nuclear powered aircraft after periods respectively of ten and twenty years, pointing out that each such aircraft would require from five to ten times as much fissionable material as one bomb. At the request of General Crawford and Admiral Stevens he also posed the question of the justification, in lieu of the full-scale tactical nuclear delivery system, of the development of one nuclear-propelled prototype, to be available for exploitation in the event fissionable material became less scarce. Dr. Conant expressed the opinion that barring an over-riding priority for the development of a nuclear-propelled delivery system, the diversion of any considerable amount of effort to such a program could not be justified.[35]

The JRDB in turn referred the matter to its Policy Council, and after a report rendered its decision on 12 May: "With the advice of the Policy Council, the Board finds that it seems probable that ten years from now the problem of delivery of atomic bombs will, for a few aircraft, justify the diversion of five to ten times as much fissionable material for use as a propellant for one aircraft as is used in the manufacture of one bomb." The JRDB professed its inability to predict the priority of this problem over the next twenty years, but stated its belief that the development of nuclear propulsion systems should not be permitted to seriously retard the development and manufacture of atomic bombs. It also stated that the development of nuclear propulsion systems for aircraft should be correlated with an "authoritative planned program for development of atomic reactors for breeding and for mobile propulsion" in order to avoid a duplication of effort which the limited supply of scientific skill and fissionable material could not support. It suggested that this decision be periodically reviewed in the light of new facts.[36]

Stating that the CAE should not reexamine the NEPA problem in the light of this reply, Conant proposed that the Committee meet informally with the Policy Council on 25 July, a suggestion which received ready concurrence.[37] Various points of view were expressed at the two meetings held on the date mentioned, one a discussion meeting and the second an executive meeting which followed. The two extremes appeared in the stands of Conant, who wished to have the whole project terminated as premature, and of Greenewalt, who proposed that the project be reorganized in the form of a single contract with a more competent company than Fairchild. Oppenheimer, Groves, and Brereton expressed opinions between these extremes, Oppenheimer advocating turning the project over to the AEC for preliminary work, with a supervisory panel to see that the AAF interests were protected, and Groves and Brereton supporting this with the addition that an aircraft company should also be brought in to provide the aeronautical specifications of the nuclear engine. At the earlier meeting, for which no formal record is available, LeMay had apparently stated the willingness of the AAF to have the AEC take over the project provided that the interests of the AAF were protected. Brereton added at the later meeting that the AAF attitude was that it was being frustrated in carrying out the project by the passive attitude of the AEC and that it would be relieved by a termination if its interests were protected. Conant summarized the situation in a compromise statement which all [illegible] and which he transmitted to the [illegible] on 30 July, listing the following main points:

(1) The AAF should be advised to terminate NEPA promptly.

(2) The AEC should be asked to put more emphasis on a high temperature reactor program.

(3) The AEC should maintain close liaison with the AAF on the program.

(4) The AEC should contract with a highly qualified aircraft company to review specifications for a nuclear engine.

The Navy's nuclear propulsion program for ships (NEPS) was also discussed in somewhat vague terms at the meeting, and Admiral Solberg agreed to bring in policy recommendations.[38]

The attitude of the AAF on the recommendations of Conant was formally stated to the JRDB on 17 September by General Carl Spaatz. In brief, while accepting the main principle of transferring the responsibility for the program to the AEC, he objected both to the termination of NEPA without provision for the integration of its activities into those of the revised program and to the proposal for a contract by the AEC with an aircraft company to supervise engine specifications. He urged that the coordinated program to be established under the aegis of the AEC provide for "the direct participation of the interested Armed Forces agencies and the aircraft industry" and that it "lead towards the foundation of an industry in the aircraft power plant field." He proposed that the AEC make direct arrangements with the Air Force and the Navy Bureau of Aeronautics for the transfer of the NEPA program.[39]

The JRDB accepted in general the proposed emendations of the Air Force. On 23 December it suggested[40]

> that the Atomic Energy Commission accept the responsibility for establishing and actively prosecuting a single unified and coordinated program, with the direct participation of interested Armed Forces agencies and selected aircraft contractors. Following a review by a [illegible] of the Atomic Energy Commission

> of all work in the field, including the current NEPA program, it is recommended that the Atomic Energy Commission formulate a plan to effect the program described above, integrating those phases of the current program required to maintain engineering effort abreast of the nuclear research phases.

The letter further recommended that the AEC continue its cooperation with NEPA until the new program was established. This proposal from the JRDB was supplemented on 30 December by a letter from the Air Force outlining its views on the new program.[41] The program for a thorough review by an impartial board of the feasibility of nuclear propulsion of aircraft was handled by the AEC through a contract with the Massachusetts Institute of Technology, effected on 21 May 1948. The resulting Lexington Project submitted its report, favorable in nature, on 30 September 1948.[42]

The report, which will not be reviewed in detail here, concluded that "there is a strong probability that some version of nuclear-powered flight can be achieved if adequate resources and competent manpower are put into the development." It listed the following characteristics as attainable:

Concluding that a really intensive effort would be required if the plane were to fly within 15 years, it estimated that the cost would probably exceed a billion dollars. It found a tug-tow combination powered by some variation of the turbojet to be the most promising possibility.

The report recommended that the program be first established in an initial phase of approximately three years in which the objective would be to arrive at a sound basis for making major design choices and determining feasibility. This would involve research on materials; experimental and theoretical studies on shielding; studies on reactors, power plants, the airframe, and testing problems; and an appraisal of the military usefulness of the tug-tow scheme. Development of the reactor was seen as the outstanding problem because of the rigorous requirements for small size, high power, high temperature, and reasonably small content of nuclear fuel. Since no materials were available to assure the meeting of these standards, the development of suitable reactor materials, combined with ingenuity in design, was the most critical need of the program. A second serious problem was resolving the uncertainty as to the weight of the shielding required.[27]

Meanwhile, the urgency of the requirement for the development of nuclear powered aircraft had been publicly emphasized by two governmental commissions outside the National Military Establishment. The President's Air Policy Commission had reported on 1 January 1948:[28]

> The possibility of employing atomic energy for the propulsion of aircraft and guided missiles is sufficiently important to warrant vigorous action by the Atomic Energy Commission, the Air Force, Navy, and the NACA. Some work of a preliminary nature has already been done in this field by the AEC, the Air Force, and the NEPA project. Immediate steps should be taken to intensify research effort in this field under a plan which would be supported by all of the above agencies....

This was followed two months later by the report of the Congressional Aviation Policy Board, which stated:[29]

> The nuclear-energy propulsion for aircraft (NEPA) project should be accorded the highest priority in atomic energy research and development, and every needed resource and facility should be devoted to its early accomplishment. In the event of war or in any international situation likely to lead to war, nuclear energy for the propulsion of aircraft would be comparable in significance to the atomic bomb itself.

Meanwhile, work on Project NEPA continued, though apparently slowed by the cold blast of disapproval coming from the CAE and the lukewarm attitude of the AEC. A briefing for the MLC was held at Oak Ridge on 25-26 June 1948, but Rear Adm. R. A. Ofstie and Col. J. H. Hinds stated their opinion to Col. A. A. Fickel of the Special Weapons Group that it was "singularly unimpressive" and further suggested that the Air Force modify its optimistic discussion of nuclear propulsion possibilities in the MLC Annual Report or that it include a statement of exception as to Army and Navy concurrence. According to Fickel, the interim objective of NEPA at this time had become the design of a test stand engine of open cycle type. This would consist essentially of a cylindrical reactor containing fuel rods of U-235 placed lengthwise in a matrix of graphite. The air blast would pass through the rods themselves, which would be perforated lengthwise. The major technical problems in the reactor lay in providing a non-corrosive coating for the air ducts and in strengthening the reactor assembly. The shielding problem for the crew also remained unsolved, and the estimated weight of shielding unacceptably high, though no tolerance dose for the crew members had been finally established. A possible clash with the Navy's submarine reactor project ([illegible]) also appeared in the offing over the small amount of fissionable material (49 kilograms of plutonium and 250 of uranium 235) allocated for research by the AEC.[43]

The knotty problem of the military urgency of NEPA and its relative value as compared to [illegible] had been referred by the RDB to its Panel on Long Range Objectives. This panel met on 10 August

1948 that the NEPA program was potentially of far greater military value than NEPS, but also far more difficult and of long range aspect.[44]

The Lexington Report was forwarded to the MLC on October 1 by the AEC, which requested the views of the National Military Establishment; however, no early action followed while the various agencies considered the Report. The RDB referred it to its Committee on Atomic Energy and Committee on Aeronautics for consideration on 21 October, and on 9 November the Board instructed its Executive Secretary to initiate two studies to determine the effect of the proposed development program on (1) other AEC programs and (2) non-atomic research and development programs of the NME.[45]

A second communication came from the AEC on 8 December, requesting the views of the MLC on the Lexington Report. It expressed the opinion that the magnitude of the nuclear-powered flight project called for a decision from the highest governmental level and asked the MLC for its suggestion on the best method of obtaining such a decision at the earliest possible date. General Manager Carroll L. Wilson of the AEC explained that the Lexington Report had now been reviewed by the Commission's General Advisory Committee, which had pointed out that the project would require heavy usage of the limited supplies of technical manpower and fissionable material, as well as a billion-dollar, 15 year program, and urged a review, utilizing at least as much time and competence as the Lexington Project, from the nation's highest level of strategic planning. The Advisory Committee [illegible] meantime the [illegible] of a modest program of [illegible] theoretical study "to establish a [illegible] basis for making design choices and for determining feasibility," much of which would lie within the normal course of reactor development.

The GAC had proposed in more detail that a two-phase interim program be established, with the AEC accepting responsibility for research and development on reactors, materials especially suited for an aircraft reactor, and shielding and with the NME and National Advisory Council on Aeronautics undertaking studies on suitable aircraft and propulsion systems (possible through the existing NEPA Project). It had also recommended the formation of a suitable coordinating group and provision for a comprehensive review at the end of three years. As an interim program the AEC stated that it would expand its reactor work in the areas mentioned and suggested that the NME undertake the other phase. It also proposed that joint measures be undertaken to coordinate the program.[46] These proposals were to provide the basis for the establishment of the Aircraft Nuclear Propulsion Program (ANP), which was to absorb NEPA.

Meanwhile, the Air Force was taking vigorous action to break the log jam and get the propulsion program under way, under whatever name. Even before the receipt of the Lexington Report Brig. Gen. R. C. Wilson, one of the Air Force members, had stated to the MLC that the Air Force was preparing to offer a new three point program: (1) the JCS was to be requested to establish a requirement for the development of the nuclear propulsion of aircraft; (2) new legislation was to be sought to permit a budget extending beyond the present one-year limit; (3) industrial participation was to be sought on a basis similar to that [illegible] S. On [illegible] the Air Force members recommended that the MLC dispatch a letter to the AEC generally approving the Lexington Report and proposing immediate action on it, but no action was taken. The Air Force also offered a motion in the Committee on Atomic Energy on 17 December to inform the RDB that the latest budget figure of $3,293,000 was justified and should be approved, but this was defeated 7 to 2. On 4 January, however, the Air Force secured approval on a motion in the MLC to dispatch a letter to the AEC stating that the NME was prepared to examine a reactor program in conjunction with the AEC and NACA and work out procedures for coordinating the development of NEPA in concurrence with the proposals in the AEC letter of December 8.[47]

Meanwhile, the Air Force had presented a proposal to the Joint Chiefs of Staff, asking that they arrive at a decision on the strategic importance of nuclear powered flight and the degree of emphasis to be given to NEPA Project. This included a time phased program, with cost estimates. The JCS accepted the Air Force suggestion that the views of the MLC and the RDB first be obtained on the study presented, and forwarded it for evaluation. Providing for the ultimate construction of two aircraft, the proposal included a financial estimate of $825,460,000, which was based on a three phase program.* Phase I, extending over fiscal 1949-1953, would

* At the end of fiscal 1948 actual expenditures on NEPA had amounted to $2,191,821.49, of which $10,990 had been expended in fiscal 1946, $44,051.25 in 1947, and $2,191,821.49 in 1948.

[illegible] $215,710,000; Phase II, 1954-1957, $584,750,000; and Phase [illegible] (flight test), 1958-1959, $25,000,000.[48]

By the time the views of the MLC and RDB had been obtained--on 21 May 1949--a compromise solution had been reached by the establishment of the less extensive program proposed by the AEC on an interim basis. At a meeting on 29 January representatives of the Air Force, Navy, AEC, and NACA had agreed that the AEC would accept responsibility for the nuclear phase, the Air Force for the engine and air frame, and the NACA for supporting aeronautical research. Policy direction would come from an ad hoc committee including representatives of each of the above four agencies. During the [illegible]-year interim period the new Aircraft Nuclear Propulsion program would be supplied with approximately $10,000,000 per fiscal year, provided by the AEC, Air Force, Navy, and NACA in proportions of 50, 30, 10, and 10 per cent respectively. The NEPA Project itself would continue as a phase of the larger program. This arrangement was approved by the MLC and CAE.[49]

These developments and the establishment of the Weapons Systems Evaluation Group, which began to function in late February 1949, induced the Air Force to recommend that the JCS defer a decision on the military urgency of the new system of propulsion pending an evaluation by the new agency. This would utilize the information accumulated by the interim program, which would supplement the largely theoretical approach of the Lexington Project. The JCS approved this recommendation, made on 21 May, on 5 July 1949. At the same time, pending the evaluation of urgency, the JCS informed the AEC [illegible] that [illegible] support [illegible] the present program.[50]

A coordinated aircraft nuclear propulsion program had therefore finally begun to function, though on an interim basis pending final evaluation of military urgency. This was largely a result of the insistence of the Air Force on continuing the program it had independently begun and skillful defense of it in the complicated network of agencies overseeing the national atomic program. Like most long range development projects involving extensive background research the ultimate outcome remained a gamble, but one which the growing availability of fissionable material and technical information was to make seem more and more logical. Meanwhile, it remained the prime example of Air Force sponsored atomic research leading toward satisfying a specific requirement.

Radiological Warfare and Defense

The great burst of radioactivity accompanying the explosion of an atomic bomb attracted attention from the first as one of its most impressive phenomena, supposedly dooming to death any survivors of the blast and heat effects within the target area. It was rather quickly realized, however, that the number of such fatalities from this cause would be few indeed. Use of the scarce fissile material to secure the most widespread blast effect dictated a rather high air burst, and residual surface radioactivity would be small, since most of the radioactive products would be carried away in the atomic cloud. Persons surviving the other effects could generally expect to survive the [illegible] radioactivity.

The underwater explosion at Bikini in 1946 again raised the possibility of use of the bomb primarily for its radioactive effects, [illegible] the diffusion of [illegible] intensely radioactive spray [illegible] unexpectedly great, as was its lasting effect on the ships on which it fell. After consideration, however, it was realized that the number of suitable targets (for instance, vital cities with a body of water of considerable depth in immediate proximity) was very limited. Although the Bikini results provided the Navy with sufficient evidence to press successfully for the development of a penetrating weapon, they failed to alter the basic concept of atomic air warfare--use of the scanty supply of fissionable material to achieve the greatest possible blast effect over the widest possible area.

Another possibility for radiological warfare remained, and this received increasing attention during the latter part of 1946. Several scientists had pointed out that the Hanford atomic piles were producing as a by-product material which was potentially useful for such a purpose.* Regarded as a nuisance in the manufacturing process, the material was being stored in underground tanks--partly because of possible future utility and partly because of its dangerous property. The amount of such products could be increased at will by diverting neutron activity from other purposes. Unlike the atomic bomb, production of the active material for radiological warfare was not considered a serious problem. The technical difficulties lay in developing a practicable means of handling and delivery.

The Air Staff first took official action in this area in August 1946, when Maj. Gen. Curtis E. LeMay, Deputy Chief of Air Staff for

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*See H. D. Smyth, Atomic Energy for [illegible], Princeton, 1946, p. 65. As [illegible] prepared [illegible] with the [illegible], utiliz- ing fission products from a [illegible].

Research and Development, suggested in a letter to AC/AS-4 that radioactive fission products be investigated as possible means of offensive warfare. Referring particularly to the approaching conference with Manhattan District representatives on 3 September, he urged that this technique not be overlooked by the AAF in its campaign for "a definition of its responsibilities and authority with respect to the handling and delivery of the atomic bomb." In accompanying notes he pointed out a number of basic factors which he considered to underly the development of means of radiological warfare: (1) The plutonium pile produced 10 times the amount of radioactive material as a by-product that it produced through the manufacture of plutonium and its explosion in a bomb. (2) One pound of this material, with a half life of a year, was equal to 1600 pounds of radium, sufficient to poison the entire water supply of New York City. (3) It consisted of from 20 to 30 elements, which might be separated to give a wide variety of duration and intensity of effect. (4) There was no fundamental limit on quantity. (5) No practicable countermeasures were known other than removal, which might be impossible. (6) The material could be delivered by an aircraft with suitable shielding. (7) The principal use would be in denial of installations. (8) The proposed system was basically similar to the use of biological warfare agents, but was easier to control and less likely to meet effective countermeasures.[51]

The Air Chemical Officer replied on 26 August confirming the interest of the AAF in the use of radioactive materials as weapons. He urged that LeMay's [illegible] from M[illegible] all the applicable information available, [illegible] that [illegible] effective elements produced as by-products, their chemical and physical properties, quantitative data on present and possible future production, effects on personnel and materiel of various combinations, methods of protection and decontamination, safety requirements for handling. He suggested the Chemical Corps as the logical location for the over-all responsibility because of its experience in safety measures and protective devices, and the possibility of applying the same techniques used with chemical and bacteriological agents.[52] However, the conference mentioned by LeMay was almost entirely concerned with organizational problems and the establishment of security procedures, and nothing further was accomplished at this time.

During 1947, with Manhattan District in process of dissolution, the AEC and the AFSWP in the throes of organization, and the AAF struggling for a share in atomic research and development, little additional progress was made. Col. K. D. Nichols of the AEC proposed in January that the military services consider together with the AEC the scope and nature of a radiological warfare program, and in turn Maj. Gen. Alden H. Waitt, Chief of the Army Chemical Corps, suggested that the AEC initiate a research and development project in the utilization of radioactive materials for military purposes.[53] The letter ultimately reached the Committee on Atomic Energy of the Joint Research and Development Board, which in late July ruled against requesting the establishment of such a project because of various difficulties. It did recommend, however, that the AFSWP undertake a continuing study of the topic and that the [illegible] and AEC be informed of the need for information and study of the subject.

This was concurred in by the JRDB, which requested the AFSWP to undertake a study on the feasibility of the use of radioactive materials for military purposes. In December 1947 the JCS also recommended that the subject continue to be given intensive study.[54]

As a result of this decision the AFSWP established a Radiological Warfare Study Group in February 1948. It may be noted that the AFSWP had already been assigned responsibility for radiological defense within the National Military Establishment under its charter, and accordingly had established a Radiological Defense Division. The Technical Branch of this agency had already been assigned the area of radiological contaminants; however, by far the greatest amount of activity had been in the development of defense procedures, instrumentation for detection, and training. The AFSWP, it now appeared, was without the qualified personnel to undertake the type of evaluation of radiological warfare envisaged by the JRDB and JCS except possibly over a lengthy period; and before significant progress had been made events took a new turn.[55]

At almost the same time the subject had been assigned to the AFSWP, the General Advisory Committee to the AEC at its sixth meeting had pointed out the importance of the problem and urged that it be studied if only to help illuminate the defensive aspect. As a result the AEC wrote to the MLC on [illegible] October 1947 proposing the establishment of a joint study panel. The MLC countered on 17 November with the proposal that the AEC participate in the panel to be established by the AFSWP, where the matter rested for several months. On 22 March 1948 the AEC, at the renewed insistence of the General Advisory Committee, again proposed to the MLC that a joint panel be established.[56]

Support for this came from the Air Force, which had meantime developed a new interest in the subject as the result of a study by Rand. The Rand study, initiated by the project itself as the outcome of a question by General George S. Kenney, Commanding General of the SAC, was completed in December 1947, when advance copies were made available to the Air Staff, and later published on 10 March 1948 as RA-15026. A presentation was also made to the Air Staff by Dr. David T. Griggs, a principal author of the study, on 22 March 1948. Essentially a preliminary feasibility report, the study presented a favorable picture of radiological warfare possibilities, particularly in regard to ease of producing the active agents and tactical opportunities which would be opened by their use. Delivery possibilities were also described favorably, particularly in regard to crew shielding and the use of current aircraft types. Although not containing Restricted Data, the basic information having been drawn from such sources as the Smyth Report, the study produced a considerable impression within the Air Staff. The Chief of Staff, USAF, at the suggestion of Maj. Gen. S. E. Anderson, Director of Plans and Operations, accordingly recommended to the JCS that it propose an intensified effort in the area to the Research and Development Board.[57] The JCS recommendation, following the line proposed by the Air Force, came on 6 May 1948. Meanwhile, concurrence, somewhat reluctant, had come from the RDB, following a favorable recommendation from the MLC. Since the AEC had also been kept [illegible], the Joint AEC-NME Panel on Radiological Warfare was at once [illegible] and held its first meeting [illegible] May 1948. [illegible] many of the JRDB, meeting on 18 May, expressed certain reservations concerning the JCS recommendations, suggesting that the Rand study was based on inadequate information and was excessively optimistic. The CAE accordingly proposed that action in the radiological warfare area be limited to the work of the Joint Panel pending a complete report from it.[58]

The Joint NME-AEC Panel on Radiological Warfare consisted of the following members: Dr. W. A. Noyes (Chairman), Brig. Gen. James McCormack, Jr. (Secretary), Dr. A. M. Brues, Col. J. H. Hinds, Dr. W. M. Latimer, Dr. E. O. Lawrence, Dr. A. L. Loomis, Dr. W. M. Manning, Dr. F. C. McLean, and Dr. E. P. Stevenson. Colonel Hinds was the only representative of the National Military Establishment, General McCormack being drawn from the Military Application Division of the AEC. The meetings were generally attended, however, by numerous others, including members of the AEC, MLC, and NME, as well as expert consultants, among whom were representatives of Rand. At the first meeting, on 23 May, it was agreed "that the potentialities of radiological warfare are sufficiently clear to indicate that an active program of experimentation and development should go forward without delay." It was recommended that specific projects which appeared to have merit should be prosecuted without further reference to the Panel. In regard to defensive programs it was agreed that the first task of the AEC and NME was to seek out the problems, including the obvious one of public education, and that experiments in offensive use should also be utilized to supply data on these. It was expected that two or [illegible] at intervals of two or [illegible]. As a method of procedure it was agreed that Dr. Noyes would work at the head of a small selected staff during the summer and present a report at the next meeting, in approximately three months.[59]

The report of the Noyes group was prepared by a working staff of seven individuals from the AEC, two from the AFSWP, and two from Rand. Offered to the Panel at its second meeting on 29 August, the report included 15 recommendations, which may be summarized as follows:[60]

(1) that the JCS be informed that present production limitations made offensive radiological warfare impossible for at least two years;

(2) that they also be informed that the same factor would also continue to limit its use after that period to selected targets and that its use would probably not be a decisive factor in a major conflict;

(3) that the use of radioactive materials to deny localized areas during planned evacuations should be made feasible in about two years;

(4) that main attention be directed to gamma emitters for offensive use;

(5) that studies on a laboratory scale only on other types of emitters be continued;

(6) that prime responsibility for the development of dissemination methods be delegated to the National Military Establishment;

(7) that this be placed as to insure prosecution of a vigorous and coordinated program;

(8) that this program be such as to insure development of satisfactory dissemination methods within two years if possible;

(9) that the development of protection, detection, and decontamination measures be carried forward by adequate administrative action;

(10) that the AEC assume responsibility for other phases, particularly production of materials, [illegible] of biological effects, etc.

(11) that the AEC give high [illegible] its program of reactor development to research [illegible] looking to [illegible] production of RW materials;

(12) that the separation of the fission products zirconium and columbium from Redox solutions be investigated at a priority to insure completion of laboratory stages in one year;

(13) that the entire program be reviewed during the fall of 1949 to determine whether to establish a stockpile of a gamma emitter;

(14) that the several phases of radiological warfare be so reclassified as to permit the NME and other agencies to pursue adequate defense programs;

(15) that the Panel hold a further meeting on 6 December 1948 to review actions taken and make further recommendations.

The report also set forth a number of general conclusions, some of which threw an entirely new light on the subject of radiological warfare. These fell into four areas: type of emitter, dosage and contamination density, productive capacity, and munitions. In regard to type of emitter, the report concluded that the gamma emitters were the only feasible type, since they did not require entrance into or contact with the body. Other conclusions in this area nearly eliminated the widely held concept of using the Hanford wastes in crude form as a source of material for dissemination. The report pointed out that evaporation or other reduction in volume of the wastes would still leave a bulky product, difficult to handle. Separation of such gamma emitters as zirconium and columbium would be necessary, and this would involve considerable research and the construction of new plants. For various reasons the size of the resulting stockpile would also be quite limited. The report proposed as a preferable procedure that tantalum be irradiated in existing or later developed high-flux piles.

In regard to dosage, the report distinguished 2 types of targets, proposing 30 roentgens exposure per day per person for large targets of ten square miles or more, [illegible] [illegible], while [illegible] specialized targets of 1 square mile or less such as military installations would require 10 to 100 times as much. A factor x would be introduced where the population spent an appreciable time shielded by buildings. Using an x factor of 3, it was concluded that 1 megacurie of radiation per square mile would be required for minimum denial contamination of large-area targets, although no serious results might show for 1 or 2 weeks. This amount could be carried by 1 plane, although a factor y would also have to be applied to take care of uncertainty of delivery. Contamination of an area to such an extent as to deny entrance or crossing was considered to be impracticable. In regard to productive capacity, the report pointed out that by separating zirconium and columbium from pile wastes 1 megacurie a week could be produced, enough to maintain a stockpile equilibrium of 10 megacuries. This would suffice for 1 large target of 10 square miles or for 1 small area target of 1/3 square mile. The maximum tantalum production at Hanford, if all excess reactivity (except that for polonium production) were utilized, would be about 1 megacurie per month, sufficient to maintain an equilibrium stockpile of 5 megacuries. However, a stockpile of 100 megacuries could be built up by replacing all U-238 in 1 pile with U-235 and tantalum. Production of plutonium would necessarily suffer, but it would then be possible to contaminate a large area target of 15-20 square miles each month or 1 square mile in small area targets.

The report also gave some consideration to the study of the form of munitions to be utilized and the shielding problem. It concluded that pellets of the order of magnitude of one millimeter in diameter would be most feasible, the use of fine dusts being impractical because of uncertain diffusion and greater ease in decontamination. It projected a cluster-type munition with ejection of the pellets by shotgun shells as apparently adaptable, and recommended emphasis on high altitude delivery. It concluded that the shielding problem would not prove too difficult to solve (through use of multiple shields) provided the munition was contained within a cube not to exceed 3 feet on a side and the personnel concentrated in the nose of the aircraft.

Briefly examining the possibility of decontamination and other defensive measures, the report found considerable ground for optimism. It pointed out that the results of experiments conducted at Hunter Point in August indicated that non-imbedded particles of nearly all sizes could be effectively removed by hosing. The report also pointed out that satisfactory detection instruments were already available and that a large military training program in radiological defense was already under way.

The recommendations of the study group were adopted by the Joint RDB-AEC Panel on Radiological Warfare at its meeting on 29 August 1948. These came before the RDB for action on 23 September. Meanwhile, however, two other developments had taken place which were to influence the action taken. On 18 August the Long Range Objectives Panel of the Committee on Atomic Energy submitted a report to the Chairman of the RDB which included an extended discussion of radiological warfare. Although the report pointed out certain limitations—such as the [illegible] controlling the packaging, delivery, dissemination, and ultimate effects of radioactive materials, as well as the [illegible] of sacrificing some plutonium production to attain the necessary output--it also stated that "unless the use of offensive radiological warfare appears totally unpromising, development of this form of warfare must be continued." On 13 September the Chief, AFSWP, submitted a proposed program for the coordination of all aspects of the area, offensive and defensive. After recommending the adoption of the Noyes Panel Report with two slight changes, he explained that he intended to establish a radiological warfare advisory staff with an outstanding civilian expert as chairman. He proposed that the general coordinating authority assigned the AFSWP over radiological defense through its charter be expanded to include all phases of radiological warfare.[61]

Both reports were considered by the CAE at its meeting of 23 September 1948. The report of the Joint Panel was approved with slight reservations, one of which was to suggest that consideration of the ultimate feasibility of offensive radiological warfare be postponed for more than the two year minimum suggested in the report. A motion by Colonel Hinds to approve the AFSWP proposal was modified by an amendment offered by Brig. Gen. R. C. Wilson, USAF, and further by an amendment offered by Brig. Gen. K. D. Nichols, USA, Chief of AFSWP. As a result it was simply recommended to the RDB that the Department of the Army be assigned responsibility for development of the means of dissemination of radiological agents, without reference to an extension of authority by the AFSWP in this field.[62]

The AEC approved the Panel's report on [illegible] October, including the allocations of responsibility for the [illegible] between the [illegible] for the development of methods of dissemination to the latter and for the production of materials to the former. It also agreed that the Department of Defense should have responsibility for the defensive phase, including detection and decontamination, and agreed to offer necessary aid and support for these activities. The General Advisory Committee of the AEC concurred with the findings of the report during the same month, and at its November meeting the Research and Development Board approved the recommendations concerning the report made by the CAE. The RDB made clear that it was not delegating any of its functions to the AFSWP.[63]

As a result of the above decisions the Army Chemical Corps was charged with the development of the phase of the program assigned to the Defense Department. This was established as Project 4-12-01-01, the Selection and Use of Radioactive Materials as Toxic Agents, on 16 December 1948. An initial sum of $500,000 was transferred to the Army for the program by the AFSWP. The proposed program was reviewed, slightly modified, and approved both by the Army (GSC) and AFSWP. It closely followed the lines suggested by the Joint Panel.

The Chief of Staff, USAF, assigned the responsibility for coordinating the Air Force phase of the RDB AEC program in radiological warfare to the Director of Armament. The Air Force was requested to prepare a review of its proposed program in general terms so that it could be attached to the report of the Joint Panel as an annex. This was prepared in its first form by Rand. It indicated that the Air Force program will comprise two main phases: (1) selection of potential targets and (2) [illegible] of the weapon, including the analysis of operational feasibility. The first would be based on such factors as the amount of radioactive material available, the optimum content per item of munition, operational limitations imposed by the weapon, the dissemination pattern, radiation intensities in the target complex, possible defensive actions, and the effects of the weapon. Logistics would be affected by such factors as problems of ground handling, servicing of the specialized aircraft, and the specialized handling techniques required during air delivery. All three would be affected by the problems surrounding shielding and the degree of radiological toleration to be allowed personnel.[65]

The Joint Panel held its third meeting on 10 January 1949 to review the progress made throughout the RDB and AEC on the program. After giving general approval to the steps which had been taken within both agencies, it urged the accelerated development of high flux reactors and the establishment of a standby pile at Hanford as soon as radiological warfare was considered of practical military importance. The Panel recommended furthermore that a mechanism be established for determining with least delay both the military desirability and technical feasibility of new ideas within the area, that a pilot plant study be made of methods of separating fission products resulting from the [illegible] process, that adequate field testing facilities for dissemination devices be provided, and that the possibilities of   to a short-life weapon material [illegible]. Although originally designed as an ad hoc panel whose services were [illegible] only [illegible], the [illegible] of the program [illegible] monitoring [illegible].[6]

Two important series of developments closely related to the studies and evaluations of radiological warfare which should be noted were made late in 1948. On 6 July the JCS had requested the RDB to supply for their use a comparative technical evaluation of biological, chemical, and radiological warfare, among which the resemblances, particularly in methods of application and results (casualty causing without physical destruction), had already been remarked. The RDB in turn requested Dr. Noyes, who also served as Chairman of the Research Council of the Chemical Corps Advisory Board, to prepare this evaluation by combining the studies made by the Research Council on biological and chemical warfare with those being made by the Joint Panel on Radiological Warfare. Dr. Noyes accepted this task and submitted the evaluation requested to the RDB on 24 October. This was to have an important later effect in the working out of a combined program by the Chemical Corps. This was known as CBR (Chemical, Biological, Radiological).[67]

During the year 1948 the AFSWP had also carried out an extensive series of organizational and training actions, together with some research, in the area of radiological defense.* In regard to research, the most important achievement was probably in carrying out the request of the JRDB, made on 14 October 1947, "to assume primary responsibility for coordination of research and development of radiological protective devices, and to undertake a survey of the decontamination work being done by various Government agencies." As a result a Radiological Protection Committee was formed in January 1948. The Committee sponsored several investigative projects by

* See Chapter III.

the Army Chemical Corps, and these served as a basis for a report by the AFSWP to the CAE of the RDB on 13 December 1948. This recommended that research in the field of radiological decontamination be centered in the Navy Radiological Defense Laboratory and that final development of end items be carried out by the Chemical Corps in line with requirements furnished by each service. Activity in the area would be subject to a continuing review by the AFSWP. The report was approved in general by the CAE on 17 December 1948, but not immediately acted on by the RDB.[68]

In reviewing the advances in radiological warfare to the end of 1948 it can be seen that the subject was still in a very elementary stage, with nearly all accomplishments in the offensive phase consisting of preliminary evaluation and planning and the assignment of responsibility for various phases. Nevertheless, these had sufficed to explode some outstanding misconceptions, such as the belief that the radioactive wastes at Hanford would be a large-scale "free" source of materials. Other limitations, such as the impracticability of large-scale stockpiling and the fact that the production of plutonium would have to be exchanged for any extensive use, were also revealed. A definite program was under way, however, with assurance of ample technical backing, and this might ultimately be of great importance in the strategic mission of the Air Force.

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CHAPTER XVI

OPERATION SANDSTONE AS A COORDINATED EFFORT

Origin and Purpose

Operation SANDSTONE (Unclassified) was the second of the post-war atomic tests and the first of those conducted jointly by the Atomic Energy Committee and the military services. Unlike Operation CROSSROADS (Unclassified), which was essentially a military effects test of the Nagasaki type bomb on warships and other types of equipment, Operation SANDSTONE was primarily a proof test of three new types of atomic cores developed since the two original types produced in 1945. Although a number of special observations were made of the essential nature and results of an atomic explosion in order to extend the knowledge acquired from the explosions at Alamogordo, Hiroshima, Nagasaki, and CROSSROADS, these were kept secondary to the main purpose of determining the practicability and yield of the new weapons. The accomplishment of these aims of the Atomic Energy Commission became the determining factor in the operation, while the role of the military elements was principally to provide logistical support and certain specialized support operations. As later stated by the Test Director, principal representative of the AEC in the conduct of the operation, the objectives were described as follows:[1]

1. To improve the [illegible] through testing the [illegible] Atomic [illegible],

2. To improve the long range military position by obtaining such information from the behavior of particular models that better and more efficient weapons might be designed, and

3. To advance peaceful as well as military applications of atomic energy by increasing fundamental knowledge of nuclear phenomena.

Operation SANDSTONE originated in a recommendation early in 1947 by the Los Alamos Scientific Laboratory, which had been engaged in the development of improved weapon designs since the TRINITY test on 16 July 1945. The Laboratory pointed out that field tests, with the experimental weapons fired statically in the air, were needed to provide data which would allow the determination of the designs permitting the most effective use of available fissionable material and add to the general theory of implosion-type weapons. The AEC referred the recommendation to its General Advisory Committee, and on 3 April 1947 the Committee approved it, suggesting that the tests be conducted in early 1948. Chairman Lilienthal of the AEC obtained the preliminary concurrence of President Truman on 16 April and on 25 April wrote to the Military Liaison Committee to describe the broad objectives of the test program. A series of joint meetings of the AEC and MLC followed, beginning on 6 May 1947. On 27 June Chairman Lilienthal and Brigadier General [illegible], representing the MLC, again conferred with President Truman, who approved the plan to test the new atomic weapons in early 1948 and asked that he be informed when a definite plan was ready. [illegible] ... Los Alamos on 9 and 10 July ... [illegible] ... 28 July ... [illegible]

Scientific Laboratory to proceed with preparations for the tests. It requested that the Laboratory nominate a Test Director and prepare a preliminary plan as quickly as possible. It engaged itself to secure the assistance of the Armed Forces in selecting a test site and in conducting the operation.[2]

On 28 July Chairman Lilienthal of the AEC wrote to the MLC, pointing out the need for the new tests and requesting the following types of advice and support from the Armed Forces: (1) recommendations as to the location of the proposed proving ground, (2) an AFSWP unit to transport, assemble, and place the weapons to be tested, (3) an aircraft unit to operate eight drone planes to take samples of the bomb cloud and transport planes to carry samples from the test site to Los Alamos, (4) a planning group or committee from the Armed Forces to make plans for logistical support, (5) engineer troops to prepare the detonation, control, and instrument sites, (6) a unit to carry out high speed and general photography, (7) a health unit to monitor [illegible] protective measures.[3]

The MLC replied on 7 August, stating that in compliance with the AEC request it had recommended that the Joint Chiefs of Staff appoint a special committee to draft the necessary policy instructions for the military components. It also included further recommendations [illegible] technical requirements, emphasizing that the [illegible] should be used to enable scientists to [illegible] instrumenta- [illegible]

[illegible]

USAF; and Lieutenant Colonel [illegible], USA, with Captain James S. Russell, USN, sitting with the committee as advisor for the AEC. The committee recommended to the JCS the acceptance of the MLC recommendations, including the appointment of a commander for the task force which would provide military assistance to the AEC and of two deputies, each of these to be from a different service, and the JCS concurred in these recommendations on 10 September.[4]

On [illegible] September the JCS [illegible] the nomination of Lieutenant General John E. Hull, USA, Major General William E. [illegible], USAF, and Rear Admiral William S. [illegible], USN, by their respective services to serve as members of the Joint Proof Test Committee, which had been directed to (1) delineate the organization of the task force, (2) outline the [illegible] on all aspects of the test which were of concern to the Armed Forces. Capt. James S. Russell, USN, and Colonel John H. [illegible], USA, were designated by the AEC and MLC respectively to represent them as ex officio members.

Organization of [illegible]

The Joint Proof Test Committee reported to the JCS on 15 October to present the basic plan for the organization of the joint task force and to describe the responsibilities of the [illegible] military components. It also recommended that [illegible] be [illegible] as the site for the permanent [illegible] proving ground. The report of the Proof Test Committee, which was [illegible] JCS [illegible]/6 and approved on 18 October, [illegible]

[illegible]

[illegible]

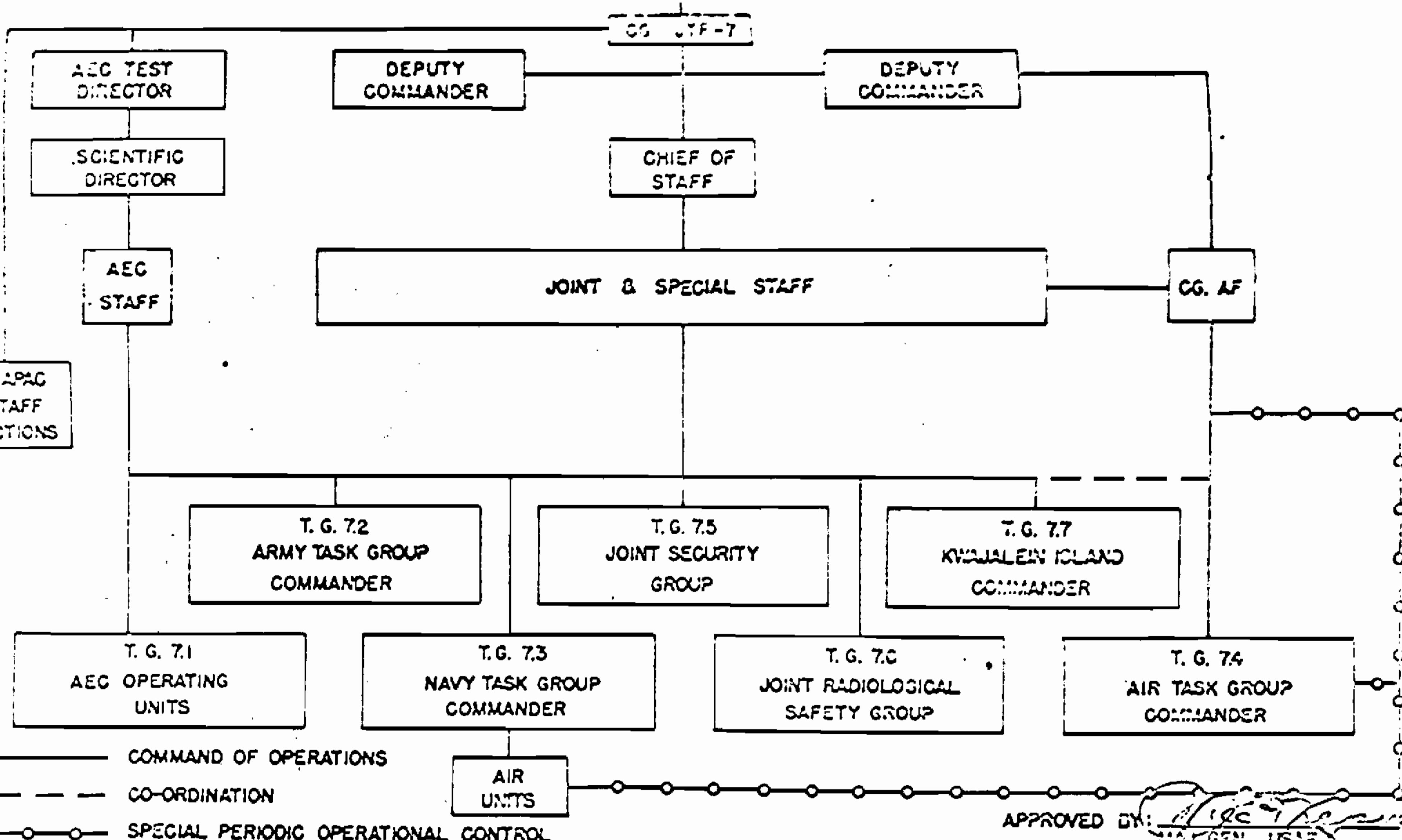
same time informing the JCS that the Secretary of the Treasury had been requested to transfer $20,000,000 to the Navy Department to cover the cost of participation by the Armed Forces. The exceptions taken by the AEC were settled by negotiation during the next two months.[5]

The task force organization had actually already begun to function on 30 September, when Brigadier General Claude B. Ferenbaugh reported as Chief of Staff—the [illegible] day on which Gen. Hull had been designated [illegible] the report of the Joint Proof Test Committee had been in large part [illegible] by the [illegible] staff. Under the plan approved, the [illegible] of the task force was charged with [illegible] personnel, [illegible], and [illegible] to support the [illegible] the AEC, which would provide the scientific personnel and equipment necessary to complete the [illegible]. The [illegible] would furnish the task forces for [illegible]. A Test Director, designated by the AEC, would be [illegible] for direction of the technical test activities [illegible] with the task force commander. The latter would have two [illegible] Maj. Gen. William E. Kepner and Rear Adm. William S. Parsons. Kepner would also serve as commander of the [illegible], but [illegible] in regard to the [illegible], which [illegible] command. [illegible] was to be set up a "J" [illegible]

[illegible]

[illegible]

[illegible]



APPROVED BY:
MAJ. GEN., USAF
COMMANDER, AIR FORCE, JTF7

to the Joint Chiefs of Staff was through the Chief of Staff, United States Army, who was designated their executive agent by the JCS on 4 November as recommended in the report of the Joint Proof Test Committee.[6]

Under the above staff organization seven subordinate commands were organized, designated as task groups. In accord with the designation of the larger organization as Joint Task Force 7, the task groups were designated in tenths added to that number. Task Group 7.1 (AEC) was designed to support the technical and scientific tests and headed by Capt. James S. Russell, USN, who was also designated Test Director by the AEC. Under Task Group 7.1 operated Task Unit 7.1.1, the scientific unit headed by Dr. Darol K. Froman, who was also designated Scientific Director. This unit was made up of personnel from the J Division at Los Alamos. Task Group 7.1 was in addition to its test functions assigned the important duty of classifying documents and photographs in accord with the Atomic Energy Act of 1946. Task Group 7.2 (Army) under Brigadier General David A. D. Ogden, was charged with all construction on and the military security at Eniwetok Atoll. Made up principally of personnel from the Corps of Engineers, it was also responsible for billeting, sanitation, hospitalization, transportation, maintenance of utilities, and the general housekeeping for units ashore. Task Group 7.3 (Navy) was headed by Rear Admiral Francis C. Denebrink, who also commanded all Naval forces assigned to JTF-7. It was responsible for the security of Eniwetok Atoll against outside attack and the operation of all naval forces, including water transport. It provided off-shore patrols, boat pool transport, communications afloat, [illegible] air-sea rescue work, submarine cable laying, helicopter service for scientific personnel, and certain test operations. Task Group 7.4, commanded by Major General Roger M. Ramey, was the air task group, whose functions will be discussed in detail later. Task Group 7.5, commanded by Lieutenant Colonel Philip Cibotti, USA, was a joint security group which was assigned the responsibility for safeguarding information and documents which were classified as Restricted Data and located ashore. Task Group 7.6 (Joint Radiological Safety) was responsible for the detection and determination of types and intensities of radiation and for keeping the Radiological Safety Officer informed of radioactive areas. It was commanded by Commander Frank S. Winant, USN. Task Group 7.7 was headed by Captain J. P. W. Vest, USN, who was also commander of the Naval installation on Kwajalein. Made up of the personnel of this installation, it was the JTF-7 command unit on this atoll. It was responsible for billeting, transportation, sanitation, recreation, hospitalization, and utilities maintenance, and military security (except Air Force) on the island.[7]

On 19 July 1947 the President had authorized the AEC to establish proving grounds in the Pacific Ocean for routine experiments and tests of atomic weapons, and the MLC had been invited to make recommendations on the characteristics and location of the site. In its reply of 7 August the MLC recommended that the site selected be permanently available, convenient for logistical support, not subject to violent storms, suitable for [illegible] observation, large enough for at least two detonations, and [illegible] sufficiently remote to insure that ocean currents from the site [illegible] would travel at least several hundred miles before touching [illegible] shores.

During September a group consisting of members of the Joint Proof Test Committee and representatives of the AEC visited the Marshall Islands, and after some discussion of the comparative merits of Kwajalein and Eniwetok Atolls, fixed on the latter. The AEC officially selected Eniwetok as its proving ground on 11 October, and the JCS concurred by approving the report of the JPTC on 18 October. The atoll consists of some 30 small islands ranged around a lagoon approximately 120 feet in depth and with easily navigable entrances, affording anchorage for large vessels. The principal difficulties connected with the choice of the site lay in the facts that the Marshall Islands were held in trusteeship from the United Nations and that it was inhabited by 142 natives. It was considered, however, that the trusteeship agreement would permit declaring the atoll and surrounding waters a closed strategic area and used for the desired purpose provided that the native population was suitably provided for. On 25 November the President accordingly directed the Secretary of Defense to proceed with the evacuation of the natives. They were provided for by being removed, with their own consent, to Ujelang Atoll on 20 December. Meanwhile, on 1 December the President, in accord with the trusteeship agreement, announced the construction of the proving ground. On the following day the Security Council of the United Nations was notified of the decision to declare the atoll and its territorial waters a closed area. Advance elements of the task force arrived before the end of the month and began preliminary construction. On 31 December the State Department publicly announced the establishment of a danger area extending 100 miles east and west and 75 miles north and south from the center of the atoll. It also formally notified all foreign governments of this.[8]

Although the staff of JTF-7 was actually functioning before this time, its official existence began on 18 October with the approval of the Joint Proof Test Committee by the JCS. After a visit to the site by Gen. Hull and members of his staff in late October forward headquarters, designated JTF Forward, were established at Fort Shafter, Oahu, T. H. Washington headquarters was designated JTF Main until 15 February 1948, when it became JTF Rear while JTF Forward became JTF Main. On 8 March 1948 it was reorganized into three echelons. Meanwhile, the principal tasks to be accomplished by the staff in order to place the task force on a fully functional basis were seen as follows: (1) establishment of personnel policies, a personnel procurement program, and a personnel administration system; (2) establishment of adequate and workable security policies and measures; (3) drafting of an over-all plan for the operation; (4) establishment of procurement and shipping procedures and policies; (5) reaching agreement on the provision of funds for the operation; (6) establishment of service tests desired by the various components of the Armed Forces. Most of these were solved by routine staff action.

The task force became financially solvent with the transfer of $5,000,000 from the AEC to the Navy for the use of Operation SANDSTONE on 25 October, followed on 31 October by $15,000,000 more. The operating plan was prepared by J-3 and issued in the form of Field Order No. 1 on 14 November 1947. The first elements of the task

JOINT TASK FORCE SEVEN
BY TASK GROUPS

STRENGTH REPORT

AS OF 31 MARCH 1948

61-JTF-10
7 [illegible] 48

ORGANIZATION	OFF			WO	ENLISTED(W)			ENL(N)			CIV(CIV SER)		CIV	TOTAL			GRAND
	A	N	AF		A	N	AF	A	N	AF	REC	OTHER	(OTHER)	A	N	AF	TOTAL
HQ JTF-7	49	40	17		39	11	5					14		88	51	22	175
HQ AF, JTF-7	1	1	18				15							1	1	33	35
TG 7.1	37	6	2		45	14					7	50	95	82	20	2	256
TG 7.2	90	6	2		1303	37	20						4	1393	43	22	1462
TG 7.3		417				5163			331						5911		5911
TG 7.4			254				1399			1						1654	1654
TG 7.5	26	16	3		142	100	12							168	116	15	299
TG 7.6	32	24	12		4	20					4	1	2	36	44	12	99
TG 7.7		1	1												1	1	2
TOTALS	235	511	309		1533	5345	1451				11	65	101	1768	6187	1761	9893
ORIGINAL PERSONNEL ESTIMATION *														1924	4326	2540	8790

* AS ESTIMATED IN THE REPORT OF THE PROOF-TEST COMMITTEE TO THE JOINT CHIEFS OF STAFF 18 October 1947.

force, in the form of units of Task Group 7.2 (Army), landed on Eniwetok on 28 November and began unloading on 2 December. By the end of the year 1,481 personnel were on the island, and shortly after sections of headquarters began their transfer from Washington to Fort Shafter, the forward headquarters.[9]

It was determined to establish the requirements for tests desired by the military services in connection with the atomic explosions by 1 November. After circularization of the services the Joint Proof Test Committee approved 11 service tests as follows:[10]

	Requested by	Description	Conducted b
1.	Corps of Engineers, USA	Exposure of 2 reinforced concrete structures to determine structural damage.	CTG 7.2
2.	Corps of Engineers, USA	Exposure of 2 reinforced concrete structures without collective protectors.	CTG 7.2
3.	Corps of Engineers, USA	Exposure of an earth barricade to determine shadow effect from blast.	CTG 7.2
4.	Bureau of Docks, USN	Exposure of 175 varied units for evaluation	CTG 7.3
5.	USAF	Determination of blast accelerations by accelerometers installed in aircraft.	Comdr, A Forces
6.	Signal Corps, USA	Detection of the explosion by visual observation of the moon.	Comdr. A Forces
7.	Bureau of Medicine USN	Exposure of small packets containing biological assay material.	CTG 7.6
8.	Bureau of Ships, USN	Exposure of small sample of materials with various coatings for purpose of establishing surface effects produced.	CTG 7.6
9.	Bureau of Ships, USN	Field test and evaluation of several radiological instruments of new design.	CTG 7.4

Requested by	Description	Conducted by
10. Bureau of Ships, USN	Exposure of small steel plate samples to obtain shielding data applicable to estimating radiological effect of atomic bomb against any type of structure.	CTG 7.6
11. Chemical Corps, USA	Exposure of 1 Field Collective Protector E24R1 in each of 2 concrete structures.	CTG 7.6

Security

The matter of security was given great emphasis throughout the course of Operation SANDSTONE, which unlike CROSSROADS was a "closed" operation. No foreign military observers and no representatives of the press were permitted to accompany the task force. The fact that new types of weapons were being tested, the alteration in the international situation since 1946, and the rigorous requirements of the Atomic Energy Act of 1946 all dictated a strict control of security matters which was applied to all phases of the operation.

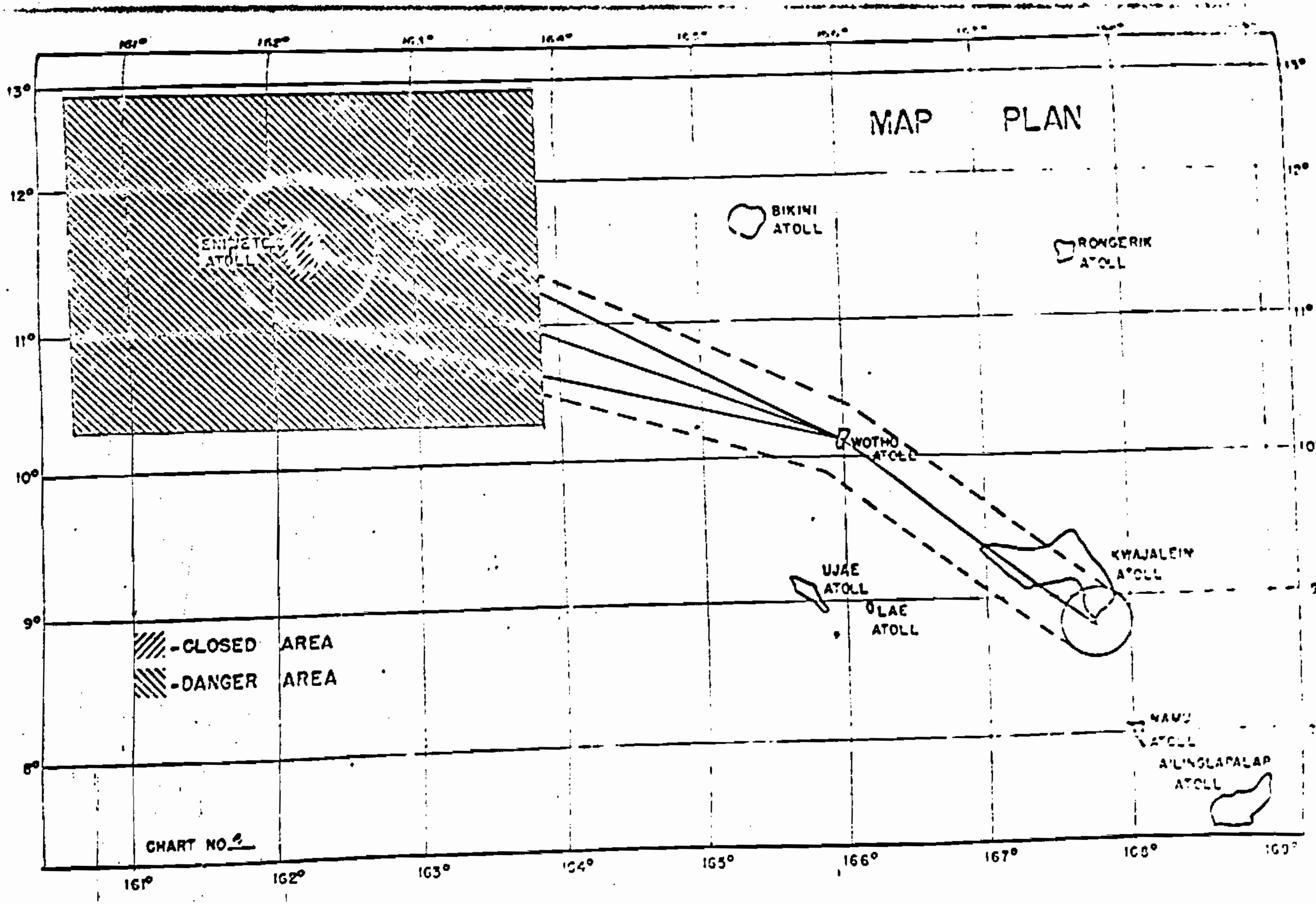
Several changes were made during the early stages in regard to the date of public disclosure of the existence of the test program, although it was realized from the first that this could not be deferred indefinitely. Originally the Atomic Energy Commission, which held statutory control over the dissemination of Restricted Data, planned to prevent any disclosure of the task force or the operation for a period of 2 months after its beginning. It was agreed with the JCS that the date for a particular test should be classified TOP SECRET and that the location of the test and the general time for the tests SECRET. These high classifications caused immediate complications on the formation of the Joint Proof Test Committee and the first assembly of the task force staff in late September. As a result plans were revised to provide for declassifying the location and general time of the tests through a public announcement by mid-October. The State Department, however, protested that such an announcement would be detrimental to the national interest if made during the meeting of the Security Council of the United Nations or the Foreign Ministers' Conference in London, which immediately followed. A postponement of six weeks was accordingly agreed to, and a brief public statement was finally made on 1 December, when the requirements of the trusteeship agreement regarding the Marshall Islands and other factors hardly allowed a further delay. This was followed by two other statements during the month. No further public releases were made till after the tests.

After security requirements for the task force had been generally outlined by the JPTF, Gen. Hull assigned the responsibility for staff planning to the Assistant Chief of Staff, J-2, Colonel Thomas S. Sands, USA. The main objective of J-2 thus became, as in all the joint atomic test operations, the protection of the security of AEC Restricted Data. This essentially involved a counter-intelligence operation, although some attempt was also made to maintain a positive intelligence program as well. The counter-intelligence plan prepared by J-2 provided for a continuing security control of personnel, test equipment and material, documents, photographs, information, and communications. It indicated the possibility of loss of security or hindrance to task force operations by reconnaissance, espionage, and such "conventional" methods as monitoring radio communications and the public press.

Implementation of the plan was a function of all units and personnel, subject to staff control by J-2. As the scope of the physical security requirement became apparent, however, it was decided that a special operating security unit was necessary, and as a result Task Group 7.5 (Joint Security) was organized under Lt. Col. Philip R. Cibotti.

The Joint Security Group was assigned responsibility for such functions as the protection of Restricted Data ashore, including all installations, equipment, and classified materials; the conduct of periodic security surveys of the islands; continuance of the personnel security clearance and indoctrination program; conduct of air and water travel controls. The Group placed guards on all target and other sensitive islands, and these controlled both ingress and egress. The remaining islands were subject to weekly security inspections. As installations approached completion, "restricted" and "exclusion" areas were established in order to enforce the policy of compartmentation which had been determined on by the Joint Proof Test Committee. These areas were controlled by the use of colored badges and entry lists.[11]

The possibility of reconnaissance of the tests by foreign aircraft or submarines were considered, and responsibility for preventing this was assigned to the Naval Task Group (TG 7.3). A danger area was declared around Eniwetok Atoll on 30 December 1947 extending 100 miles east and west and 75 miles north and south of the center, and all foreign governments were notified of this. Although the possibility of radioactive contamination was the primary reason for this, it was also regarded as a means of maintaining security. Meanwhile


MAP PLAN
ENIWETOK ATOLL
BIKINI ATOLL
RONGERIK ATOLL
WOTHO ATOLL
UJAE ATOLL
LAE ATOLL
KWAJALEIN ATOLL
AILINGLAPALAP ATOLL
-CLOSED AREA
-DANGER AREA
13°
12°
11°
10°
9°
8°
161°
162°
163°
164°
165°
166°
167°
168°
CHART NO. 4

on 2 December the United Nations Security Council was informed that Eniwetok Atoll and its territorial waters were a closed area. Off-shore patrol was established during February, both air and surface, and this was gradually increased during March, the sea patrol being augmented to five destroyers and destroyer escorts and daily aerial searches established. Some 11 submarine contacts, ranging in certainty from doubtful to actual, were made before the tests began, and on 10 March 1948 Gen. Hull reported to the JCS his intention to warn submerged submarines detected within the danger area by depth charges and to take any means necessary to prevent their entering the closed area. This procedure was approved by the JCS, but was not necessary to put into effect.[12]

The first and most urgent security problem was to clear sufficient staff members to proceed with planning for the operation. The AEC had established the "Q" clearance, requiring a full background investigation by the FBI for all personnel of the Commission and its contractors who were to receive Restricted Data, as provided by the Atomic Energy Act. Whether this requirement should be applied to military personnel was still under discussion between the AEC and the military departments, but it was agreed that all personnel receiving Restricted Data during Operation SANDSTONE would require a Q clearance. Since such a clearance required about 60 days for processing, and since this was the first operation necessitating large numbers of such clearances, serious difficulties arose. To cope with these a wide use was made of emergency Q clearances for both military personnel involved in the planning phase and essential civilians. The FBI, J-2, and the Personnel Clearance Section of the

AEC maintained continuous liaison; and the FBI granted a high priority for Task Force clearances. By the end of the Tests 2158 Q clearances had been initiated, of which 1868 had been granted, 218 were outstanding, and 72 had been cancelled. Since about 400 persons already had Q clearances, over 2,500 of the approximately 14,500 persons involved in the operation were Q cleared. Personnel in the forward area not having access to Restricted Data were required to have P approvals, based on a check by the FBI of its name and fingerprint files.[13]

Movements of personnel were also closely controlled. Counter Intelligence Corps agents under Task Group 7.5 established check points for travel at the ATS and NATS terminals at Honolulu, Kwajalein and Eniwetok, and on the various islands of the atoll and on the ships restricted and exclusive areas were established to which access was strictly controlled. A special team from the Armed Forces Special Weapons Project maintained a guard over the fissionable material throughout the operation. Unannounced musters were held from time to time for sight identification and physical count. Visitors were limited to high governmental officials, including particularly Congressmen, military officers, and officials of the National Military Establishment and the AEC. All were required to have Q clearances, and no specific weapon data was given them without the approval of the Test or Scientific Directors.

A program of security education was also worked out. This consisted essentially of the following requirements: (1) issuance of security regulations to all task group commanders, who were responsible for their dissemination; (2) signing of security acknowledgments and agreements by all personnel; (3) dissemination of information through posters, lectures, and a movie; (4) instructions to visitors in the United States, Hawaii, and Kwajalein.

A close control was also made of documents carrying a military classification or the AEC classification of Restricted Data. Each task group appointed a Restricted Data control officer, who maintained records of all Restricted Data within the group and returned all documents containing such data to the AEC through the CJTF-7 at the end of the operation. All material collected or reports made at the test site were required to be classified by the Classification Officer of Task Group 7.1 and the approval of the Test Director secured before being sent to installations other than the AEC. The Test Director was responsible for determining what constituted Restricted Data within the Task Force. All deliveries of Restricted Data were made through the AEC and all Restricted Data was returned to the CJTF for ultimate return to the AEC prior to departure of the task groups from the forward area. To insure the safe delivery of Restricted Data between the test area and mainland, courier teams of Q-cleared personnel drawn from Task Group 7.5 were established. These maintained a semi-weekly service beginning in mid-January 1948.[14]

Communications security presented a serious problem because of the extensive use of radiophone connections among the multiple ships and islands involved in the operation. To minimize the danger of monitoring of communications by an unfriendly power, a combination of very high frequency channels, low power, and code words was resorted to. Numerous spot checks of the circuits employed for intra-Task Force communication were made and undesirable practices brought to the attention of the units and individuals concerned. There remained, however, an inherent risk in such a large-scale use of radio communication. Because of time limitations this had to be accepted. Standard communications security measures were employed for the incoming and outgoing radio traffic. No formal censorship was applied to personal correspondence, this being left as a matter of individual responsibility.[15]

Based on a conclusion that photography constituted the most revealing type of intelligence information, rigid security controls were applied. Within the operational area the possession or use of photographic equipment or supplies by anyone other than official photographers was forbidden. These individuals were issued special badges. All weapon photography was handled by two persons from Sandia Corporation--Messrs. Udey and Sweeney. All film was issued from a central point--Bolling Field--where it was marked with an individual code number which remained on it and the resulting prints. All film was then conveyed by special couriers to the official photographer or camera crew chief, who recorded it in a Field Issue Log, which was inventoried by a representative of Task Group 7.5. All exposed film was treated as Top Secret-Restricted Data until processed and classified. It was carried back by special couriers of J-2. Since the Task Force would be dissolved before processing and editing was completed, the AEC agreed to assume complete security control of this phase from the beginning. A simple laboratory was established in the forward area for emergency processing, but approval by the CJTF-7 or the Test and Scientific Directors was required before any use was made of it. Control of this was maintained by the Security

Officer, Task Group 7.1, assisted by monitors from Task Group 7.5. Film passed by the AEC as containing no Restricted Data was reviewed for military classification by a special panel of officers from the AFSWP.[16]

Logistics

It has been said that the core of SANDSTONE was logistics, and this is true to the extent that it is true of every large-scale military operation requiring an overseas movement to a sparsely populated area within a limited time. The demands for rapid organization, planning, construction, procurement and transportation of both common and unusual types of equipment were both complex and heavy. To meet the developing problems a series of agreements were reached among the participating agencies for handling of the various logistical responsibilities, and insofar as possible these were distributed on the basis most logically in accord with customary supply procedures in the area. The normal service supply agencies were responsible for providing units, ships, and individuals with their initial supplies and equipment. The AEC was responsible for the procurement of technical supplies and equipment not common to any service, although in numerous cases the military services actually procured these items for themselves and were later reimbursed by the AEC. The Commander-in-Chief, Pacific Fleet, was responsible for the logistic support of the Naval units of the Task Force, as well as for the rations and petroleum supplies (POL) of the task force, while the Commander, U. S. Army, Pacific, was similarly responsible for the logistic support of land-based Army units and the re-supply of Army type items to Air Force units (except as above). The Commanding General, Seventh Air Force (later redesignated the Pacific Air Command) was responsible for normal support service to aircraft and for assistance in the rehabilitation of Kwajalein for Task Group 7.4.

The bulk of materials for base construction was procured from available Army and Navy stocks in Oahu, T. H. Items not available there were procured in the United States through Washington headquarters of the task force. The normal channel of procurement was through the task group commanders to the supply agencies, except that Army type items were first submitted to the Task Force J-4 for approval and processing. During the operation approximately 55,000 tons of equipment and supplies went into the operation, of which about 30,000 came from the United States and 25,000 from Oahu. The principal shipping agencies were the Naval Supply Centers at Pearl Harbor and Oakland, the Naval Advance Base at Port Hueneme, and the San Francisco and Seattle POE's.[17]

The Air Force and the Navy were given joint responsibility for the air movement of supplies, equipment, and personnel necessary to the success of the operation, and this responsibility was passed respectively to the Air Transport Command and the Naval Air Transport Service, since it was decided that the problem would be handled by augmentation of the regular service rather than the setting up of a special unit. After discussion it was also decided that the Air Transport Service (ATC) would handle all transport of supplies and personnel other than Naval, which would be handled by the NATS. During the course of Operation SANDSTONE the Air Transport Service moved a total of 3,0[illegible]6,[illegible]53 pounds of cargo, mail, and passengers. An exact figure for passengers is not available, but it was known to exceed 6,500. This was by far the bulk of the air transport for the operation. Air transport will be discussed in more detail in the following chapter.[18]

The main headquarters of JTF-7 was gradually removed during January 1948 to Fort Shafter, Oahu, where Headquarters JTF-7 was officially opened on 15 February, absorbing JTF Forward. Washington headquarters then became JTF Rear. The JTF naval flotilla, including the USS Mount McKinley, which served as the command ship, and three others, left Terminal Island, California, by 1 March. After picking up the headquarters staff on 8 March at Honolulu, the flotilla proceeded to Eniwetok, anchoring in the lagoon on 16 March. In addition to headquarters personnel, it carried a major part of most of the task groups with the exception of 7.2 (Army), which was already on the scene, and 7.4 (Air). The flotilla was screened by five destroyers and given air cover by Navy patrol planes. It followed wartime procedures, including blackout and zigzagging.[19]

Construction Program*

The construction program for Operation SANDSTONE was of great importance because of the complex character of the atomic detonating techniques and test instrumentation and the longer range objective of establishing a permanent atomic proving ground. Unlike CROSSROADS, a large part of the personnel and nearly all the instrumentation were to be shore based, and all the atomic bombs were to be fired from towers. These factors, applied to the local situation at Eniwetok and Kwajalein, meant that five major types of construction must be undertaken: (1) rehabilitation and some new building of housing and other facilities for personnel and aircraft; (2) razing, leveling, and soil stabilization on five islands; (3) construction of firing and photo towers; (4) construction of specialized buildings for housing and protecting test equipment; (5) construction of footings for test devices.

Arrangements for rehabilitating the Eniwetok facilities began with the visit of Gen. Hull and his party (including Capt. Russell, Dr. Froman, Capt. Hill, and Gen. Kepner) to survey the test site in late October 1947. At that time it was agreed that the Army Task Group (7.2) would assume responsibility for rehabilitating the housing and living facilities, left from wartime occupation, which were sufficient to quarter at least 4,000 personnel but were in very poor condition. It was determined that work would be initiated by a Provisional Battalion at the earliest possible date. This unit would consist principally of Army Engineers augmented by Navy and Air Force detachments, and would draw supplies from the Commander, U. S. Army, Pacific Area (USARPAC). Engebi, Aomon-Biinairi, and Runit were selected as the Zero islands at the same time. It was also arranged that the Seventh Air Force would supply an Aviation Engineer unit to construct facilities for the Air Task Group on Kwajalein. Here construction began by 15 November, since the construction unit in question was already on the island.

As a result of the above arrangements the 1220th Provisional Engineer Battalion was activated and arrived at Eniwetok from Pearl Harbor on 28 November. This unit began to unload material and supplies in quantity and to prepare the way for Task Group 7.2, commanded by Gen. Ogden, which reached the scene in late December. The core of the task group was composed of the 18th Engineer Construction Company and the 2d Engineer Special Brigade, drawn from the Western Ocean Division of the Corps of Engineers. The Division also supplies all common construction material for the task force. Meanwhile, reflecting the importance attached to the construction program, an Engineer Section had been added to the task force staff under Col. David H. Tulley, USA, as Staff Engineer. This section was charged with supervision of the phases of the construction program which were the exclusive responsibility of the task force, including the preparation of plans for the rehabilitation and construction of housing and utilities and for the corollary tests of the Armed Services, as well as the actual construction based on these designs, the construction of drone aircraft facilities, and certain other types of construction for which requirements and plans were prepared by the AEC.[20]

The preparation of requirements for the permanent proving ground was the responsibility of the AEC. These were prepared by Task Group 7.1 and turned over to the Staff Engineer for implementation. They covered the preparation of terrain; field engineering, including docks, roads, and prepared beaches; and the construction of specially engineered structures such as towers, blast footings, shelters, and gamma measurement stations. The design engineering of the specialized facilities (other than those for the military tests) were also the responsibility of the AEC. This however, was performed by Jackson and Moreland Company, of Cambridge, Massachusetts, under sub-contract to Edgerton, Germeshausen and Grier, which was one of the principal contractors to the AEC for certain other aspects of Operation SANDSTONE.

Certain construction projects were also carried out by private contractors. Three 200-foot towers were required for mounting the atomic bombs, and these had been ordered forehandedly by the Los Alamos Scientific Laboratory in 1946. They were erected under a contract by Morrison Knudson-Peter Kiewet Sons, Incorporated, along with the four 75-foot photographic towers. It was found necessary to join Biijiri to Aomon Island by a 700-foot causeway 30 feet in width, and this was constructed under contract by the Hawaiian Dredging Company, Limited, which also built the foundation for the photographic tower which was erected on a coral head in the lagoon.[21]

The laying of coaxial cables both underwater and underground was a considerable construction operation. The submarine cable phase, requiring the laying of 914,050 feet, was handled by Task Group 7.3 (Naval), and this group assisted the Scientific Group in laying the underground section, as did Task Group 7.2.

All the test islands were densely wooded with coconut palms with the exception of Engebi, which had been cleared during Japanese and American occupation during the war. Biijiri, Runit, and large parts of Aomon and Rojoa Islands were now similarly cleared and leveled. Large sections of these, particularly in the vicinity of the Zero towers and gamma stations, were covered with asphalt, oiled, or treated with cement to stabilize the soil as much as possible. This phase of the construction, entirely performed by the troop labor, of Task Group 7.2 comprised 221 acres cleared and graded; 16,605 square yards of bituminous paving; 80,[illegible] square yards of surface oiling; and 30,000 square yards of cement soil stabilization. Five landing strips for liaison planes were also constructed and stabilized on Aomon, Biijiri, Runit, Aniyaanii, and Parry, these being approximately 60 feet wide and 500 feet long. Excellent landing strips suitable for much larger aircraft already existed on Eniwetok and Engebi.

Work on the grading began early in December, while at the same time a survey was made of the islands. This was completed on 20 December 1947, and work on the towers immediately began. All towers were completed by 17 February 1948, a result considerably aided by a test erection by the contractor at Sandia in November. The photographic towers were a standard Navy design manufactured by the International Derrick and Equipment Company. It was found necessary to erect only four of the six shipped. Serious defects appeared in the Zero towers, particularly in the hoists and electrical aspects, and these caused personnel using them considerable difficulty and some peril. It was necessary that all Zero and photographic towers, as well as many instrument stations, be tied to the control station on Parry Island. Laying of the cables began on 5 January and was completed by 17 March.[22]

The principal concrete construction involved three timing stations, three blast structures, eight gamma stations, numerous footings for mounting blast measurement instruments, and winch bases. The timing stations, located 3900 feet from each of the Zero towers, were constructed to withstand 13 psi and an impulse of 4.5 psi-seconds. Their main purpose was to house the electronic equipment for measurements of transit time and "alpha." The blast structures were similar in purpose and design to the timing stations except that the strength requirements were not as severe because of their greater distance (5000 feet), amounting to 10 psi and 4 psi-seconds. The gamma stations were heavy concrete buildings constructed on various islands at distances ranging from 2250 to 5400 feet for housing equipment for measuring the amount and character of gamma radiation from the explosion and atomic cloud. The principal requirement for these was a high degree of resistance to gamma penetration, since the desired radiation was to be introduced through collimating tubes containing various amounts of boroncarbide absorber. The concrete mixes to be employed for these buildings was of great importance in achieving the various purposes intended, and an expert in this field--Dr. Roy W. Carlson--was brought in to supervise this matter. In the case of the gamma stations a mix containing limonite and a large percentage of small metal scrap was used to attain the desired characteristics. The construction of blast footings and winch bases presented no particular problem. Altogether, 2,534 cubic yards of concrete were poured, and this required the fabrication of 27,566 square feet of forms and placement of 222,655 pounds of steel reinforcements.[23]

To deal with the problem imposed by the physical separation of the sites by water, the four provisional engineer companies were each quartered on a separate island--the three test islands and Eniwetok. DUKW's were used to negotiate the channels between the test islands. The original target date for completion of construction was 15 March, when the Scientific Test Group would arrive to begin installation of the instrumentation. Actually it was considered to be only 85 per cent complete; however, work on Engebi site of the first test, was so nearly complete that the scientists could proceed with their work immediately after their arrival on 16 March. Construction work was completed on all the islands during the first part of April, prior to the first shot on the fifteenth.[24]

Final Arrangements and Test Operations

Seven weapon assemblies and six nuclear charges had been delivered to the Test Director at San Pedro, California, in late February. These were carried on two specially modified Navy weapons ships, the Albemarle (AV-5) and the Curtiss (AV-4). All weapons and weapons parts, except nuclear components, were carried on the Curtiss, where all assembly work was also accomplished. The Albemarle was fitted to serve as a laboratory ship for the members of the Scientific Test Group, whom it housed. The U.S.S. Mount McKinley (AGC-7) served as the command ship, housing the Commander, JTF-7, the two deputy commanders, and the Test and Scientific Directors, the Command, Naval Task Group, and his Staff. The other principal ship of the Task Force was an escort carrier, the U.S.S. Baikoko (CVE-115), which served as a base for the helicopters. Timing and firing, however, were carried out from an elevated station on Parry Island, where the sequence timer, a series of cams driven by an accurate electrical device, closed at proper times the numerous switches which started the multitude of instruments and cameras, and then finally armed and fired the bomb.

Because of prevailing winds, firing was done in succession from the north to avoid radiological fall out on the unused sites. For a similar reason--to keep radiological fall out to a minimum on the Zero islands--and also to gain the advantage of the darkest portion of the sky to serve as background for the Teller experiments, the towers were placed at the western edge of the islands. The dates of the shots had been set approximately at two-week intervals, subject to favorable weather, beginning 15 April. The time selected for firing represented a compromise between the requirements of the Teller experiment for minimum light and of the Air Task Group for sufficient light to operate their drones. A morning lag of ten minutes between light at 20,000 feet and on the surface permitted selecting an H-hour approximately five minutes ahead of light on the surface. It was planned to begin collecting specimens and data ten minutes after H-hour, including air and ground samples, materials affected by radiation, and various types of data. Some of these would be immediately flown by C-54 to Los Alamos for analysis.[25]

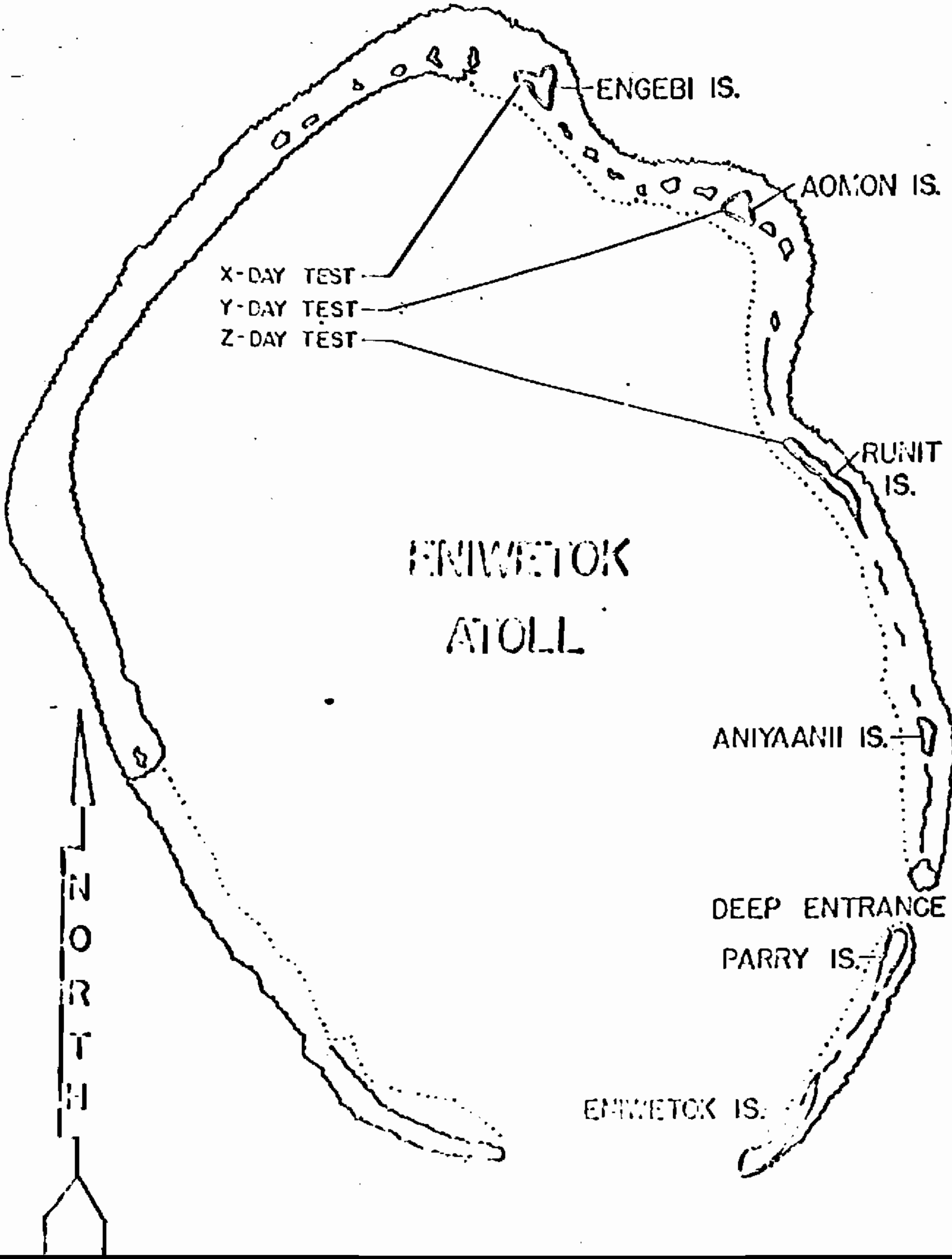
Joint Task Force 7 was fully assembled for the first time with the arrival of the Headquarters at Eniwetok on 16 March. Although the Air Task Group remained based at Kwajalein, 360 miles away, there was frequent and ready communication. The period from 16 March to 5 April was one of preparation for PX (or Peter X-Ray) Day, which would rehearse the operations of X-Ray. A considerable amount of training, particularly for the highly complicated Air Force operations, remained to be accomplished, and nearly all the instrumentation remained to be installed.

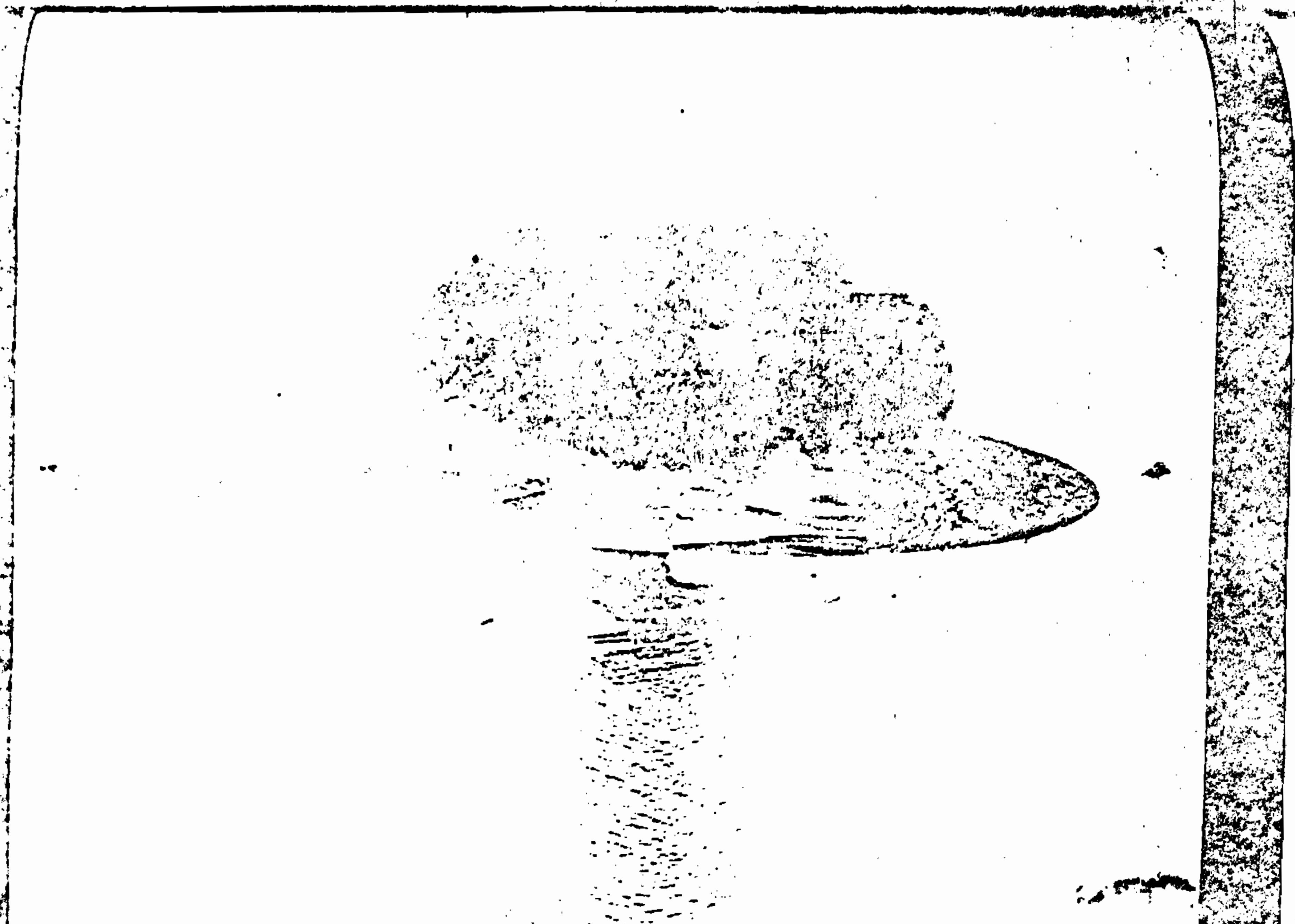
The main guide for operations now became the operations plan which had been prepared by the Scientific Unit (TU-7.1.1). Its 16 annexes provided a time schedule for every significant test activity. Since the principal function of the military elements of the Task Force was to provide logistic and special types of support for the tests, this document became the basis for all operational orders of the Task Force and the Task Groups. Activities near the shot times were covered in particular detail, and although changes were provided for, very few were necessary.[26]

A series of command post exercises had been held on board the Mount McKinley on the way to Eniwetok on 11 and 12 March 1948. The first telescoped in simulated form the actions of the three days preceding the X shot. The second simulated X-Day down to the dispatch of test samples to the United States. These exercises were necessarily limited to the handling of theoretical situations which were fed into the communications system. They were intended to bring out the type of problems which might arise during the actual tests and to illustrate the command or staff action required.[27]

FX Day, held on 8 April, was a complete rehearsal of all details of the operations scheduled for X Day except that no fissionable material was moved. Perfection of the evaluation plan was one of the special goals at this time. This had been altered prior to FX Day to provide that the four major ships, instead of moving out into the open sea, would remain in the southern end of the lagoon during the tests, along with necessary small craft. A concrete-filled practice bomb was placed in the tower on Engebi and the explosion simulated by firing a bank of photo-flash bulbs. The rehearsal was followed by a critique on 10 April, but only minor changes in procedures were made. After the rehearsal was followed by the successful shot on X Day, it was decided to cancel the rehearsals for Y and Z Days.[28]

After successful completion of the FX Day rehearsal final preparations began for the first test. There was only one slight variation from the scheduled sequence of tests, a [illegible]ponement of the Y shot for 24 hours as the result of weather conditions. Since each shot was successful, it was possible to choose the three bombs which would make a maximum contribution to knowledge. The factors governing the


ENGEBI IS.
AOMON IS.
X-DAY TEST
Y-DAY TEST
Z-DAY TEST
RUNIT IS.
ENIWETOK ATOLL
ANIYAANII IS.
DEEP ENTRANCE
PARRY IS.
ENIWETOK IS.
NORTH



1-ALB-71-YOKE DAY

selection of the three weapons chosen and the general results of the tests are discussed in a succeeding chapter. The shots were timed as follows:

Day	Date	Hour	Island
X	15 April	0617	Engebi
Y	1 May	0609	Aomon
Z	15 May	0604	Runit

The time was set at 43 minutes before sunrise in each case, for reasons already given. Final determination as to whether a specific weapon would be fired was made by the Commander, JTF-7, based on the results of a series of meetings, prior to each test, the first of which was held at 1500 on D-Day minus 3 and the last at H-hour minus 1. Since all ships, aircraft, equipment, instruments, and personnel were ready on each occasion, the principal factor was the weather. Only in the case of Y Day, which was postponed one day from 30 April, was a change necessary. Winds of the proper direction and velocity were necessary to prevent serious radiological fall-out on unused Zero islands, ships, and islands housing personnel. Rain or heavy clouds were also not desirable, although there were scattered showers just prior to the shot on X Day which failed to interrupt the operations.[29]

Roll-up

It may be said that three principles dominated the roll-up phase of Operation SANDSTONE--recovery and salvage, security, and maintenance. It is part of the basic philosophy of any military operation that as large a proportion of usable equipment and supplies as possible be recovered and retained for future use, and this was reflected in

Field Order No. 1 of the Commander, JTF-7, 14 October 1947, which directed the task group commanders to prepare tentative roll-up plans for personnel, equipment, and facilities. This, however, was prevented from becoming a matter of routine handling through the facts that large amounts of complicated and expensive equipment had been used, the accountability for which was frequently equally complex. It was also necessary to keep in mind the important facts that the Eniwetok had been officially selected as the site for a permanent atomic proving ground and that the security of both the installation erected and the explosion sites had to be protected.

The necessity for looking on the atoll as a permanent proving ground was reemphasized in a memorandum of 24 December from Chairman Lilienthal of the AEC to the JCS. He indicated a probable interval of two years between tests and suggested that the Commander, JTF-7, and the AEC work out details regarding the maintenance of the proving ground and the disposition of property. The JCS assigned this responsibility to the Task Force Commander on 20 February 1948. Meanwhile, the Task Force staff had already begun study of the related problems of the roll-up and the maintenance of the proving ground. A standby plan for the proving ground had been prepared under the direction of General Barker, J-3, and a roll-up board had been set up including representatives of the military services and the AEC. This board was responsible for the preparation of Field Order No. 2, which was issued on 8 March and established basic policy and procedures for closing out the operation. Special responsibilities were assigned each of the task group commanders in addition to the disposition of all their personnel, property, and records prior to departure from

Eniwetok. CTG 7.2 was made responsible for preparations ashore for future tests on Eniwetok and was directed to assist TG 7.1 in its roll-up activity. CTG 7.3 was assigned responsibility for any naval preparation of that time for future tests. CTG 7.6 was directed to prepare a radiological safety report on the condition of the atoll for the use of the commander assigned post-Sandstone responsibility. All Task Group Commanders were directed to prepare withdrawal and roll-up plans within two weeks of the order and to submit operational reports by Z plus 15.

These instructions still left the matters of the future security and maintenance of the atoll unsettled, and discussions on these continued during March and April. On 28 April General Hull notified the JCS that the roll-up plans included preparation of facilities for a small garrison on Eniwetok and recommended that the JCS approve and obtain the concurrence of the AEC to a transfer of military responsibility for the atoll to the Commander-in-Chief, Pacific, on or about 1 June and that it make financial arrangements with the AEC for support of the garrison. After obtaining concurrence from the AEC the JCS in early May directed the CINCPAC to assume responsibility for the atoll and proving ground, specifically requiring him to establish a garrison, maintain the status of the atoll as a closed area, maintain existing standby facilities, maintain housing and messing facilities for scientific and survey parties not to exceed 50 men at one time, and provide necessary radiological safety measures. In conformity with the conclusions reached by the Task Force, the directive provided only for general surveillance of the atoll to prevent the removal of significant samples from the Zero islands, unauthorized photography, and extensive trespassing. It was also stated that a permanent guard on the Zero islands need not be normally maintained for the garrison. The Table of Organization which was prepared by the Task Force, included 8 officers and 41 men of the Army and 7 Navy enlisted men. Later a small Air Force detachment was added.[30]

The security and radiological safety phases of the roll-up were closely related, since what would reveal Restricted Data was also frequently dangerous to approach or handle. The roll-up was therefore particularly complete on the target islands, although even here many compromises were necessary. Fortunately, post-shot observations revealed only a small deposit of plutonium in the craters, a result which simplified the problem. The concrete tower footings on Engebi, which showed a considerable encrustation of plutonium, were blasted. Test buildings of the Corps of Engineers and the Bureau of Yards and Docks were blasted or rolled far from their positions, as were the blast footings. Contaminated equipment was disposed of by dumping it into deep water. Warning signs were posted in several languages near radiologically active areas.

A considerable amount of equipment was destroyed during the tests or so contaminated that it had to be disposed of. Nearly all salvageable equipment was returned to the United States except that left for the use of the garrison, since it had been decided that it would hardly survive under local conditions the probable two years before the next tests. Return shipments began on 15 March and were completed by 15 June. Of the approximately 55,000 tons of cargo landed on Eniwetok about 24,000 required return to the United States or Oahu, and of the approximately 20,000 tons landed [illegible] [illegible] Kwajalein, about 8,000 tons were returned. The principal problems faced were the lack of packaging material, much of which had been expended in construction, and the difficulty in identifying through property accounting the ownership of various items, particularly those bought by or charged to the AEC. These were to be shipped to the Oakland Naval Supply Center, California, for inventory and disposition.

Test installations left in place on the islands, such as the gamma, timing, and blast stations, were given limited protective treatment. The gamma stations were coated, inside and out, with asphalt to discourage further oxidation and expansion of the metallic content of the concrete. The metal fittings of the three types of structures were covered with cosmoline, and the buildings were locked. These buildings, the control cables, the causeway, and two photo towers were the only test installations which might be used in a future test, and all were of doubtful permanence as features of the proving ground. The small garrison and possible visiting parties were left well provided for in regard to quarters and service buildings of various types, as well as with such equipment as small aircraft, vehicles, boats and prime movers. Electric generating, radio communication, diesel distillation, and refrigeration facilities were also provided. Buildings in poor condition were razed and others which might be used in the future but not required by the garrison were renovated to minimize deterioration.[31]

A number of severe criticisms centered around the roll-up operations, principally from the Test Director and the Scientific Director. A major difficulty was undoubtedly the lack of a well organized property accounting system. As a result it was often impossible to determine whether a given item of equipment was purchased with AEC funds or otherwise. Also, much property not returned was simply written off as expended without further attempt to account for it. This led to a recommendation by the Test Director for the employment of a comptroller for future test operations. Other criticisms referred to a shortage of materials and manpower for packing, lack of an adequate plan for either destroying or guarding all Restricted Data left on the islands, failure to allow sufficient time or plan properly for satisfactory reports, and neglect to define adequately the term "permanent proving ground" or to take proper preservative measures. The Scientific Director pointed out, for instance, that the land terminations of the control cables were poorly protected, that the surviving photographic towers were left unpainted, that uncoated metal piling was used for the causeway, and that the concrete buildings erected were hardly likely to be useful for future tests even if they survived. He concluded that as far as existing structures were concerned a future operation would be worse off than Operation SANDSTONE.[32]

Although these criticisms are difficult to assess, it appears from the reports of Operation GREENHOUSE which followed two years later that they had some foundation. All the steel structures and equipment mentioned above were deteriorated beyond use. Most of the concrete structures had been covered by sand, and since no maps of their locations could be located, they had to be found by soundings. The causeway had to be rebuilt.[33]

Financing

The cost of Operation SANDSTONE was originally roughly estimated at $27,700,000, of which $20,000,000 would be expended by the military services. Accordingly, during October 1947 the Atomic Energy Commission transferred the latter sum to the Bureau of Supplies and Accounts, Navy Department, to which it had been agreed to assign administration of the fund. Over-all control went to the Commander, JTF-7, whose staff approved all projects prior to any allocation of funds.[34]

A full fiscal agreement was reached among the services and the AEC, and issued by the Task Force on 20 October. It provided that the Armed Services would be responsible for the following expenses: pay and allowances of military personnel, subsistence and clothing for them, transportation costs of military and civilian personnel on government-owned ships and aircraft, costs for tests conducted by the Armed Services which were not planned or requested by the AEC, motor vehicles required for transportation of military personnel in forward areas, costs of all recreational facilities and equipment in forward areas, all costs for fuel, lubricating oil, gasoline, and other operational expenditures of ships and aircraft required in the Operation. The SANDSTONE fund would be charged with all construction costs, administrative expenses, pay and expenses of civilian personnel (except civil service employees of the services), costs of all supplies and equipment required for the tests, costs of conversion and reconversion of ships and aircraft, travel costs of military personnel on temporary duty directly connected with the project, maintenance and operation costs of bases in the forward area, packing and handling charges for supplies, transportation charges when this was not accomplished by military vessels or aircraft, expenses for [illegible] or continued operation of test bases (including a permanent proving ground). Interpretation was left to the Task Force Commander, with fiscal and accounting procedures to be in accord with those of the respective services.[35]

Cost estimates which were now submitted in more detail by the services fell considerably below the first $20,000,000 estimate, amounting to $13,201,250. This was distributed as follows:

	Army	Navy	Air Force	Total
Land and Structures	$1,601,000	$1,911,200	$ 830,000	$ 4,342,200
Supplies and Materials	490,000	775,000	1,525,000	2,790,000
Transportation of Things	1,815,000	433,800	2,052,250	4,301,050
Travel	211,333	127,333	379,334	718,000
Personal Services	30,000	30,000	30,000	90,000
Communication Services	10,000	10,000	10,000	30,000
Other Contractual Services	10,000	10,000	10,000	30,000
Equipment	300,000	300,000	300,000	900,000
Totals	$4,467,333	$3,597,333	$5,136,584	$13,201,250

This estimate proved to be more than ample, and by 1 May 1948 it had become apparent that only about $10,000,000 would be expended by the services in support of Operation SANDSTONE during Fiscal 1948. Accordingly, $8,000,000 was returned to the AEC and $2,000,000 earmarked for later return. The AEC was, however, requested to make $4,000,000 available to the Task Force for Fiscal 1949, to be used in closing out the Operation. At the end of Fiscal 1948 the obligations of the services amounted to approximately the following sums: Army

$2,740,000, Navy $5,180,000, and Air Force $2,160,000. Since direct expenditures by the AEC amounted to approximately $3,500,000, the total cost of Operation SANDSTONE to the AEC amounted to approximately $17,000,000. This did not include the cost of the weapons expended or the routine operational costs which the services had agreed to carry.

References for Chapter XVI

1. Report to AEC by Test Director, JTF-7, Pt. I, Vol. I, 1-1.

2. *Ibid.*, Vol. I, 1-3 to 1-7.

3. Air Force Participation in Operation SANDSTONE, Vol. I, Chap. 1.

4. JCS 1795/1, 10 Sept. 1947.

5. Report of Test Director, Vol. I, 1-8 to 1-11.

6. AF Participation, Vol. I, Chap. 1.

7. Report to JCS by Commander, JTF-7, Vol. I, 17-20.

8. *Ibid.*, Vol. I, 41-50; Report of Test Director, Pt. I, Vol. I, pp. 1-12, 1-19.

9. Report of CJTF-7, Vol. I, 33-50.

10. *Ibid.*, Vol. I, 36-37.

11. *Ibid.*, Vol. I, 73-78.

12. *Ibid.*, Vol. I, 122-23.

13. *Ibid.*, Vol. I, Annex I, Pt. I, pp. 18-67.

14. *Ibid.*, Vol. I, Annex I, Pt. I, pp. 18-59; Report of Test Director, Pt. I, Vol. II, 10-11 to 10-13.

15. Report of CJTF-7, Vol. I, Annex I, Pt. I, pp. 65-67.

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17. Report of CJTF-7, Vol. I, 61-63.

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19. Report by CJTF-7, Vol. I, pp. 55-57.

20. *Ibid.*, Vol. II, 33-36, 41-45, 91-96.

21. *Ibid.*, Vol. I, 91-99.

22. Report of Test Director, Pt. I, Vol. I.

23. *Ibid.*, Pt. I, Vol. II, Report 8.

24. Report of CJTF-7, Vol. I, 55, 99-101.

25. Report of Test Director, Pt. I, Vol. I, Summary, pp. 24.

26. Scientific Director's Report of Atomic Weapons Tests at Eniwetok, 1948, Vol. I, 154, and Appendix 4.

27. AF Participation, Vol. I, Chap. 5.

28. Report of CJTF-7, Vol. I, 123-24.

29. Report of Test Director, Pt. I, Vol. I, 1-31 to 1-34.

30. Report of CJTF-7, Vol. I, 141-44.

31. Report of Test Director, Pt. I, Vol. II, 16-1 to 16-10.

32. Ibid., Pt. I, Vol. II, 15-4 to 15-5; Report of Scientific Director, Vol. I, 161-66.

33. See Vol. IV on Operation GREENHOUSE.

34. Report of Test Director, Pt. I, Vol. I. 17-2 to 17-3.

35. Ibid., Pt. I, Vol. II, Appendix B.

CHAPTER XVIII

AIR FORCE PARTICIPATION IN OPERATION SANDSTONE

Early Planning and Organizing

As seen in the preceding chapter, participation by the Air Force in Operation SANDSTONE (Unclassified) was principally based on the need for three types of support mentioned in the AEC memorandum of 28 July 1947: (1) a unit to provide eight drone aircraft to collect chemical samples of the bomb cloud immediately after detonation and transport aircraft to carry these samples to Los Alamos; (2) air transportation to assist in logistical support; and (3) a unit to provide complete photographic coverage. As given effect by the recommendations of the Joint Proof Test Committee and action by the staff of Joint Task Force 7, these and most other air functions which developed as the operation progressed were assigned to the Commander, Air Forces, JTF-7, and the Air Task Group. On 12 November Major General William S. Kepner was designated Commander Air Forces, JTF-7, in addition to his functions as Deputy Commander. Field Order No. 1, JTF-7, on 14 November delegated to him responsibility for all air operations except helicopter and off-shore patrol, including meteorological service, military security within the Air Task Group, inter-island air transportation, air sea rescue, and aerial photographic service. He was also directed to establish a unified system of air traffic control in the Kwajalein-Eniwetok area and was assigned control of all task force aircraft during the test operations, with the sole exception of the Navy patrol planes, which remained under the Island Commander, Kwajalein (TG-7.6). The Air Commander was made responsible for operational planning for the units under his control and was directed to submit for approval, by 15 February 1948, plans for the following types of operations: air operations (general), to include drone planes; inter-island air transport; air-sea rescue; photographic service; meteorological service; typhoon emergency. Operational control of the participating air units was also to be executed by the Air Commander, and this was later extended in time to cover the period from 48 hours prior to each shot, actual or practice, to 24 hours afterward. Although control of the off-shore patrol planes was never given to the Air Commander, it was provided that they would be available for air-sea rescue at his call.[1]

The first definite steps to organize the Air Task Group were taken on 8 October when Headquarters, USAF, notified General George S. Kenney, Commanding General of the Strategic Air Command, of the nature of the proposed task group and directed him to organize, man, equip, and train such a unit. The Air Materiel Command, Air Proving Ground, and Air Transport Command were also directed to provide appropriate assistance. Brigadier General R. M. Ramey,* Commanding General of the Eighth Air Force, who had headed the Air Task Group at CROSSROADS (Unclassified), was assigned responsibility by General Kenney for fulfilling this assignment and commanding the Air Force task group. He immediately flew to Washington for a conference with General Kenney and General Kepner, who held a triple responsibility

*Gen. Ramey was promoted to Major General during the course of the operation.

as Deputy Commander, JTF-7; Commander, Air Forces, JTF-7; and Chief, Special Weapons Group, the last being the staff segment of Headquarters, USAF, which monitored atomic matters. Ramey submitted a hasty estimate of the supplies and personnel needed for a project utilizing 30 aircraft for 60 days. Meanwhile, the Chief of Staff, USAF, on 13 October had directed his deputies to support the operation with priority second only to the 55 group program. The Special Weapons Group was designated monitoring agency for the Air Force, while the DCS/Operations, DCS/Personnel and Administration, DCS/Materiel, and Comptroller were directed to assign project officers.[2]

A period of rapid planning and organizing followed. One of the first steps was to send a party of staff officers to inspect Kwajalein, where it had been decided to base most of the aircraft, but they found few facilities left from Operation CROSSROADS, the last occasion of its large scale use by the Air Force. There was, however, a small station of the Air Weather Service and an Aviation Engineer Squadron which was just beginning a demolition program. This work was stopped, and the squadron was diverted to new construction and rehabilitation. The island as a whole was being operated as a Naval installation under Captain J. P. W. Vest, whose command was incorporated into the task force as Task Group 7.6.

By 22 October Generals Kepner, Ramey, and McMullen had prepared a broad plan of operation which would allow proceeding with the procurement of personnel and supplies. In general, it provided for the rehabilitation of Kwajalein by USAF Pacific Air Command engineers, readying of 25 aircraft plus air-sea rescue and AAC units for operation from Kwajalein at least two weeks prior to the tests, and delegation of responsibility for requisitioning [illegible] to their individual problems to the commanders of subordinate units. Tables of organization were completed in late November, and most key personnel were selected by name from within the Eighth Air Force.

Most of the visits for coordinating the preparation of the various participating units were made by Colonel Nelson P. Jackson, Colonel William S. Rader, and Colonel Herbert L. Grills of the Air Commander's staff. These officers, traveling from the Washington headquarters of the Task Force, paid repeated visits during November, December, and January to the main centers of preparation for the work of the Air Task Group at Fort Worth Air Field, headquarters of the Eighth Air Force, and Eglin Field, location of the 1st Experimental Guided Missiles Squadron. Aside from the assembly of the necessary equipment and personnel, preparation of operational plans, and training, a major concern was planning for the forward movement of the units and their supply both en route and while in the operational area.[3]

By late November it was established that the Air Task Group would be composed of personnel from five principal sources: (1) nearly all Eighth Air Force units (SAC), (2) the 1st Experimental Guided Missiles Squadron (AFG), (3) the 311th Reconnaissance Wing (SAC), (4) the Air Sea Rescue Service (ATC), (5) the Air Weather Service (ATC). Personnel from the latter two sources were already in Hawaii and Guam, but it was estimated that 1165 others would require movement overseas from the Zone of Interior, these consisting essentially of four main elements: the Air Task Group staff, the Headquarters and Service Detachment, the Drone Detachment, and the Photographic Detachment. It was decided to move them in four echelons: [illegible] by water about 10 February, [illegible] by B-17's of the 1st

Experimental Guided Missiles Squadron, 87 by unit aircraft of the 311th Reconnaissance Wing, and 175 or more by the ATC after 1 February. All processing was to be completed at the home stations rather than the POE in order to simplify movement.[4]

When the military services were circularized in October for proposed tests of particular interest to them the Air Force submitted an outline of seven test requirements as follows:

1. Blast characteristics: establishment of velocity and pressure gradients at various levels above the surface through the use of drone aircraft.

2. Height and rate of cloud ascent: development over the first 15 minutes after the blast, with the measurement of radioactivity by drone aircraft at appropriate intervals.

3. Incendiary data: plot of heat intensities, velocity, and duration of induced surface winds.

4. Radiation data: direct radiation over effective distances and fall-out contamination due to rainfall; pattern of surface contamination and life of lethal radiation.

5. Effects of precipitation.

6. Meteorological data: to be collected over a large area around Zero Point, both before and after the detonation.

7. Decontamination: the Chemical Corps to determine all possible factors involved in the decontamination of various surfaces, including the degree and endurance of contamination, and to devise field methods for nullifying contamination.

As noted previously only the first of these was officially accepted as a military service test, although several of the others were performed under various descriptions by the AEC task group or the military services.[5]

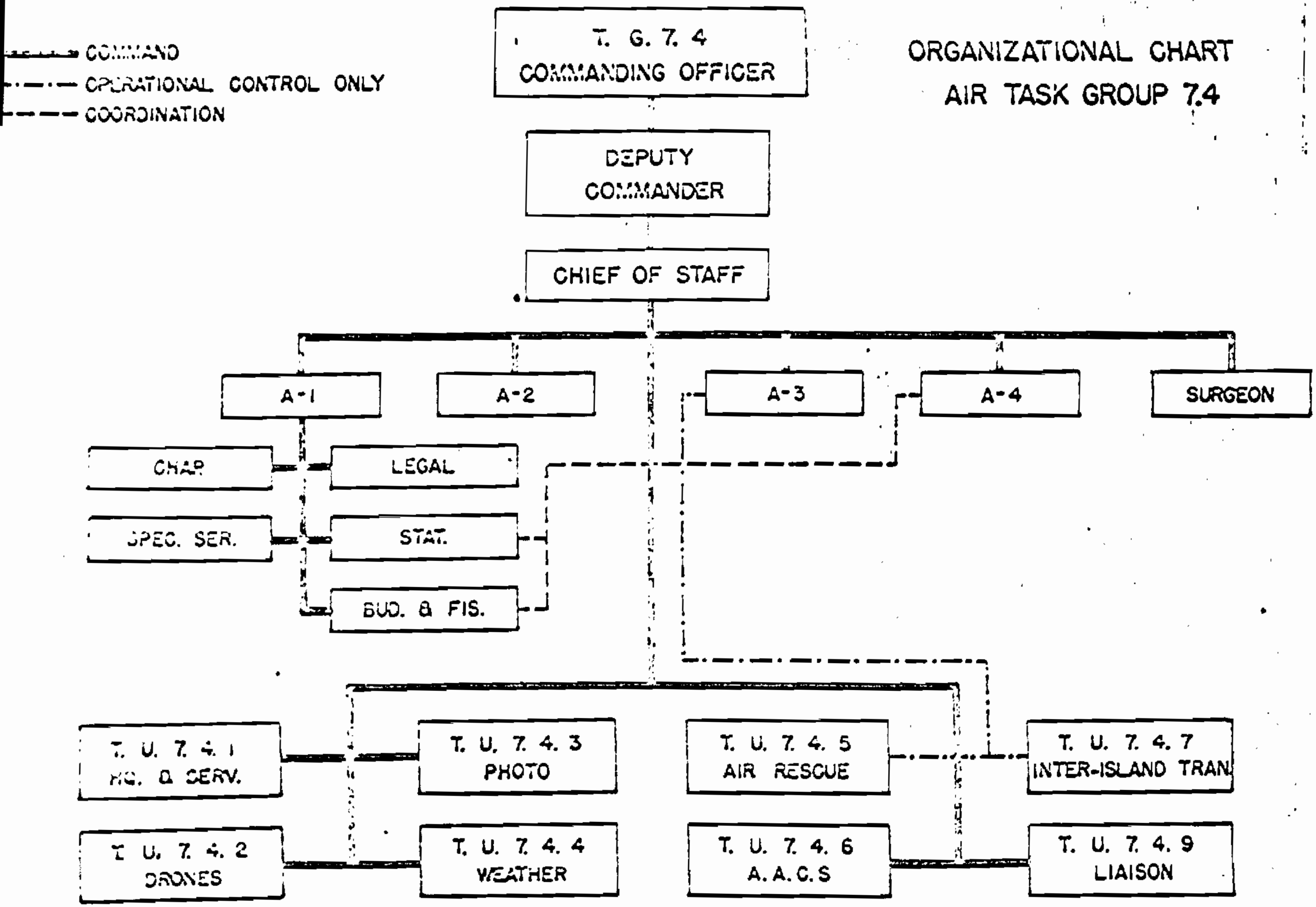
Organization and Forward Movement of the Air Task Group

Task Group 7.4 (Air) was officially organized on 9 January 1948 at Fort Worth under the command of Brig. Gen. Roger M. Ramey. Under

Operations Order 1-48, issued 12 January, the Air Task Group became responsible for carrying out the following 10 assignments: (1) operation of radio controlled aircraft for the collection of radiological specimens from the atomic cloud; (2) providing both aerial and ground photographic coverage for Operation SANDSTONE as directed by the Staff Photographer, JTF-7; (3) providing complete meteorological service, including tracking the atomic cloud; (4) providing communications essential to the operations of Task Group 7.4; (5) providing air-sea rescue service in the operating area; (6) providing inter-island air transportation for passengers, mail, and freight; (7) operational control of the special ATC aircraft for rapid courier service to the United States while in the test area; (8) providing means and a plan for evacuating all personnel from Eniwetok Island on one hour notice; (9) providing means and a plan for protecting personnel and materiel from the effects of a typhoon; (10) providing a suitable aircraft to transport a radiological safety representative into the target area within 10 minutes after H-hour. Three of the above--operation of drone aircraft, photographic service, and meteorological service--may be considered to have been of primary importance, while the others represented either support or limited special operations. The successful accomplishment of these missions would obviously require the operation of a complete Air Force base at Kwajalein capable of providing all services normally considered part of an air base operation, in addition to several others of unusual or highly specialized type.[6]

Task Group 7.4 was divided into eight task units with the following designations and missions:[7]

ORGANIZATIONAL CHART
AIR TASK GROUP 7.4



COMMANDER, AIR FORCES, PERSONNEL AND AIRCRAFT UTILIZATION CHART

UNIT	OFFICER AF	OFFICER A	OFFICER N	EM AF	TOTAL	AIRCRAFT NO	AIRCRAFT TYPE	REMARKS
COMDR., AIR FORCES	17	1	1	13	32	1*	B-17	SEE NOTE A.
TASK GROUP 7.4	15			35	50	1	B-29	
TASK UNIT 7.4.1	44			511	555			
TASK UNIT 7.4.2	98			363	461	24*	B-17	SEE NOTE B.
TASK UNIT 7.4.3	18			36	54	3 2	F-13 C-54	
TASK UNIT 7.4.4	45			208	253	9	B-29	
TASK UNIT 7.4.5	12			18	30	2 2	B-17* OA-10	SEE NOTE C.
TASK UNIT 7.4.6				30	30			
TASK UNIT 7.4.7	11			10	21	12 3 1	C-54 C-47 PBY4Y2	
TASK UNIT 7.4.9	4			14	18	12* 2	L-5 L-4	SEE NOTE D.
OTHER SERVICES ATTACHED*	10			176	186			SEE NOTE E.
TOTAL	274	1	1	1414	1689	75		
TASK UNIT 7.3.4						4* 2	SIKORSKY BELL HELICOPTERS	SEE NOTE F.
TASK GROUP 7.7						1*	PB4Y2	SEE NOTE G.

A. COMMANDING GENERAL'S AIRCRAFT.
B. ONE (1) DRONE LOST DURING X-RAY DAY OPERATIONS.
C. "DUMBO" TYPE B-17 AIRCRAFT.
D. ONE (1) L-5 SURVEYED BECAUSE OF MAJOR DAMAGE.
E. PERSONNEL USED TO AUGMENT AACS AND AIR CARGO. (CHARGED TO TASK GROUP 7.4).
F. OPERATIONAL CONTROL DURING TEST DAY MINUS ONE UNTIL RELEASED.
G. ON LOAN FROM NAVY FOR AIR RESCUE SERVICE.

1. Task Unit 7.4.1 (Headquarters and Service), which would include the procurement of personnel and equipment, third echelon supply and maintenance of aircraft, and base housekeeping.

2. Task Unit 7.4.2 (Drone), which was established to operate 24 B-17's for air sampling, four of which were also equipped to record blast acceleration.

3. Task Unit 7.4.3 (Photo), which was designed to provide both aerial and ground coverage of the tests, including technical, documentary, and historical aspects.

4. Task Unit 7.4.4 (Weather), which would provide complete weather service for Operation SANDSTONE through ground detachments located at Eniwetok, Rongerrik, Majuro, Wake, and Kwajalein, and an air detachment of eight B-29's at Kwajalein.

5. Task Unit 7.4.5 (Air Rescue).

6. Task Unit 7.4.6 (the Army Airway Communications System), which would be operated by the Air Transport Command.

7. Task Unit 7.4.7 (Inter-Island Transportation), which would be provided by the ATC for supply service to the island groups.

8. Task Unit 7.4.8, used only for movement purposes.

9. Task Unit 7.4.8 (Liaison), composted of mixed Air Force, Army, and Navy liaison planes and personnel, and established on Eniwetok for inter-island transport.

Aircraft for the above units were obtained from a variety of sources. The most important need was for the drones and their control aircraft (mothers). It was finally determined to use 24 B-17's for this work—12 drones and 12 mothers—allowing for 50 per cent spares. These were equipped by the Air Materiel Command and turned over to Task Unit 7.4.2. The 514th Weather Reconnaissance Squadron at Guam furnished eight specially equipped B-29's for the mission of air weather reconnaissance. The Strategic Air Command supplied two F-13's and two C-54's. The former were specially modified as flying camera platforms. Local transportation among the islands of the atoll was provided by 11 L-4's and L-5's, obtained from various sources. Longer distant transportation among Eniwetok, Kwajalein, and Majuro was provided by three C-47's and one C-54 from the Air Transport Command; 11 C-54's for rapid courier service to the United States and the air evacuation mission came from the same source. Various other sources in the Air Force supplied two OA-10's and two B-17's (equipped with Dumbo units) for the air rescue mission. The Navy provided six helicopters (four HO3S's and two HTL's) and two PBM's.

Altogether the task force had assigned to it a total of 80 Air Force, Army, and Navy aircraft, exclusive of those of the Air Transport Command and Naval Air Transport Service which operated on regular schedules to the Marshall Islands. With the exception of those assigned to Task Group 7.3 (Naval) these operated under the control of the Commander, Air Forces, and on test days all passed under his control of general supervision. At these times the number of aircraft actually operating in the Eniwetok area amounted to about 50. The distribution of aircraft and personnel among units of the task force was as follows:[8]

Unit	Number	Type	Officers	Enlisted	Total
Comdr., AF	1	B-17	19	13	32
TG 7.4 (staff)	1	B-29	15	35	50
TU 7.4.1	0		44	511	555
TU 7.4.2	24	B-17	98	363	461
TU 7.4.3	3 2	F-13 C-54	18	36	54
TU 7.4.4	9	B-29	45	208	253
TU 7.4.5	2 2	B-17 (Dumbo type) OA-10	12	18	30
TU 7.4.6	0			30	30

Unit	Number	Type	Officers	Enlisted	Total
TU 7.4.7	12 3	C-54 C-47	11	10	21
TU 7.4.8	0		(temporary, for movement only)		
TU 7.4.9	12 2	L-5 L-4	4	14	18
Other Services Personnel Attached to TG 7.4			10	176	186
TU 7.3.4	4 2	HO-3S (under operational control during tests) HTL (" " " " ")			
TG 7.7	1	P54Y2 (" " " " ")			
TOTALS	80		276	1414	1690

As has already been seen, the principal source of personnel for the Air Task Group was the Eighth Air Force of the SAC. Other sources of personnel which were drawn on heavily were the 1st Experimental Guided Missiles Group of the Air Proving Ground Command, which supplied most of the personnel for Task Unit 7.4.2; the 16th Photo Reconnaissance Squadron of the 55th Reconnaissance Group, Strategic Air Command, which supplied most of the personnel for Task Unit 7.4.3; the 514th Weather Reconnaissance Squadron, Air Transport Command, which supplied most of the personnel for Task Unit 7.4.4; and the Seventh Air Force, which supplied most of the personnel for Task Unit 7.4.5; and the Army Airways Communications System, Air Transport Command, which supplied the personnel for Task Unit 7.4.6; and the Air Transport Command, which also supplied the personnel for Task Unit 7.4.7. Total strength for the Task Group was 261 officers and 1401 airmen. This did not include 19 officers (of which 17 were Air Force) and 13 airmen on the staff of the Air Commander, JTF-7.[9]

The principal problem relating to the assignment and training of personnel was the location and assignment of sufficient trained personnel to operate and maintain the complicated electronic equipment utilized in the drone aircraft system. Because of the limited time, it was hoped to avoid the necessity for any individual training. Nevertheless, some training of "beeper" pilots, communications technicians, and electronics maintenance technicians had to be carried out. Unit training was confined to the operational site at Eniwetok and Kwajalein, except that a command post exercise was held by the Air Commander on board the Mount McKinley on the way to Eniwetok on 11 and 12 March.

Closely related to the problem of personnel assignment was that of security clearances. Under the Forrestal-Lilienthal agreement of 22 December 1947 military personnel were required to have Q clearances (necessitating an FBI background investigation) for access to Restricted Data supplied by AEC contractors, while any access to Restricted Data was to require an M clearance (requiring a similar background investigation by the military department itself). The organization of the task force, however, preceded the agreement, and special arrangements were necessary. It was agreed that all personnel given access to Restricted Data must have a Q clearance. Operation SANDSTONE was the first assignment of the services requiring such clearances in large number. In general, the following groups from the Air Force were required to have Q clearances: the Air Commander's Staff, the headquarters staff of Task Group 7.4, all photographic personnel, and the commanding officer and operations officer of Task Unit 7.4.2. As a result of this and other demands from the services, the FBI was flooded with requests, a large backlog was created, and a waiting period of 60 days was needed to obtain the Q clearance. This seriously handicapped the work of initial planning. Personnel must requiring access to Restricted Data were allowed to have a "P" approval, based on a negative file check by the FBI.[10]

The principal over-all guide for accomplishment of the Air Force mission was Operations Plan 1-48, which was issued by Headquarters, Air Forces, JTF-7, on 12 January 1948. It was prepared by Colonel William R. Shephard, Operations Officer for Task Group 7.4, Colonel Nelson P. Jackson, and other officers of the staff of the Air Commander and the Commander, Task Group 7.4. In designation of responsibilities and duties it followed the organization determined on of subdividing Task Group 7.4 into eight subordinate units. It was divided into five main paragraphs covering the general situation, mission, tasks for subordinate units, administrative and logistic matters, and command and signal matters. In addition a series of annexes described in detail the various responsibilities of the task units on P (Practice), X (First Test), Y (Second Test), and Z (Third Test) Days. This was supplemented on arrival at the test area by the issuance of a series of seven detailed Operations Orders from 14 March to 8 May.[11]

Movement of the Air Task Group overseas began early in February 1948. The Strategic Air Command was designated monitoring agency for the movement, and the responsibility was further assigned to the Eighth Air Force. The movement order which was prepared originally provided for processing personnel for overseas movement in accord with the current POM directives; however, certain modifications were necessary to provide for the specialized nature of the movement, and these were covered in a special POM directive issued in late November 1947. The main water movement, including the ground echelon of Task Group 7.4, left port at Oakland, California, on 10 February aboard the Pickaway (APA 222) and arrived at Kwajalein on 22 February. An advance air echelon departed from Hamilton AFB, California, the aerial POE by 12 February and arrived at Kwajalein on 17 February. Later sections of the air echelon, including Task Unit 7.4.2, began to move from the same point on 10 March, the last arriving on Kwajalein on 20 March. By the end of the month the movement of the personnel of the Air Task Group was complete, numbering slightly under 1,500. The bulk of its supplies and equipment, except the portion moved by air, was unloaded during the last two weeks of February from three main supply vessels at Kwajalein, amounting to approximately 3,500,000 pounds.[12]

The principal logistics problem affecting the Air Force was securing replacement parts and proper maintenance for the more than 70 aircraft of widely assorted types which the Air Task Group itself was operating. The problem was complicated by the division of air operations between Eniwetok and Kwajalein, with only the latter capable of anything resembling third echelon maintenance. The situation was further complicated by the policy of holding the use of the airlift for such supplies to a minimum in order to reserve space for the movement of vital scientific and technical equipment. A fairly satisfactory solution was the use of Table II pack-up kits augmented by a number of special items, particularly those which would provide for the needs of the specially modified aircraft.[13]

Nature of Air Operations Required

As they developed, the air operational phase of SANDSTONE may be divided into at least 10 main aspects, which may be described as follows: (1) transportation of personnel, supplies, and equipment between the United States and the test area; (2) weather reconnaissance of the ocean areas surrounding the test site; (3) collection of fission products from the atomic clouds and of blast acceleration data through the use of drone aircraft carrying scientific instruments; (4) aerial, documentary, and scientific photography; (5) maintenance of aerial security reconnaissance and air rescue service within the operational area; (6) aerial survey of the target area after the detonation to determine the feasibility of measuring surface radioactivity by airborne instruments; (7) removal of scientific data by helicopter from contaminated or otherwise inaccessible areas; (8) tracking of the course of the radioactive residue from the atomic cloud in the atmosphere; (9) rapid return of radioactive test samples and photographic film to laboratories in the United States; (10) air transportation of personnel and equipment between islands in the test area.[14]

For the above operations and functions, many of which were extremely complex, the task force had assigned to it some 80 Air Force, Navy, and Army aircraft of assorted types, exclusive of the aircraft of the Air Transport Command and Naval Air Transport Service which serviced the Marshall Islands on regular schedules. Most of these were under the operational control of Task Group 7.4 (Air Force), with the remainder under Task Group 7.3 (Naval), but all operated under the direction of Commander, Air Forces, JTF-7, during the actual time of the tests. On test days the Air Commander controlled the movements of about 50 of these in their operations in the Eniwetok Area.

Several factors combined to render the air operations quite complex. First, many physical conditions made operations difficult or hazardous. These included rtduced visibility, the violent shock wave and intense radioactivity accompanying the explosions, the pressure of radio-controlled drone aircraft in the flight pattern, and the need for precise timing. Second, it was necessary to base Task Group 7.4 and most of its aircraft on Kwajalein, with Eniwetok used principally as a staging area for the drone aircraft. At the same time the Air Commander was located on the U. S. S. Mount McKinley with the Task Force headquarters, where he was dependent on a complex system of radio communications.

Air Transportation

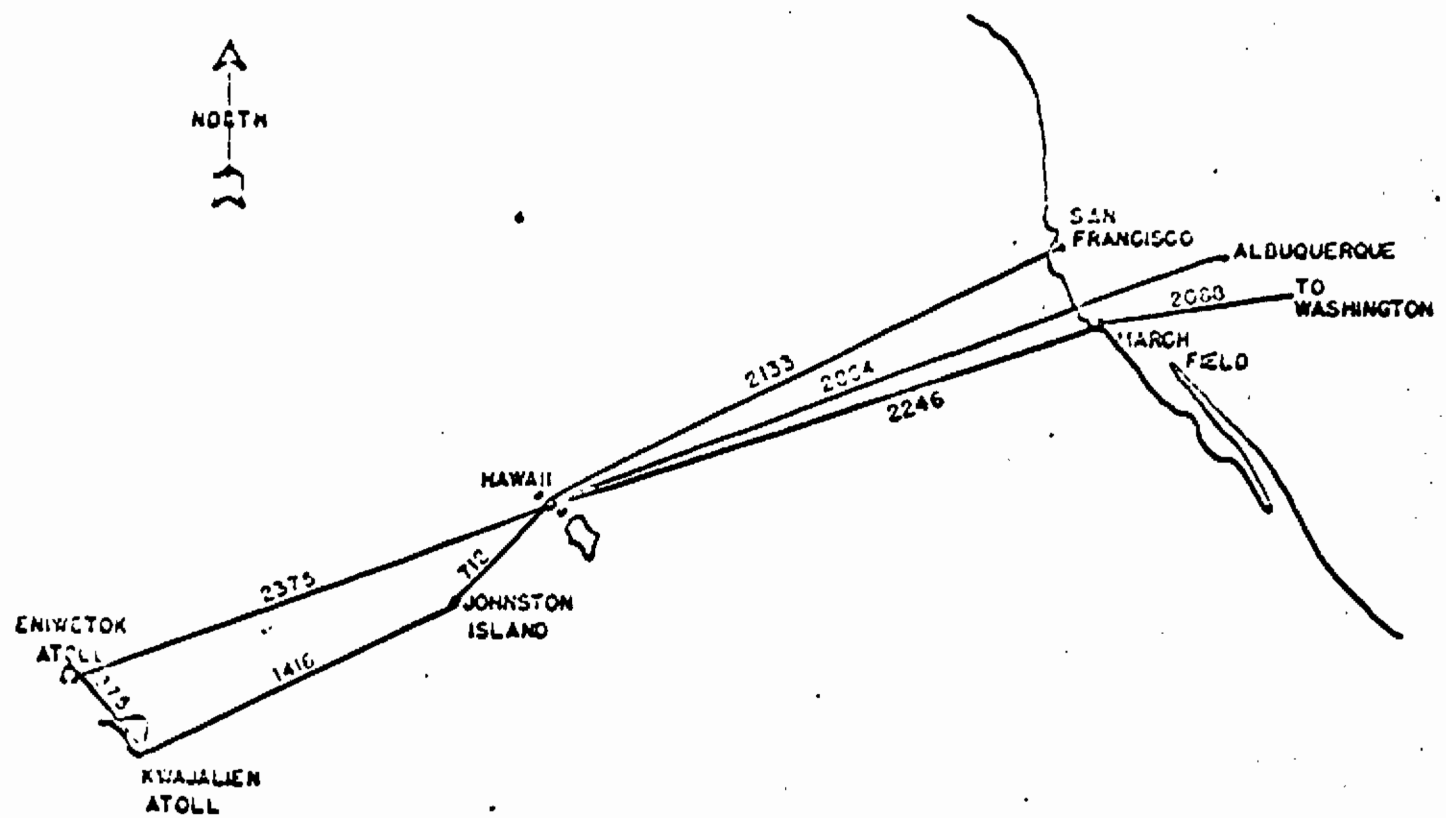
Air transportation became an increasingly important phase of the Air Force's participation in SANDSTONE as the operation progressed. It eventually developed five distinct aspects--transportation to and from the United States, liaison transportation among the Marshall Islands, rapid courier service to the United States, immediate transportation of test results to the United States, and emergency air evacuation. It was not necessary to put the latter into effect, this remaining in the planning stage.

The Air Force and the Navy were given the responsibility for the air transportation of personnel, supplies, and equipment involved in the operation, and they in turn designated the Air Transport Command and the Naval Air Transport Service to carry out this function. Both of these had served Operation CROSSROADS in the same capacity. After some consideration of the possibility of establishing a special transport unit such as the Green Hornet employed during CROSSROADS, it was agreed that none would be established to handle the assignment but that instead both services would handle the load through augmentation of their normal schedules. The Air Transport Command (through its subcommand, the Air Transport Service) would transport all personnel and equipment which required air movement other than Naval, which would be carried by the NATS. The latter would also give additional support in the event backlogs developed. Under this policy the NATS operated on a normal space available basis, while requests for monthly allocations of the ATC airlift for the remainder of the operation were submitted monthly to Headquarters, USAF.

The reports of Operation CROSSROADS proved very helpful in planning for the airlift, particularly in enabling the prediction of peak periods of utilization and in emphasizing the unreliability of logistical estimates. The results of both operations demonstrated that estimates of tonnage made by shipping agencies 60 days in advance accounted for less than 35 per cent of the actual shipments. Requests for monthly allocations of airlift space were based on combined estimates of all JTF-7 agencies and a study of movement figures. All westbound priorities were controlled from JTF-7 headquarters in Washington, although sub-allocations were given to Forward Headquarters at Fort Shafter for shipments from Hickam Field, and to the USAFPAC liaison officer at Fairfield-Suisun Air Force Base, the principal aerial POE in order to expedite rush shipments of AEC equipment from Los Alamos. Eastbound priorities were controlled by the Fort Shafter headquarters of the task force through the USAFPAC theater priorities board.

This system worked smoothly, with few backlogs developing. Because of excellent water shipping facilities, allocations through January were considerably undersubscribed. Air transportation movements increased markedly during February, and allocations were slightly exceeded during March and April because of the large number of emergency requests for air shipment. The principal item during

AIR TRANSPORTATION



DISTANCES ARE IN NAUTICAL MILES

CHART NO 1

this period was additional B-29 engines for the weather reconnaissance aircraft. The somewhat irregular accumulation of air freight during the first few months conflicted with the normal pattern of regular equal movements of the increments for a shipping channel. This was corrected at Fairfield-Suisun by allowing credits on non-active days, to be used when excessive shipments arrived, and possible delay was eliminated.

Two special operations which were necessary to meet requirements of the task force were the movement of large quantities of essential electronic equipment from Washington and Boston just prior to the sailing of the principal task force convoy from Terminal Island, California, on March 1 and the movement during the same period of over 20,000 pounds to camera repair and test equipment from Wright Field, Ohio, to MacDill Field, Florida, and then to the test area via Fairfield-Suisun. Delays in manufacture had held back the electronic equipment beyond the surface shipment deadline, and a special movement of C-54's was arranged to enable the 35,000 pounds of equipment to depart with the flagship and convoy. The photographic equipment was moved by C-74 as far as Fairfield-Suisun and then by C-54.

Like other phases of the operation, air transport was effected by security requirements. After considerable study, the Air Transport Service's recommendation that shipments be marked and ticketed in the clear, as was the case during the war, was adopted. A special air transport channel--19X--was established to serve Operation SANDSTONE at Kwajalein, a channel being the designation for a route over which cargo and personnel are moved to a general designation. The channel directive, which was sent to all ATC stations, was supplemented by classified explanations to the aerial port of embarkation and the few stations possibly concerned in the Pacific area. This represented the use of a cover plan by which routine methods provided both for efficient operation and for the limiting of the number of persons knowing the actual designation.[15]

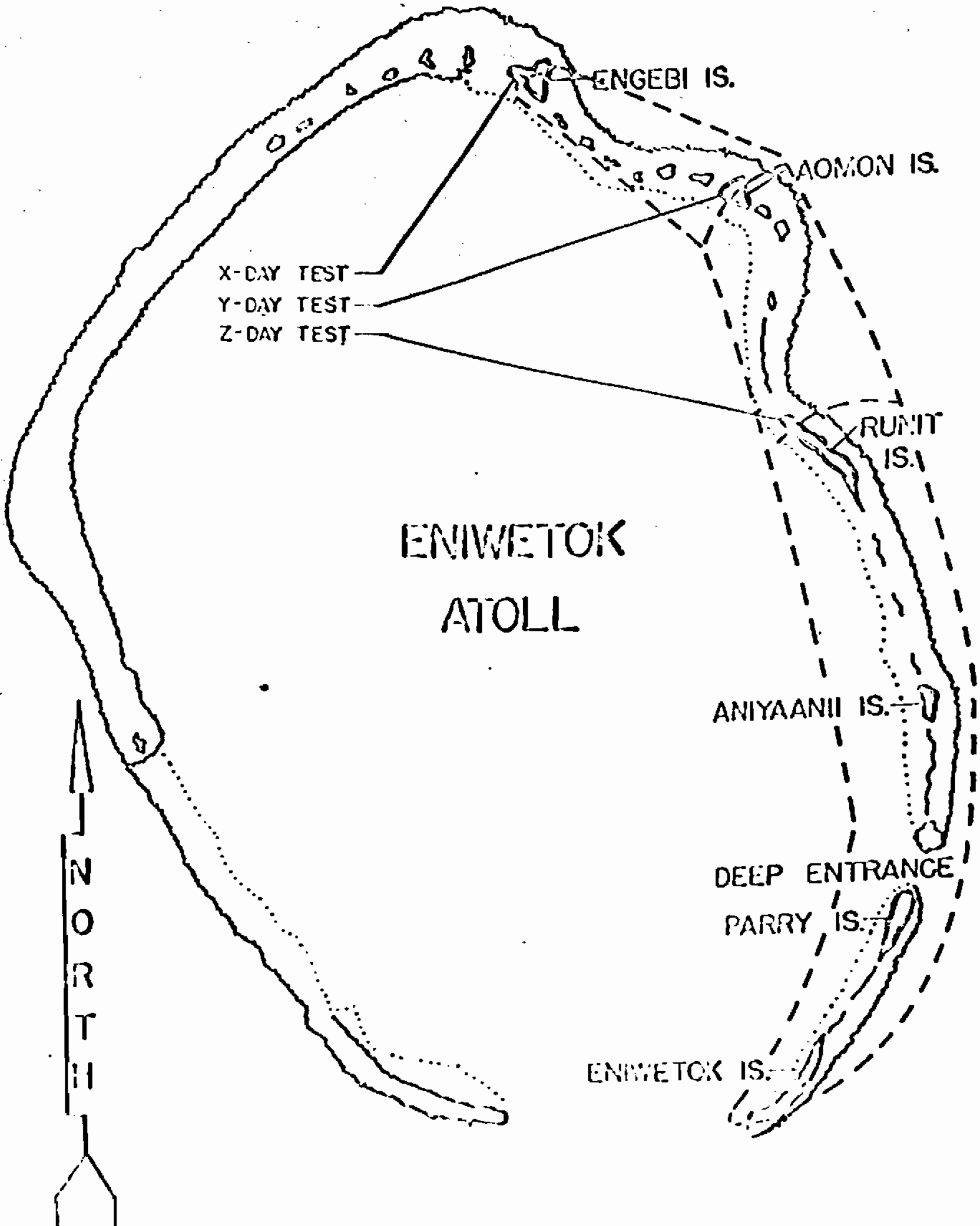
Through experience it was determined that a schedule of five round trip flights a week from the United States to the test area would meet the task force requirements. Since a C-54 had a normal payload of 7,500 pounds from San Francisco to Oahu and 12,000 pounds from this point forward, the additional traffic generated in Oahu could normally be handled without additional aircraft. Except for the forward movement of the Task Group 7.4, which was made from Hamilton Field, Fairfield-Suisun and Moffett Fields, near San Francisco, were the aerial ports of embarkation. The regularly scheduled routes from these were to Hickam Field (Oahu), Johnston Island, and Kwajalein. Since there were no scheduled air routes to or from Eniwetok in the beginning, a shuttle airline was instituted between Eniwetok and Kwajalein, where both ATS and NATS planes connected. Three C-47's and one C-54 were assigned by the ATS for this purpose.[16]

Accurate, close figures for the total movement by airlift are not available; however, it was estimated by task force officials that more than 3,000 persons and 350 tons of air freight were moved from the United States to the test area. Probably nearly an equal amount of air freight was carried from Hawaii to Kwajalein. The ATS listed a total of 3,0[illegible]5,153 pounds as the weight of cargo, mail, and passengers moved during the operation (1 November 1947-15 June 1948), but this included many short movements within Eniwetok Atoll and from there to Kwajalein. Exclusive of the short flights within the atoll, [illegible] passengers were carried by the ATS for [illegible] SANDSTONE during the same period. Over 3,000 of these, however, were moved in the comparatively short flights between Eniwetok and Kwajalein.[17]

Soon after Task Group 7.2 began the work of preparing the proving ground at Eniwetok it was realized that some type of air transport would be needed among the islands of the atoll. Nearly all the islands figuring prominently in the operation either had existing landing strips or space suitable for one, and the boat trip from Eniwetok to the farther islands consumed up to two and a half hours. Two L-4 Army aircraft had been sent with the Engineer Special Brigade, and at the suggestion of the Tactical Air Command these were supplemented by L-5's. Four were secured from the Navy at Oahu and two more secured from the Air Force on Kwajalein. Five more were secured from Air Force sources in the United States and moved to Eniwetok on the USS Bairoko. Eventually 11 aircraft were in operation between seven of the islands. They carried approximately 5,000 passengers while operating on a seven-day, dawn to dark schedule. This transportation system reduced the two and a half hour time by water from Eniwetok to Engebi to 20 minutes.[18]

Six helicopters, supplied by the Navy, were used for intra-atoll transportation and for collecting test samples after the explosions. These, however, were under the control of Task Group 7.3 (Naval) except on practice and test days, when they passed under the control of the Air Commander, beginning 43 hours before H-hour. The unit operated four HO 3S (Sikorsky) and two HTL-2 (Bell) helicopters, the former carrying two passengers each and the latter one. During two months' employment following their arrival 16 March on board the USS [illegible] these aircraft [illegible] hours. Their [illegible] was to provide rapid transportation and [illegible]

LIAISON OPERATIONS



rescue assistance when needed, but their primary mission was to carry out a variety of specialized transportation functions on the test days, including conducting radiological safety surveys from the air, recovering test samples, and serving as a control point for the radio-controlled tanks which entered the bomb craters.[19]

Another phase of the transportation problem, which had to be planned for but was not necessary to put into effect, was the emergency air evacuation of personnel (in the event of a shift of wind and resulting radiological fall-out). Although the direction of prevailing winds made fall-out in dangerous amounts extremely unlikely, detailed plans were made for the eventuality. During January the number of persons to be evacuated was estimated at 75 to 100, all of whom would be located on Eniwetok and Parry. Four C-54's were requested from the ATC with which to carry out the evacuation, which was scheduled to begin immediately with the shift in wind, with the planes held on Eniwetok for the purpose. Later a change provided for holding the aircraft on Kwajalein while the personnel left on the islands of Eniwetok and Parry would take shelter until the fall-out ceased and then be evacuated. The number of persons on the two islands, however, continued to grow until it reached 400, including the Air Force personnel required under the revised decision to fly drone aircraft from Eniwetok rather than Kwajalein. The evacuation plan was then changed to provide for evacuation of all personnel not under the Air Commander, JTF-7, by two LCI's, while those under him would be moved by the C-54's.[20]

One of the special requirements given to the Air Force was for the rapid movement of radiological test samples and photographic film to the United States for processing. Radiological samples collected on air filters and ground samples were to to moved to Los Alamos, while still camera film was to go to Washington and motion picture film to Los Angeles. To handle these shipments five flights were set up following each test. The first two carried air filter samples obtained by the drone aircraft and the third ground samples from the blast site. Each cargo was accompanied by scientists and couriers. Only one stop was made enroute to Albuquerque--at Hickam Field, Oahu, where cargoes and attendants were transferred to other C-54's with only a few minutes' delay. The fourth and fifth flights, carrying the films, stopped at Hickam and at Riverside, California. The 5 flights left Eniwetok respectively at 2, 3, 8, 6, and 30 hours after the time of each shot.[21]

Meteorology

The Air Force directive of 8 October 1947, outlining the responsibilities of various sections of the Air Force in supporting Operation SANDSTONE, assigned the responsibility for providing all weather information to the Chief of the Air Weather Service of the Air Transport Command. The importance of the meteorological mission was emphasized by the establishment of the position of Staff Meteorologist in JTF-7 Headquarters, a post which was filled on 20 October by Col. Benjamin G. Holzman, USAF, who had served in a similar capacity at CROSSROADS and at TRINITY (Unclassified). Col. Holzman assembled a small staff consisting of a deputy meteorologist, also from the Air Force, and assistants from the Navy and Weather Bureau.

The first task of the Staff Meteorologist was to survey the area for facilities for weather observation. Of the four stations in the [illegible] Kwajalein, Wake, Guam, and Johnston Island [illegible] only those at Kwajalein and Wake were considered close enough to be of [illegible] use in forecasting for the purposes of the operation. It was accordingly decided to augment the facilities at these and to establish additional stations at the nearby atolls of Rongerik and Majuro as well as at Eniwetok itself. Each of these stations would provide a minimum of four rawinsondes (radio and/or radar wind, temperature, and humidity soundings) per 24 hours. All these stations would participate in a weather observational network, and in addition Kwajalein and Eniwetok would provide local forecast and briefing service. Equipment and trained personnel for the stations was provided by the Air Weather Service, which organized four Mobile Weather Units. They arrived at their destinations and began operations late in February.

It was also decided that aerial weather reconnaissance would be necessary, particularly for increasing the density of the network, tracking the atomic cloud, and assisting in certain phases of a related Operation At first it was thought that three or four B-29's flying simultaneous missions over different tracks, would be sufficient, but at the suggestion of the Chief, AWS, the number was increased by assigning the 514 Weather Reconnaissance Unit, operating eight B-29's, for the duration of SANDSTONE. Because of the season, the squadron, whose normal mission was typhoon reconnaissance, was currently available. For the duration of the operation the squadron transferred to Kwajalein, arriving there 10 March 1948. The Air Weather Unit was organized as Task Unit 7.4.4.

The major ships of the task force flotilla--the <u>Mount McKinley</u>, <u>Curtiss</u>, <u>Albermarle</u>, and <u>Bairoko</u>--were also equipped to serve as surface observational stations. Soundings were rotated among them to provide for a total of four rawins (radar wind soundings) and four radiosondes in the test area. The <u>Mount McKinley</u> served as weather center for the entire weather network--afloat, ashore, and in the air. Here reports and other data was compiled and analyzed to provide the final forecasts.[22]

Several factors combined to make such an elaborate forecasting system necessary. Since tropical weather is characterized by many vagaries and its mechanisms are incompletely understood, forecasts for periods beyond 24 hours cannot be prepared with any considerable degree of accuracy, particularly in regard to the detailed information on the structure of winds at various altitudes and on cloud patterns which was desired. The wind structure was the most important single requirement, as this determined whether the detonations could be safely conducted. Precipitation over the target area would jeopardize a number of the radiological tests planned, and an excessive number of low lying clouds would of course interfere seriously with aerial photography. Even with the extensive network employed, the preparation of the type of forecast necessary was essentially a carefully chosen gamble. Only in the case of the Y shot was a postponement necessary, this being for 24 hours, and the detonations took place under generally satisfactory conditions. It may be noted that the operation of the meteorological net was considerably handicapped by the location of its headquarters with limited quarters and facilities aboard ship, with resulting communications delay.

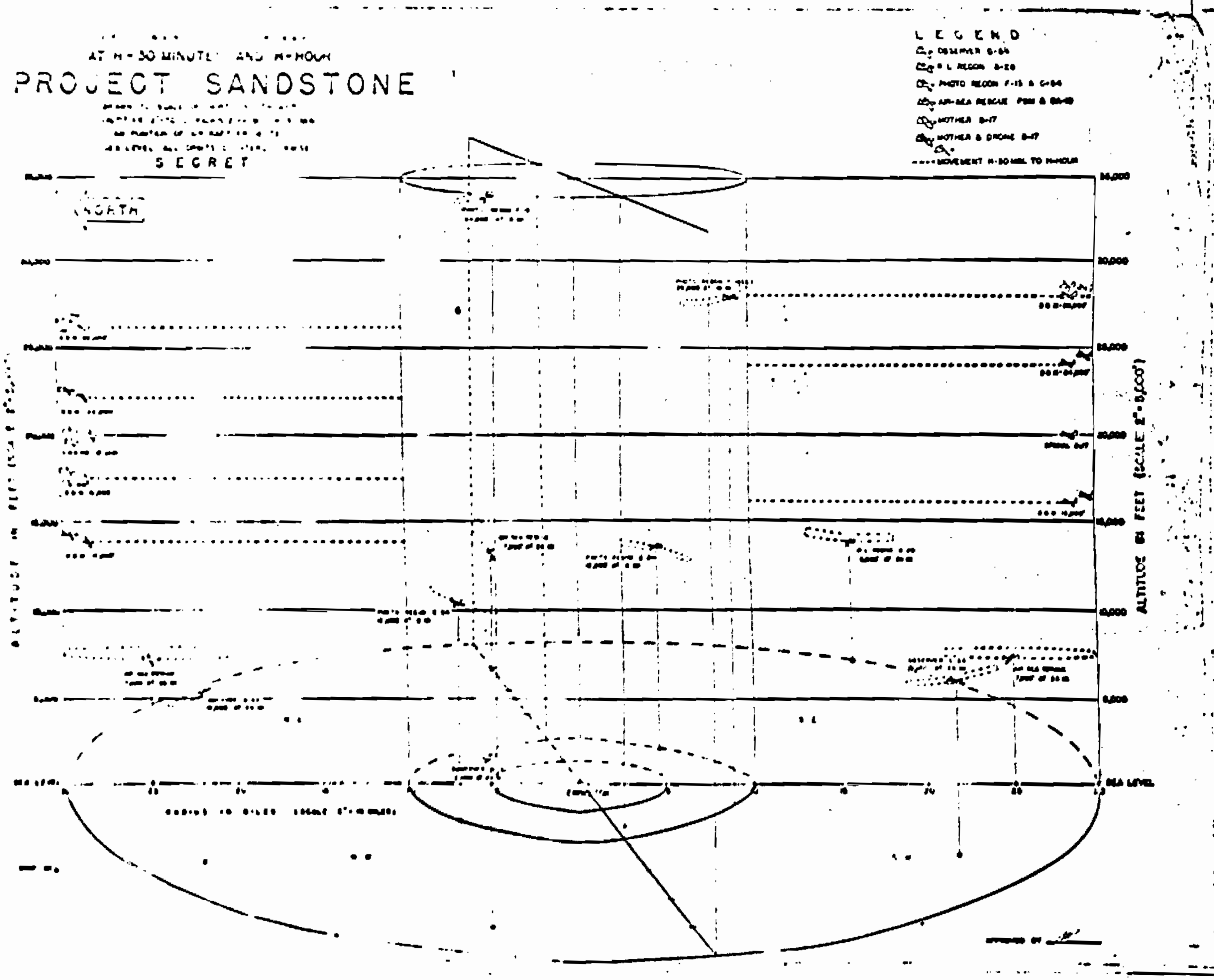
Cloud Sampling and Blast Acceleration Tests by Drone Aircraft

The need for drone aircraft to perform cloud sampling was stated by Chairman Lilienthal of the AEC in his letter of 26 July to the Military Liaison Committee as one of the seven principal types of support required from the National Military Establishment. Although the Navy had also operated drone aircraft at CROSSROADS, this

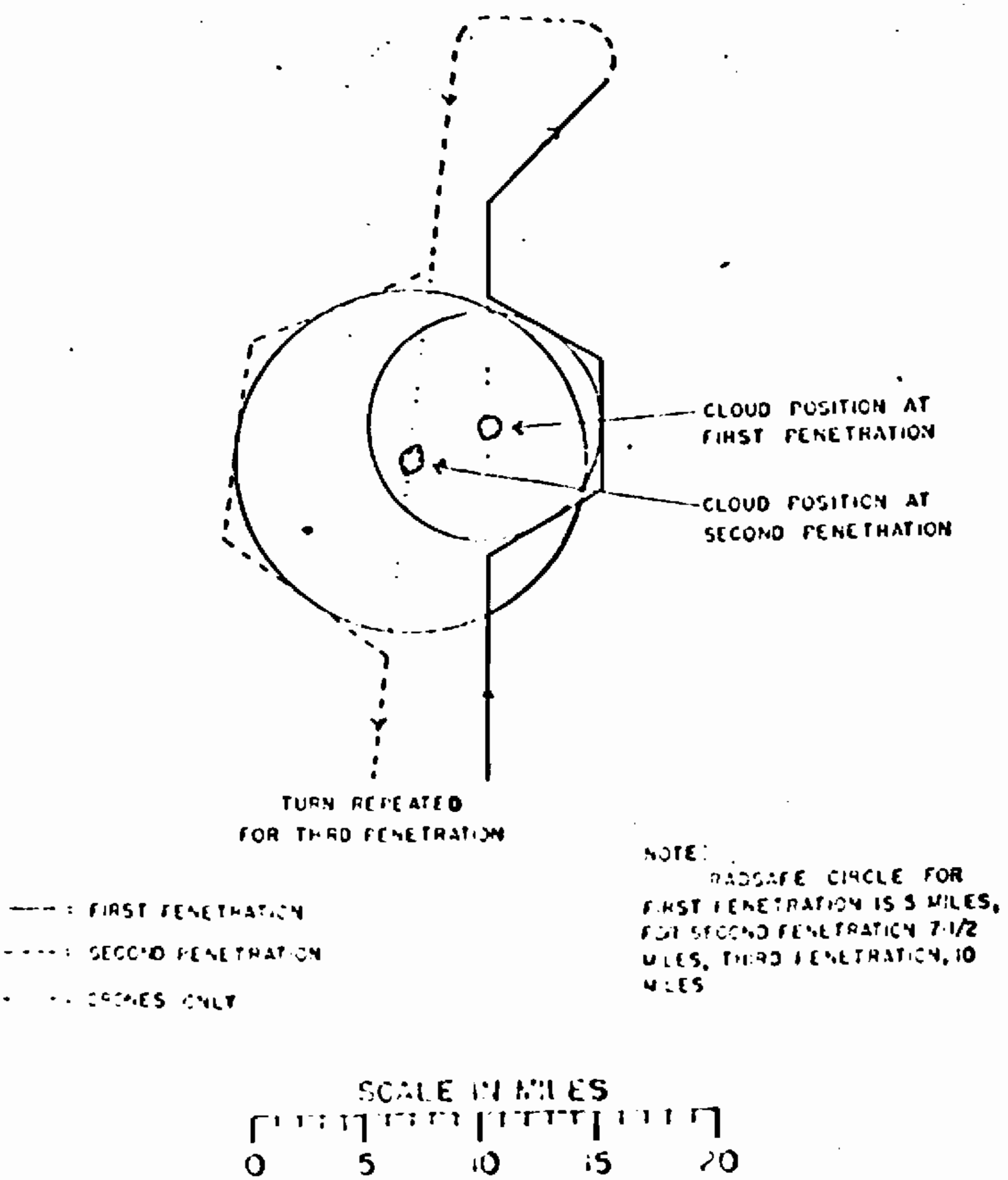
AT H-30 MINUTES AND H-HOUR

PROJECT SANDSTONE

SECRET



FLIGHT PATTERN USED FOR SUCCESSIVE DRONE PENETRATIONS OF CLOUD



requirement went to the Air Force for fulfillment. Headquarters, USAF, having received word of the probability of a drone requirement for the proposed atomic operation, took steps in July to investigate capabilities in this field. The 1st Experimental Guided Missiles Group had been maintained at the Air Proving Ground as a drone aircraft unit since its participation in CROSSROADS, operating B-17's. Since it was quickly determined that use of B-29's would require at least two years of development, the continued use of the B-17's and their related control equipment became mandatory.

The AEC had mentioned a need for eight drone aircraft, each of which would carry two filters each, of the same type used at CROSSROADS. This reflected a belief that operation of one drone at each 2,000 foot level from 14,000 to 28,000 feet, with three passes by each aircraft, would be desirable. As a result the Air Force requirement was first set in August at ten drone and six control planes (mothers). This would allow for two spares of each type. By December this had been raised to 12 of each type, and later it was increased to 15. This reflected a feeling that the limited maintenance facilities, complex electronic equipment, long flights over water, and operations during darkness, might result in a considerable rate of attrition.[23]

Although the 1st Guided Missiles Unit had a few planes, most of the drones and control planes had to be specially modified by the Air Materiel Command. The last of these were delivered on 5 March. The drone organization had meantime become part of the Air Task Group as Task Unit 7.4.2. It was at first planned to operate the drone unit entirely from the Air Task Group base on Kwajalein, some [illegible] miles from the target point; however, the insistence of the [illegible] Unit on the speedy removal of the filters led to a decision to [illegible] the drones on Eniwetok immediately after the flights, while the mothers returned to Kwajalein. Later it was decided to have the drones flown to Eniwetok on the day before each test and take off from there as well. The drones were flown off and landed by land based equipment, while they were controlled during the remainder of the flights from the mother planes.

Air filters with special filter paper were installed on the top and bottom of the fuselage of each drone. These were serviced by personnel from the Scientific Unit of Task Group 7.1. In addition, flight analyzer equipment and radar altimeter cameras were placed on all drones. At the suggestion of the Air Force, blast acceleration tests had been included in the military test program, and special equipment was installed on four of the drones for this purpose. This consisted of AFS-10 scope cameras and a 14 channel oscillograph which recorded readings from 5 strain gauges, 8 pressure gauges, and 1 accelerometer.

Drone operations began with the take-off of the mother aircraft from Kwajalein shortly after midnight on the test days. Drone take-offs got under way at Eniwetok at 0300 hours, spaced approximately 20 minutes apart. After being picked up by the mother planes the drones arrived on station before H-hour minus 30 minutes. Four of the drones were placed on the south side of the Zero point at 14,000, 18,000, 22,000, and 26,000 feet; and the other four were placed on the north at 16,000, 20,000, and 24,000 feet. All were directed into the atomic cloud for 3 passes, each beginning 5 to 10 minutes after detonation. Visual means of control were essential, and this forced a nice timing of the shots, since darkness on the ground was required by certain AEC experiments. A time of 43 minutes before sunrise, which was approximately five minutes before dawn (on the surface), was determined on, as this would provide sufficient light at higher altitudes along with darkness at the surface of the earth. The three penetrations by all the drone planes were completed within 40 minutes after the shot. Manned planes observed successive radiological safety circles of 5, 7½, and 10 miles during the 3 passes by the drones, which were first directed into the cloud and then picked up on the other side by the mothers, which had followed prescribed courses around the cloud. The drones were then conducted to Eniwetok, where they were landed by ground control teams.[24]

On Y Day the drone at 20,000 feet, which carried blast acceleration test equipment, was moved to 30,000 feet to make a simulated bombing run, timed to coincide with the time of detonation. On Z Day a similar run was made at 20,000 feet. No damage was sustained on either flight.

Photography

The AEC letter of 28 July to the MLC had requested establishment of a military unit to accomplish "high speed and general photography," and by August there appears to have been unofficial agreement that this requirement was reflected in the designation of a Staff Photographer for the proposed Task Force--Brig. Gen. Paul T. Cullen, USAF, who had served as head of the AAF photographic unit at CROSSROADS. He was charged with coordinating the activity of the various photographic units, providing plans for accomplishing the photographic mission, monitoring execution, personnel procurement, security coordination, and the procurement of technical equipment and supplies. At CROSSROADS, the Navy had held responsibility for the [illegible] [illegible] photography and a Naval officer, Admiral Quackenbush, had served as Staff Photographer. The assignment to the USAF of full responsibility for the photographic coverage of SANDSTONE represented an effort to completely unify this function under one service.

The photographic assignment thus handed to the Air Force had four principal phases: technical photography for measurement, technical photography to illustrate scientific reports, documentary photography to portray the sequence of events and method of accomplishment, and identification photography for security. The latter assignment was later turned over to the J-2, JTF-7, but the accomplishment of the other three was enough to severely tax the resources available. Eventually it was necessary to turn over the technical photography for scientific measurement to Task Group 7.1 (AEC), with which close coordination was maintained on all phases.

The photographic principal operational unit was established as Task Unit 7.4.3. However, instead of a close vertical organization of all functions under this designation, four types of operating organizations were set up, a decentralized pattern with an aerial photographic unit, an organization to install cameras and timing equipment in photographic towers, technical and documentary teams, and an emergency film-processing laboratory. These collaborated in carrying out the three principal phases of the photographic mission. While a vertical organization would have made for easier administration, it was considered that the organization followed made for greater functional efficiency. The greater part of the personnel and equipment was drawn from the 311th Air Division of the SAC, of which Gen. Cullen was commander. This did not, however, entirely fill the need, and a number of technicians were supplied by the Army and Navy to alleviate the shortage of skilled personnel, in addition to 24 men employed on a temporary basis by the AEC from among ex-service civilian specialists by means of a contract with the University of California. A large quantity of photographic equipment was also purchased by the AEC at the request of the Air Force for the specialized purposes of the operation.

The air photographic unit (TU 7.4.3) was modeled closely after the AAF unit at CROSSROADS, and employed the same aircraft--two C-54's and three F-13's, plus one F-13 as an operational spare. Formed from a section of the 16th Photo Reconnaissance Squadron (Special) of the 311th Air Division, SAC, it was based on Kwajalein, from which were launched all its operations. The primary mission of the air unit was to photograph the detonations and resulting visual phenomena, principally to determine the scope and nature of the blast, with documentation as a secondary aim. The photographic planes were equipped with nearly all current types of specialized aerial cameras, as well as with professional type motion picture cameras, a total of 112 cameras being used in the five aircraft. Coverage was provided for in both black and white and in color, and speeds ranged from 2,000 frames per second in the Eastman cameras to one every three seconds in the K-18 camera. The two C-54's orbited counterclockwise around the target at an altitude of 12,000 feet and slant range of eight miles. Two of the F-13's (modified B-29's) orbited at an altitude of 20,000 feet at a slant range of eight miles, while the remaining one flew a holding pattern at one side at a similar range.[25]

A special group was established to equip and service the four remotely controlled photographic towers which provided the means of covering the detonations from the ground. Although nominally a part of Task Unit 7.4.3, it worked closely with Task Group 7.1, since satisfaction of this requirement was of extreme interest to the AEC. One tower, mounted on a coral head in the lagoon, provided coverage of all three shots, while each of the other three provided coverage for a particular shot. Principal reliance for the technical aspects was placed on Fastax cameras, which provided a speed of from 9,000 to 12,000 frames per second. Additional coverage was obtained from high-speed motion picture camera and aerial still cameras, providing a wide range of luminosity and speed, so that even a low-order detonation would be recorded. All were operated automatically by means of relays and submarine cables. Thirty cameras were mounted in each of the towers, which were located approximately five miles from the target point. In order to save time and insure effective operation, a detailed mock-up of a photo tower was constructed at Eglin Field and tested to eliminate electrical and mechanical defects in the control system.

Seven documentary photographic teams were also organized as units capable of performing all types of service on the ground. Each was equipped with professional type 35 and 16 millimeter motion picture cameras, a hand-held motion picture camera, a standard type press camera, and a large portable view camera. The crews, consisting of six persons except for one sound crew of eight, were assigned to the particular task groups with whose activities they were most directly concerned. Although this arrangement appeared logical, it led to controversy for two reasons: the teams remained under the operational direction of the Staff Photographer despite the fact that Field Order No. 1 had made the Test Director responsible for all technical photography and for the documentary coverage of the activities of Task Group 7.1; differences of opinion developed between the members of the AEC Task Group and the photographers themselves in regard to the scope and manner of the coverage. The difficulty was resolved, at least in part, by the concession of complete control of the three teams assigned to Task Group 7.1 to the Test Director. It was also agreed that technical photography for scientific measurement would be entirely handled by members of the Task Unit 7.1.1 (Scientific).

It was decided as a policy at the beginning that the logistical phase of photography, particularly the development of film, should be reduced to a minimum. It was therefore planned to process most of the film in the United States, at two points--Bolling Field, Washington, D. C., (10th Photo Technical Squadron) and at Los Angeles (Consolidated Film Industries and Eastman Kodak)--where the film would be quickly transported after the shots. For emergency processing a laboratory was equipped to make prints up to 8 by 10 inches aboard the USS Curtiss. Some difficulty was experienced in finding a suitable place for carrying out the complex cutting and editing operations on the motion picture film. After some delay a nearly ideal location was found in the Air Force Plotting Station at Lookout Mountain, Los Angeles, California. This installation, which had been declared surplus, was reactivated and renovated for use. It was to become a permanent center for such activity within the Air Force. All film was processed under the security supervision of the AEC.[25]

The photographic mission, although it was successfully carried out, occasioned the greatest amount of dissatisfaction of all those undertaken by the Air Force. Throughout the operation serious difficulties revolved around the selection of photographers, differences between photographers and scientists, shortage of proper equipment, and alleged lack of advance planning and proper instructions to personnel. As has been seen, this function was among the types of support specifically requested by the AEC of the military services and was assigned by them to the Air Force. Because of the various types of photography necessary and the lack of contact by the Air Force with atomic development work, it appeared mandatory that a vertical type of organization not be established but that the photographers work in close contact with the scientists and technicians of Task Group 7.1. The situation was further complicated by the shortage of qualified military photographers and the necessity of hiring a number of civilians on a temporary basis. The Air Force also did not possess much of the high speed and precision type equipment necessary, and although the AEC did procure it, maintenance of the unfamiliar equipment and some shortages continued to be a problem.

Serious differences also appeared to exist in regard to aims and objectives. The AEC was most concerned with technical photography, while the requirement for documentary photography was largely developed by the military services. As the operation progressed increasing concessions from the principle of unified control were made to alleviate specific complaints. In cases where the accuracy of measurements depended on close control of photography or processing, agreement was reached that scientists would do their own work, including development and enlarging. Each request to perform measurement photography was, however, treated on its own merits. Complete control of three photographic teams working with Task Group 7.1 were also yielded to the Test Director by the Official Photographer on arrival at Eniwetok, so that the principle of unified direction was virtually dispensed with. From the viewpoint of the Test Director this apparently did not improve matters, as he concluded, "Confusion, loss of time, waste of effort, general misdirection, and bickering resulted from the divided responsibility for photography..." He went on to recommend that for future operations the AEC "establish its own photographic organization over which it should maintain complete control and direction." He also looked askance at the aerial photography, stating: "As a documentary implement [it] appears to have been inessential and, inasmuch as no technical benefits were derived, does not appear to have been worth the cost." Among other complaints, he asserted that the photographers had not been given proper instructions and as a result failed to understand the need for many requirements, and that the still photography had not been used primarily for technical coverage, but mainly for photographs of personnel. In these viewpoints he was generally supported by the Scientific Director.[27]

Miscellaneous Requirements

The most important of the minor responsibilities assigned to the Air Task Group was probably the provision and operation of air rescue facilities within the operating area for Joint Task Force Seven. To perform this service the Air Transport Command provided suitable aircraft and operating personnel from its Air Rescue Service--these consisting of two B-17's, lifeboat equipped, and two

OA-10's, capable of water landings. This operation was organized as Task Unit 7.4.5. Since the Island Commander, Kwajalein, who also functioned as head of Task Group 7.7, was already conducting an air rescue service in the Marshall Islands area, coordination was necessary. Under the arrangement agreed on the above aircraft passed under the control of the Commander, TG 7.7, for operational control except on test days, when they returned to the control of the Air Commander. During the pre-dawn operations on test days two PBM's also were placed under his control, after dawn reverting to anti-submarine patrol.

Although the Air Task Group was not assigned responsibility for communications (other than its own) more than 200 Air Force personnel organized as Task Unit 7.4.6, participated in communications, to which they made an important contribution. The core of the unit had been in place on Kwajalein, but was augmented by additional personnel from the ATC. Facilities were installed on Eniwetok for communications with the long-range weather reconnaissance aircraft, radio-teletype intercept of the Guam Weather Broadcast, and weather reporting circuits from Rongerik, Majoro, Wake, and Kwajalein. Facilities were set up on the task force flagship for both very high frequency and high frequency voice communication with all aircraft in the test area. Radar beacons were installed on Kwajalein, Eniwetok, [illegible], [illegible], and [illegible] to assist the drone unit in navigational problems. Other navigational aids included standard airway and aerodrome control facilities on Eniwetok and Kwajalein.

A special support mission performed by the Air Force was to provide a C-47 aircraft for the use of the Joint Radiological Safety

XVII 33 Group (7.6) in making an aerial survey of ground contamination by the blast on target islands. The tests indicated that measurements of contamination could be made from such standard aircraft with sufficient accuracy to determine the safety of ground operations. This plane took off from Eniwetok at H-hour plus 30 minutes for its mission of radiological survey.[28]

Operations on Test Days

The principal instrument of control for the Air Commander on test days was the Combat Information Center on board the *Mount McKinley* and the attendant communications network. Operational control of the center passed to the Commander, Air Forces, JTF-7, with the entry of the ship into Eniwetok Lagoon. Previously it had been used by the Navy Task Group Commander for tracking and identifying all surface ships and aircraft encountered during the voyage to the test area, and for issuing orders and maintaining radio contact with the planes providing air cover.

The mission of the Combat Information Center on practice and test days was to plot the exact position of all aircraft participating in the operations. All aircraft checked in to the Center by radiophone at a distance of 100 miles from Eniwetok, and all further communications necessary to the operation were disseminated from this point. Prior to H-hour minus 30 minutes all aircraft made on-station reports to the Center, and this information was checked by means of a Model SK radar set (for picking up all aircraft and determining its bearing and range from the Zero point) and a Model SP radar (for determining the altitude of all aircraft entering the test area). All aircraft of the drone units orbited in their assigned sectors, either 21 miles north or south of Zero point in a counter clockwise direction, spaced by 2000 foot intervals. Aircraft with assigned altitudes divisible by four orbited to the north of Zero point. All photo aircraft, air-sea rescue planes, observer aircraft, and command aircraft also orbited in their assigned sectors, and at four minutes prior to detonation a report was made to the Air Commander that all aircraft were on station.

The position of drones was closely followed by the control planes and the Combat Information Center. Each mother and master mother aircraft was provided with the AN/APS-10 radar set, while radar beacons were placed on the four specially equipped drones as well as on Eniwetok and the target islands. Radar scope camera on the control planes were used to record the position of the drones, and the SK radar screen operated by the Combat Information Center was also photographed for the same purpose. As previously noted, drones were first landed at Eniwetok after the shots for removal of filters and decontamination (by washing with distilled water), and then flown manually to Kwajalein.[29]

Operations for X Day were simulated with such success on PX Day, 8 April, that it was decided to cancel the previously planned rehearsals for X, Y and Z Days. The aircraft simulated without major difficulty the five distinct principal air missions for X Day as follows: collection of air samples and blast data by the drones, aerial photography for documentary coverage and collection of scientific data, collection of meteorological data and tracking of the atomic cloud by the weather aircraft, collection of certain scientific data by helicopters after the blast, air-sea rescue service.

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H-hour for X Day was scheduled for 0617 on 15 April, and at the briefing at 0445 the final decision to go ahead was given by Gen. Hull. Although there was a possibility of precipitation causing a heavy rain-out of radioactive particles, the winds were such as not to menace later target or control areas. Surface winds were easterly with a velocity of 11 knots up to 10,000 feet. From this point to 25,000 feet winds were southerly with a velocity of 17 knots. From here to 60,000 feet winds were westerly with a velocity of 20 to 30 knots. There were scattered rain showers over the target area from 0600 to 0618.

Air operations on X Day proceeded according to plan with the following exceptions: (1) Imitation 2, a weather aircraft (B-29), lost a propeller and was directed to return to Kwajalein, where it was accompanied by one of the air-sea rescue planes; (2) a drone aircraft (B-17), operating at 14,000 feet, was lost when it failed to respond properly to signals from the mother plane and dived into the ocean; (3) the drone aircraft at 18 and 20 thousand feet were unable to make the third penetration of the atomic cloud when a shear effect developed which left no visible remains of the cloud at these levels.

In general, air operations on X Day were considered to have been highly successful. Samples collected by the drones were of much greater strength than those collected on CROSSROADS. Photographic operations were likewise regarded as successful in both the technical and documentary phases. Although there was operational failure of certain types of cameras, at least 85 per cent operated successfully. The meteorological unit obtained detailed information on the nature of the atomic cloud despite the temporary loss of one of its planes. The helicopter operations by Task Group 7.3 under over-all direction of the Air Commander were unsuccessful in both the pickup of radiological samples from the lagoon and the collection of earth samples from the target area. The blast had destroyed the pick-up devices for the samples attached to buoys in the lagoon, and the drone tanks were unable to make a successful penetration of the bomb crater. As planned, the radiological test samples from the drone aircraft and the photographic film were returned to the United States by three C-54's, these departing within 24 hours.[30]

The test on Y Day was held at 0609 on 1 May, after postponement from the original date of 30 April. The postponement resulted from the development of a wind structure unfavorable to radiological safety. At 1100 on 30 April weather conditions were pronounced satisfactory and Gen. Hull decided to proceed with the test on the following day. They continued to improve until shot time, when they were nearly ideal. Between this point and 22,000 feet the winds were southerly with a velocity of 16 knots. From here to 50,000 feet the winds were westerly with an average velocity of 36 knots.

Air operations were similar to those on Y Day with the following exceptions. The drone at 20,000 feet was removed from the pattern, placed at 30,000 feet, and directed so as to simulate a bombing run over the target point timed to correlate with the detonation. This placed the drone almost directly over the explosion and permitted a successful vertical photograph of it. The plane was landed without attempt to penetrate the atomic cloud for radiological samples after it became erratic in handling, apparently as a result of the blast. The 20,000 foot drone was selected because the sheer effect in the cloud on X Day had seriously affected its function of collecting radiological samples.

Air operations proceeded on schedule without major interruptions, and results were even more satisfactory than on X Day. The drone scheduled to fly at 24,000 feet had to be replaced by a spare when a tire failed on take-off, but this resulted in no serious delay. The samples collected by the seven drones which penetrated the atomic cloud were declared to be from 15 to 75 per cent stronger than those from X Day. The photographic units were able to attain an effective operational rate of 90 per cent for the cameras, an increase of five per cent. Helicopter operations were also successful. Samples were picked up from the lagoon, and a controlled penetration of the bomb crater was made by the second drone tank after the first tank had become inoperative.[31]

The test on Z Day was held as scheduled on 15 May 1948 at 0604, the weather outlook having improved steadily during the three days preceding. The wind structure was less complex than for the first two tests. Surface winds were again easterly, with a velocity of eight knots, extending to 5,000 feet. From this point to 45,000 feet winds were westerly with an average velocity of 31 knots.

Air operations were similar to those on the two preceding shot days with the exception of a few changes in the placement of drones and photographic planes. As on Y Day a simulated bombing run was made by a drone to correspond with the point and time of the detonation, but the altitude was reduced from 30,000 to 20,000 feet. It was also accompanied by a manned B-17 on a parallel course at 35,000 feet slant range from the Zero Point. The three aircraft at 20,000 feet (drone, mother, and manned B-17) were all specially equipped to record shock wave data and for photography. All photographic aircraft were moved in to a slant range of eight instead of ten nautical miles.

All aircraft completed their assigned missions successfully except those participating in the simulated bombing run. The mother plane had difficulty with the AN/APS-10 radar set and was unable to locate itself accurately in relation to the Zero Point. The simulated bombing run was aborted, but the secondary mission of obtaining radiological samples of the cloud was accomplished. All drones succeeded in making three penetrations of the cloud, and the samples obtained were said to be better than any previous ones. Shock wave equipment aboard three of the drones also functioned very successfully. Cameras were reported by the Staff Photographer, JTF-7, to have attained an operational rate of 97 per cent. Helicopter operations were also successful, although the drone tank again became inoperative in the crater and it was necessary to call on the spare.[32]

Summary and General Comments

At the conclusion of Operation SANDSTONE it could be reasonably concluded that the Air Force had creditably fulfilled the basic requirements assigned it by the Joint Proof Test Committee. In the drone operations a high degree of efficiency had been displayed, and the air transport and meteorological aspects had been more than adequately handled. Only in the case of photography did serious criticism result, and even here it could be said that the basic

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requirements had been met, though not with the smoothness and efficiency which might have been desired. It was certainly true that the highest degree of efficiency had been shown in the specialized services which already existed within the AirForce and could be readily adapted to the purposes of the operation, as for instance the long-range air transport, meteorological, and air-sea rescue services of the ATC. Fortunately, also, an operational drone unit, the 1st Experimental Guided Missiles Squadron, had been maintained since CROSSROADS, and although it was necessary to manufacture new equipment and train additional personnel, the organizational patterns and operational experience were already available. The photographic requirements, on the other hand, were exceedingly complex, necessitating the procurement of very large quantities of new personnel and and equipment, and although the assignment of the responsibility for photography to a single service was logical, there was insufficient time to meet in every detail the requirements with the comparatively limited resources available.

Although the newly autonomous Air Force had successfully met its comparatively limited requirements, some high officers who participated in the operation pointed out that the role of the Air Force had been limited to air operations in support of AEC requirements and complained that its direct participation, for instance in the research program, compared poorly with that of its two sister services. Since SANDSTONE had weapons development as its primary aim, this was not reassuring. These officers believed that the deficiency of the Air Force in atomic weapons development--its limitation to the role of weapons delivery--had appeared during CROSSROADS and that the conclusion was inescapable that inadequate action to correct this situation had been taken.[33]

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CHAPTER XVIII

MILITARY RESULTS OF OPERATION SANDSTONE

Objectives

As has been observed, the origin of Operation SANDSTONE (Unclassified) was determined by three factors: (1) continued experimentation at Los Alamos Scientific Laboratory directed toward the development of improved types of atomic bombs and the increasing necessity for putting experimental designs to a practical test; (2) the continued production of fissionable material of two types in increasing quantity and the need for determining the relative degree of emphasis to be given to each phase; (3) the increasing size of the stockpile of atomic bombs and the need for determining what types should be stored in quantity. Accordingly, the main objectives of the tests were later stated by the Los Alamos Scientific Laboratory, which had originally requested them, as follows:

1. To improve the short-range military position of the nation through testing models which may rapidly become stockpile items; and

2. To improve the longer range military position by obtaining information from the behavior of particular models which will lead toward the design of more efficient and more useful weapons.[1]

Prior to Operation SANDSTONE four implosion-type bombs had been detonated--one each at TRINITY (Unclassified) and Nagasaki, and two at CROSSROADS (Unclassified)-

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herent inefficiency of this type of detonating technique, coupled with the fact that approximately three times as much fissionable material was needed to create a critical mass, militated against its further development except for such limited purposes as a penetrating weapon or for delivery by smaller planes. At the same time it was necessary to consider that it was possible to produce approximately 10 times as much U-235 per ton of uranium ore in the K-25 plant at Oak Ridge as plutonium in the Hanford plant, and the actual production ratio between the two was approximately 8 to 1.* It was therefore highly desirable to utilize the U-235, especially since the amount of workable ore in prospect was regarded as definitely limited. To meet this situation a composite core

had been developed and was being stockpiled at the end of 1947 for use in the Mk III implosion-type bomb. Although there was little doubt that this weapon would function, there was still a large excess of U-235 to be considered.

but the percentage of plutonium needed to achieve maximum effect was not known. Consequently, the composite cores being stockpiled might be unduly wasteful of the scanty plutonium production.

In addition to the accomplishment of the primary objectives of the tests, it was obvious that they would provide the opportunity for making observations for a number of secondary purposes. One series of these was the 11 military service tests which have been mentioned in the previous chapter. The atomic detonations also provided the opportunity for the Air Force to carry out an extensive group of observations and experiments which provided much of the basis for establishing a system of long-range detection.[2] A third series of experimental observations was established and carried out by Task Group 7.1 (AEC) in order to collect further data on the characteristics of a nuclear explosion, since many associated phenomena were still only imperfectly understood. It was expected that this would provide data directly useful in the further development of nuclear weapons as well as in the advancement of nuclear physics.

The latter series of experiments will not be described in detail here since they concerned the research and development work of the AEC rather than that of the Air Force. A condensed review, however, will be given. One group centered around the development or improvement of methods of determining yield and efficiency. It was proposed to attempt to improve the method of subjecting collected fission products to radiochemical analysis, the principal procedure previously employed, by use of a radioactive tracer. It was also desired to test other methods of determining yield, especially since the radiochemical method was complicated, expensive, impracticable under combat conditions, and possibly unsuited for determining the yield of an atomic weapon based on a thermonuclear reaction.

A second group centered around the obtaining of more detailed data on the development of a nuclear explosion in its earliest phases, including the implosion phase and the very early nuclear reaction. It was hoped that this would not only lead to the design of more efficient fission-type nuclear bombs, but also that it would lay the groundwork for early testing of the fusion principle. By obtaining the high energy neutron spectrum from a fission bomb this could be used as a basis for comparison with the spectrum developed from a test fission bomb

A third group dealt with the more distant phenomona relating to an atomic explosion. This involved the measurement of the intensity, duration, and absorption over various distances by sea-level atmosphere and by other substances of the light, heat, neutrons, and gamma rays produced by the explosion. It was also intended to determine the total energy released by each bomb, and to tabulate other details about the blast wave, the heat and light radiation, and the gamma and neutron radiation. It was hoped, among other things, by this means to arrive at a more accurate statement of the magnitude of atomic bomb explosions in terms of equivalent tons of TNT.[3]

<u>Selection and Description of Bombs Tested</u>

all bombs detonated during Operation SANDSTONE were essentially identical, and all were detonated from 200 foot towers located on various islands of the atoll. The three explosions, in chronological order, were designated X, Y, and Z (or X-Ray, Yoke, and Zebra).

Since one repeat was desired for the initiator test, a full program would have provided for six shots. This, however, was regarded as quite undesirable because of the limited space at Eniwetok, great monetary cost, and expenditure of fissionable material required; and some

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satisfactory alternative was sought for. Although admittedly this, a three shot program was selected.

Efficiency of Bombs Tested and General Conclusions

The relative yields of the bombs were determined by six different basic methods as follows: (1) the intensity of gamma radiation; (2) intensity of fast neutron radiation; (3) intensity of heat and light radiation; (4) peak pressure and impulse as functions of distance from the explosion; (5) characteristics of the growth of the fire ball; (6) radiochemical analysis of fission products. Since a high degree of precision of measurement was not possible in any of the first four methods, they were regarded as rough. High-speed photography permitted, however, a rather precise determination of the characteristics of the growth of the fire ball, and this method was given considerable weight in determining relative values of yield for the three shots. This method offered promise for combat use, since its only serious limitation was that detonations must occur at altitudes exceeding 100 feet, permitting growth of the fire ball without excessive ground interference. It was believed that by the improvement of precision of measurement in the radiochemical method more accurate values of yield were obtained than ever before. By relative methods based on photography, these were also applied to the shots at TRINITY and Bikini-Able, where a good photographic record was made and corrected values obtained.

The table below gives the values calculated for the SANDSTONE detonations, the old values for the TRINITY and Bikini-Able explosions, and the new values derived by comparative methods for these:

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surements of transit times* also agreed with predicted values, indicating that the bombs were representative of their classes. (2) A large mass of data was accumulated on the effects of different amounts of tamper which would make it possible to deal with this factor in design more accurately. (3) Several new methods of determining yield were calibrated, and the Teller method of measuring (by gamma ray fluorescence of air or napthalene) rate of increase of nuclear reaction (alpha) was found to be feasible. (4) Much additional data was accumulated on the gamma, neutron, light, and heat radiation; however, because of loss of energy to the ground resulting from the low altitude of burst, the formation of a Mach stem, and other complications, it was possible to obtain only a rough approximation of the proportional distribution of energy into the various forms. The same factors operated to prevent accurate measurement of blast characteristics. (5) The new designs for bomb components were tested and performed as expected.

* Transit time is defined as "the time interval between the surge of current in the detonators and the arrival of the shock at the initiator." This is actually measured as the interval between the surge of current in the detonators and the first indication of the nuclear reaction.

success to record the rate of growth of the fire ball and of the spread of the shock wave in both air and water. These measurements were applied to the determination of relative yields with some success. In most other respects the technical photography was considered to be disappointing.[7]

Military Service Tests

The military service tests were carried out as incidental to the proof test program. They were screened by the Joint Proof Test Committee and arranged so as not to interfere with the primary experimentation. In general, they were designed to answer practical questions which might influence military operations. Nevertheless, the value of most of them, as well as some of the techniques employed to carry them out, was questioned by the leaders of the Scientific Test Unit.[8]

Service Tests 1, 2, and 3 were requested and conducted by the Corps of Engineers, United States Army. They involved the construction and exposure to the effects of Shot X of 5 structures and consequent examination of results. Two of these, placed respectively at 1,000 feet and 1,500 feet from point zero, were constructed with walls of reenforced concrete 2 feet thick. Two others were similarly constructed with 1 foot walls and placed respectively at 1,500 feet and 2,100 feet. An earth revetment, with walls stabilized by a concrete mixture, was also constructed at 2,500 feet. The object of the latter test was to study the shielding effect exerted by such a structure on the blast, and for this purpose measurements were made by the team from the Naval Ordnance Laboratory. Basically similar in nature was Service [illegible], requested and conducted by the Navy

Bureau of Yards and Docks, which consisted of constructing some 175 structures and exposing them at various distances up to 5,000 feet from Point Zero for both X and Y shots. Except for two small timber structures and a Quonset hut these were made of reenforced concrete in various shapes, and were approximately four to five feet in height and diameter. Although the principal aim was to observe the effects of blast, film badges were placed in many of these to record the effect of penetration by gamma radiation.

Various degrees of damage were suffered by the structures, but a serious omission made the tests of little value in providing guidance for the design of structures to resist an atomic explosion. The concrete structures were unanchored, with the result that they were carried along by the wind accompanying the shock wave. Much of the damage resulted from this violent movement, and the structures did not experience the same static pressures which they would have endured if anchored. The essential result was only to show that the structures moved about as expected. The earth revetment study was also inconclusive, indicating only that, as expected, some sort of shadow effect resulted. It was, however, concluded from examination of film badges placed in the structures that two-foot-thick concrete walls would be ineffective in reducing to a sub-lethal dose the effect of gamma radiation from explosions such as Shot X at a distance of less than 750 yards, while walls of one-foot thickness would be ineffective at less than 1,000 yards.

Service Test No. 5 was requested by the Air Force and carried out by the Air Task Group. It consisted of making observations of the accelerations and strains to which four of the drone aircraft used for collecting radioactive cloud samples were subjected. Those were equipped with recording accelerometers, strain gauges, and recording peak pressure measuring devices. The position of the aircraft at the time of the impact of the shock wave was also determined by means of radar from ship-based stations and photography from automatic cameras in the planes themselves. It was hoped to obtain peak pressures unaffected by a nearby ground surface, as well as information which would be useful in aircraft frame design; however, according to the Scientific Director, the results were disappointing in the first respect.

Service Test No. 6, proposed by the Army Signal Corps, was actually a part of Operation FITZWILLIAM. It was conducted by the Signal Corps under the supervision of the Commander, Air Force, JTF-7, from stations at Eniwetok and Guam, and consisted essentially of attempts to detect the explosions by the increase in reflected light from the dark portion of the surface of the moon. Although described as visual observation, the tests actually employed cameras and photo-electric cells. Only the Y shot was detonated while the moon was in the sky, and it was obscured by clouds at the Eniwetok station. At Guam no increase in light reflected was detected as a result of the explosion.

Service Test No. 7, proposed by the Navy Bureau of Surgery and Medicine, was carried out by Task Unit 7.6.6 (Technical Measurement). It consisted primarily of the exposure of numerous small packets containing biological materials to the effects of the detonations. These materials included numerous types of seeds. In addition, containers for animals were exposed on land and on rafts in the lagoon in order to develop handling techniques for future tests, as well as types of containers offering protection from blast and heat.

Service Test No. 8 was first proposed by the Navy Bureau of Ships and later amplified by a proposal from the Bureau of Surgery and Medicine. Also carried out by Task Unit 7.6.6, it consisted of exposing a large number of small samples of various coatings for the purposes of determining the effects produced by radiation from the explosions and of developing means of decontamination.

Service Test No. 9, proposed by the Bureau of Ships and carried out by Task Unit 7.6.6, consisted of field testing and evaluation of various radiological instruments of new design. These included survey instruments of the ionization type as well as integrating dosimeters, and valuable information was obtained on field performance. An attempt was also made to correlate the amount of radiation with changes in color by various crystals and Vycor glasses, as a step toward the development of cheap and simple dosimeters. This experiment was preceded by very little laboratory experimentation, and as a result the data obtained was of slight value.

Service Test No. 10 was also proposed by the Bureau of Ships, USN, and carried out by Task Unit 7.6.6. It consisted of the exposure of film badges while sandwiched between small metal plates and concrete blocks in order to obtain shielding data on various types of material which might provide shelter for personnel. Later there was considerable question as to whether the data collected would be of any great value as far as calculating the effects of radiation within a particular structure, since conditions there would be influenced by numerous special factors, such as scattering effects, intensification by Compton electrons, induced activities, and other factors.

Service Test No. 11 was proposed by the Army Chemical Corps and carried out by the [illegible] Unit ([illegible]). This required the exposure of two field collector protective units (E24R1) for filtering the air admitted to two Type A, OCE structures which would be placed at 1,000 and 1,500 feet respectively from the X shot. Radioactive contamination of the air would then be measured by recording instruments. Later it was feared that the former unit would be seriously affected by the heat and blast, and it accordingly placed on an M-boat anchored in the lagoon. Unfortunately, this sank before the blast and the OCW building was so violently handled by the explosion that the motor operating the recording equipment failed to work. Accordingly, no results were obtained.

In addition to the above numbered tests officially screened and approved by the Joint Proof Test Committee a number of other tests of military significance were carried out. A series of these were   sponsored by the Air Force, for which SANDSTONE supplied nuclear explosions.[9] Task Unit 7.6.6 carried out several others which concerned various aspects of radiation measurement, including a study of residual contamination in the craters. This included observations of the beta and gamma intensities in the vicinity of the craters for several days following each explosion and observations of the gross decay rates of samples taken from the craters.[10]

The unit also carried out an aerial survey of ground contamination with a twofold objective: (1) to measure the attenuation by gamma radiation of the atmosphere above the contaminated area, and (2) to determine the feasibility of measuring ground contamination from the air so as to decide on the safety of ground operations. The results were too uncertain to satisfy the first purpose, but it was found possible to determine ground contamination with sufficient accuracy to determine the safety of ground operations, including a parachute landing.

Task Unit 7.6.6 also conducted an experiment to determine the particle size of materials in the radioactive cloud by measurements made by means of cascade impactors installed in the concrete structures of the Corps of Engineers and in the drone aircraft of the Air Task Group. These devices collected particles whose size was later determined by electron microscopes. The information, together with data collected on radiological fall-out, was believed likely to be of considerable value in radiological safety and defense.

Effects on Military Air Operations

As SANDSTONE was primarily a proof test operation, it might be well to consider the principal military results as they affected the Air Force. Essentially, the immediate result was to make possible within the near future a 63 per cent increase in the total number of bombs in the stockpile and a 75 per cent increase in the total yield of these bombs.*

all of which would be adaptable to the Mark III and Mark IV bombs.[11] The Air Force, supplied with a much larger number of bombs of various yields, could achieve much greater operational

*The increase in number of bombs would result from the improved usage of U-235, and the still greater increase in total yield would result from both this factor and improved technology.

flexibility and could also proceed confidently to expand its atomic striking force and prepare more detailed target plans. The first heavy blow had thus been struck at the doctrine of scarcity, which had strongly influenced Air Force strategic planning in the past. For instance, it was now possible to plan for a mass delivery of bombs at the outset of war, without feat of exhausting the stockpile. The soundness of the opposition of the Air Force to the further development of the gun-type bomb was also demonstrated, since the probability of delivery of an implosion-type U-235 bomb would have to be fantastically low for a gun-type bomb to be more economical of fissionable material.

In addition to the immediately applicable effects on the types of cores to be manufactured and the effect on the national stockpile, the way had been cleared for great improvements in bomb design, including the first steps toward the fusion bomb. It was forecast by the Scientific Director that the results of this increased knowledge of the fundamental processes in atomic explosions might exceed within a few years the direct effect on the national stockpile, great as this was.[12]

Although the results of the measurements of blast, heat, and radiation effects were not all that might have been desired, they also provided a considerable fund of information applicable to such matters as radiological warfare, aircraft design, and protection from atomic explosions, to add to the disappointingly scanty information collected from the air burst at Operation CROSSROADS. The three explosions had also provided the basis for conducting Operation

which the Air Force got under way just in time to take advantage of the tests. As a result an interim system of long-range detection was to be set up sufficiently effective to report on the first Russian atomic explosion in August 1949.

Finally, Operation SANDSTONE provided the first large-scale training in the complex activity of development testing of atomic weapons since CROSSROADS and the first since the establishment of the Department of the Air Force and the Atomic Energy Commission. Since all the bombs were exploded from towers and there were no operational drops, the participation of the Air Force was in a sense less than at CROSSROADS. Nevertheless, valuable training was secured, particularly in the type of cooperation among military and civilian agencies which had not become essential in the development of increasingly complex weapons. Although the accomplishments of CROSSROADS cannot be belittled, it was essentially a Navy show with the Air Force showing up in a somewhat embarrassing light in its principal operational role of dropping the bomb. At SANDSTONE the role of the Air Force continued to be secondary, with the AEC and Army units taking precedence. Nevertheless, the Air Force fulfilled certain vital technical requirements, particularly in providing means for study of the atomic cloud through the operation of drones and in meteorology. Its handling of the photography mission was the subject of severe criticism from the AEC representatives, and this seems largely to have been the result of the late start of the operation, failure fully to understand requirements, limited time for planning, and a degree of bungling in the handling of the security aspects. Although some blame must certainly be accepted by the Air Force, most of these matters were beyond its control. On the other hand,

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its success in carrying through Operation under difficult circumstances as an auxiliary series of tests for which it held full responsibility was no small accomplishment.

References for Chapter XVIII

1. Report of Scientific Director on Atomic Weapons Tests at Eniwetok, 1948, Vol. I, App. 1.
2. See Chap. 8 for description of Operation FITZWILLIAM.
3. Report of Scientific Director, Vol. I, 24-34.
4. *Ibid.*, Vol. I, App. 2.
5. *Ibid.*, Vol. I, 34-36.
6. Ibid., Vol. I, Chap. 1 and App. 3.
7. *Ibid.*, Vol. I, 36-87.
8. *Ibid.*, Vol. I, 88-98; Vol. II, 147-61.
9. See Chap. 8.
10. Report of Scientific Director, Vol. I, 98-103; Vol. II, 147-61.
11. Ibid., Vol. I, p. 9 and App. 3.
12. *Ibid.*, Vol. I, 50-51.