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HISTORY OF THE MARK 4 BOMB (U)

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HISTORY OF THE MARK 4 BOMB (U)

This history recounts the reasons why the Mark 4 Bomb was needed, and tells the story of its design and development in broad outline.

Information Research Division, 3434

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HISTORY OF THE MK 4 BOMB

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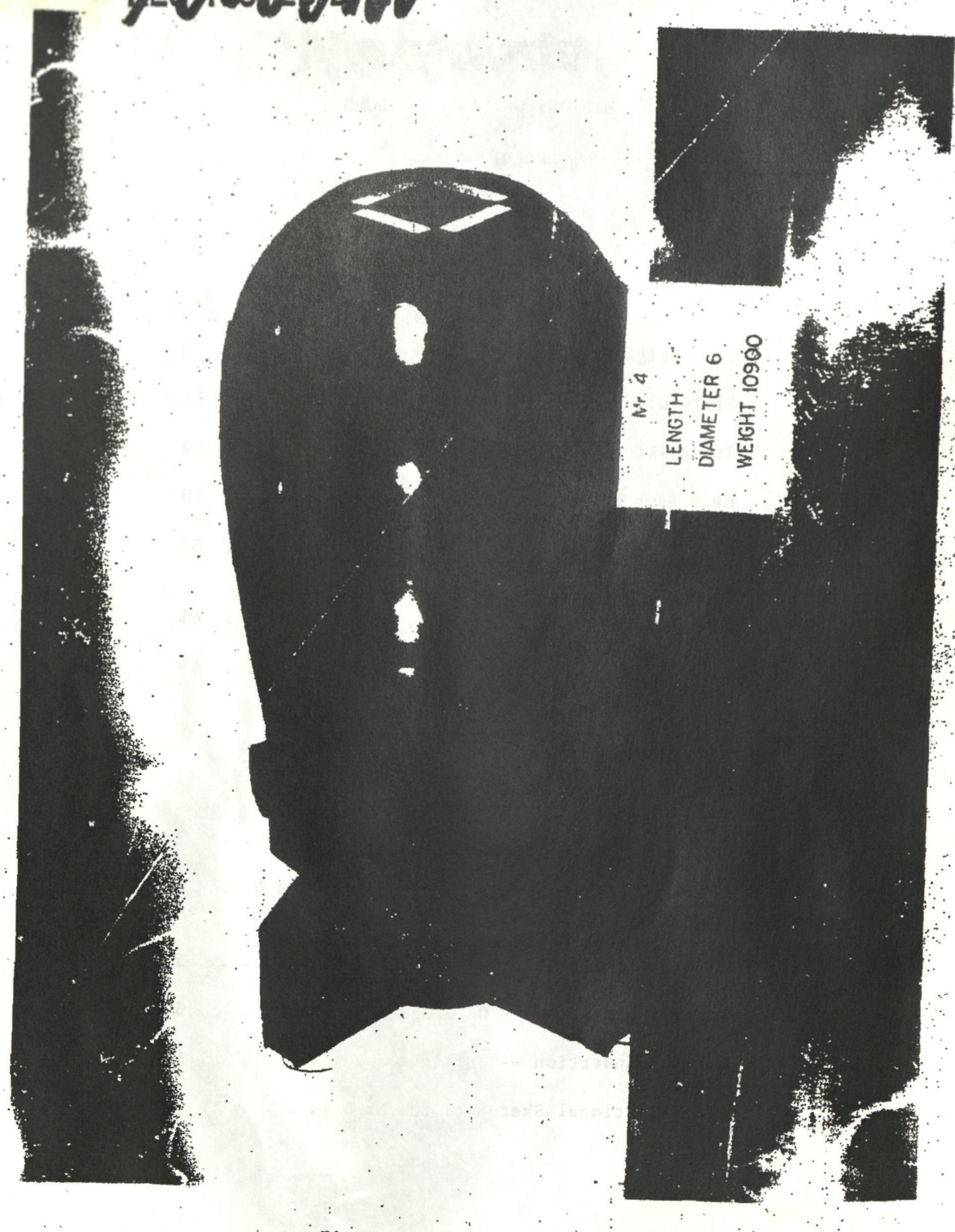

Figure 1. Mk 4 - Exterior View

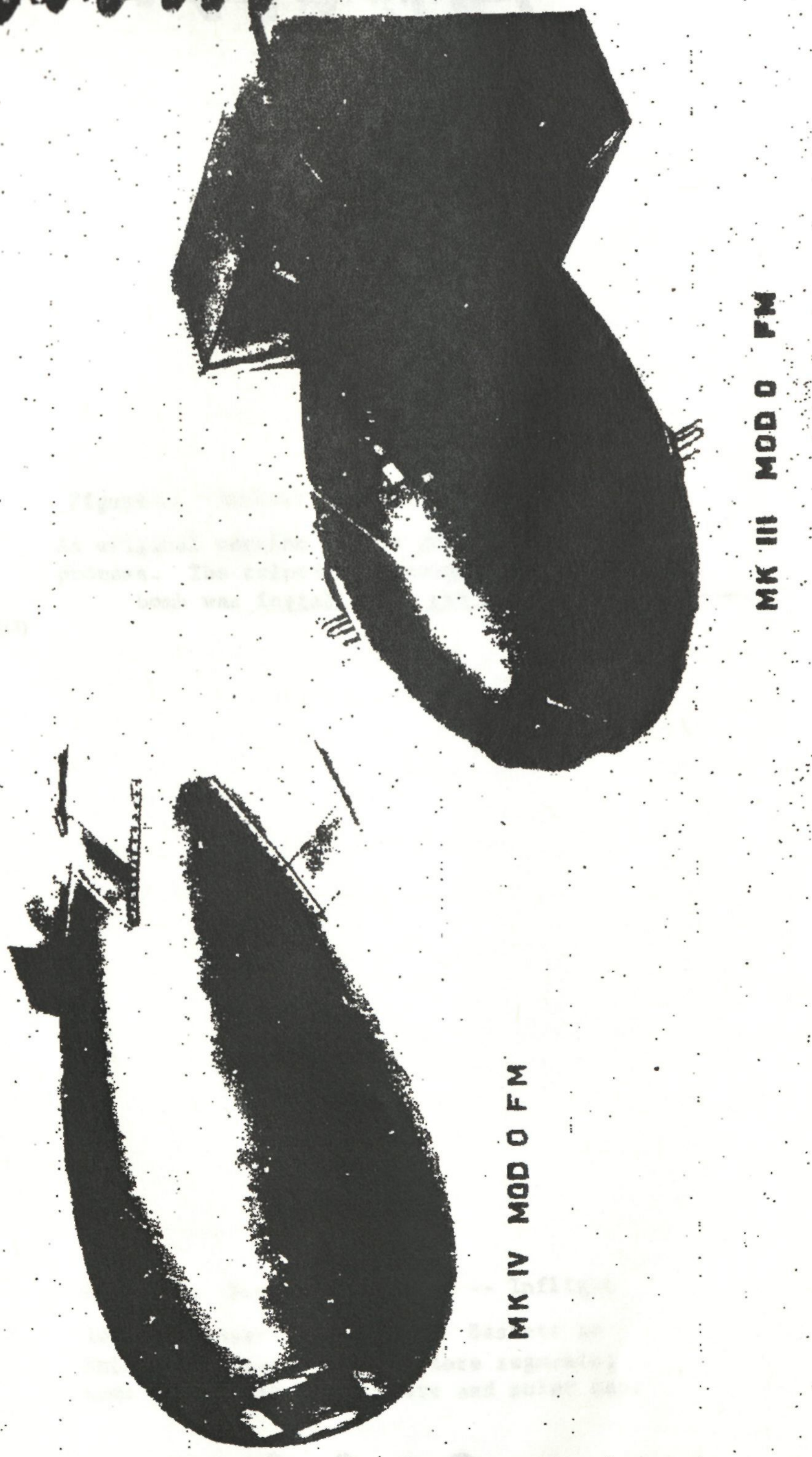

Figure 2. Comparison of Shape of Mks III and 4

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(b)(1), (b)(3)

Figure 3. Comparison of Field Assembly Procedures of Mks III and 4

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(b)(1), (b)(3)

Figure 4. Nuclear Insertion -- On Ground

An original version of the ground insertion process. The tripod was removed before the bomb was installed in the plane.

(b)(1), (b)(3)

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Figure 5. Nuclear Insertion -- Inflight

Inflight insertion version. Baskets to hold the high-explosive sphere segments; arms to hold the nose plate and polar cap.

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Figure 6. Cross-Sectional Sketch of the Mk 4

TIMETABLE OF MK 4 EVENTS

Early 1945	Initial consideration of weapon.
8/2/45	Z Division of the Los Alamos Laboratory organized - Mk 4 development started.
9/27/45	Z-Division representatives started move to Sandia Base.
9/28/45	Issuance of Z-Division progress reports begun.
10/4/45	Mk 4 schedule defined.
12/14/45	Initial practice drop made at the Los Lunas Bombing Range.
7/46	Operation Crossroads at Bikini Atoll - Mk 4 development interrupted.
8/1/46	Atomic Energy Act passed.
2/47	Z Division consolidated at Sandia Base.
4/4/47	First half-scale Mk 4 drops conducted at Salton Sea Test Base.
3/2/48	Sandia Research and Development Board organized.
4/1/48	Z Division becomes Sandia Branch, Los Alamos Scientific Laboratory.
Mid-1948	Operation Sandstone at the Eniwetok Atoll - Mk 4 development delayed.
1/15/49	Mk 4 Preliminary Evaluation Report issued.
3/19/49	Mk 4 weapon enters stockpile.

Chapter I - The Design Task

The Mk 4 weapon was the first atomic bomb to be designed as a practical piece of ordnance as contrasted to a laboratory device that would function properly only when assembled and used by highly trained personnel under closely controlled conditions. The initial approach to this bomb was made early in 1945, shortly after the wartime ordnance designs were frozen. At this time, the implosion-type weapon (which had been initially called the 1561 after its Los Alamos drawing number) had been code-named the Fat Man in recognition of its outer shape, which possessed a distinct midriff bulge. Various designs of the Fat Man were subsequently assigned Mark nomenclature, but there is some question as to the precise definition of either the Mk I or the Mk II designs. The version of the Fat Man that was manufactured and stockpiled after the end of the War (to the basic wartime design) was called the Mk III.[1]

There were several reasons why it was necessary to redesign the Mk III. In addition to the desire to create a practical piece of ordnance--one that could be used in combat by a military team of average training and capabilities--it was hoped to develop better manufacturing and assembly techniques and to clean up marginal ballistic and vibration characteristics, in the interests of improving bombing accuracy. The weapon that eventually evolved from these redesign efforts was for a time called the Mk IV Fat Man, but toward the end of the program the Roman numeral was replaced by the Arabic number 4, and herein we will generally refer to the weapon as the Mk 4.

Initially, consideration was given to design and manufacture of various ballistic or external shapes, investigation of internal pressures within the high-explosive sphere, redesign of detonators for easy installation, and the proper number of high-explosive lenses for efficient implosion. These studies, at first carried out in different parts of the Los Alamos Laboratory, were consolidated in one organization August 2, 1945, when the Z Division of the Laboratory was created to carry on activities of ordnance design and delivery of atomic bombs. Jerrold Zacharias, who had been active in the radar group of the Massachusetts Institute of Technology Radiation Laboratory, was selected to head this new organization, the Z nomenclature stemming from the first letter of his last name.

The broad area of responsibility of the new Division was indicated in a memorandum dated August 6, 1945, from Dr. Zacharias to J. Robert Oppenheimer, Director of the Los Alamos Laboratory. In part, the memorandum read:

> "With the organization of Z Division in such a fluid state, it is tempting to put nothing on paper. The Division is likely to become larger and to take on so many duties of so many different divisions that a more vertical organization than is usual in Project Y [Los Alamos] will have to be sought."

Dr. Zacharias then proposed an organizational breakdown of the Division, with work assignments as follows:

Z-1, Experimental Systems Engineering, to perform airborne testing, ballistics, aerodynamics, radar, and informer or telemetering work.

Z-2, Assembly Factory and Procurement, to procure, assemble, and ship weapons.

Z-3, Electrical Engineering, to design firing circuits and detonators.

Z-4, Mechanical Engineering for Production, to be concerned with general engineering changes, and--most pertinent to this history--the "coordination of development of streamlined gadget" (i.e., the Mk 4).

Z-5, Electronic Engineering, to handle fuze development.

Dr. Zacharias predicted that some of these groups would move to Sandia, but that the engineering people would probably remain at Los Alamos.[2]

On August 8, 1945, the day before the first--and also last--Fat Man weapon ever to be used in combat was detonated over the Japanese city of Nagasaki, a memorandum was released which outlined the Fat Man design problems in considerable detail, pointing out that it was necessary "to simplify and render more reproducible assembly of FM, to improve ballistics of FM, to incorporate simplification and developments of the individual components." Mandatory requirements were to retain the ability to monitor the weapon battery and electrical system while the weapon was being carried to the target and to keep the weapon small enough to fit into the B-29 bomb bay. Desirable objectives were to provide rapid bomb assembly, permit testing and inspection without disturbing component parts, allow shipment of a practically complete weapon (less detonators and nuclear material), provide armor to protect the bomb against shrapnel, and maintain dry air within the weapon.[3] Thus, the design task was defined and the stage set for development work.

Chapter II - Early Development

It now became necessary to provide adequate space and facilities for the work of the Z Division. The first step in this direction was taken in the fall of 1945, when the Engineering Division of Los Alamos was requested to design a testing laboratory. This laboratory would simulate on the ground the conditions which bombs and components experienced in flight. This testing laboratory was subsequently built and proved of material assistance in the development of the new weapon.

Meanwhile, a proper work location for the assembly group, Z-2, was being discussed. This organization, which was largely staffed with military and Civil Service personnel, could be administratively separated from the rest of the Division, and required an area convenient to air and rail transportation. A logical spot was the former Oxnard Field, the original Albuquerque Airport (now called Sandia Base), which already was the property of the Manhattan Engineer District, having been obtained in July 1945 for the never-consummated objective of providing space for temporary storage of atomic-bomb materiel during World War II. A meeting was held at Sandia August 29, 1945, at which time it was decided to transfer Z-2 to Sandia Base. It was also decided to remove the W-47 Flight Test Group from Wendover Field, Utah, and bring some of these personnel to Sandia Base.[4] After further discussion, it was decided that weapons production and test activities would be concentrated at Sandia and design work at Los Alamos.[5]

The first Z-Division representatives moved from Los Alamos to Sandia Base September 27, 1945, and on the following day Dr. Zacharias inaugurated the practice of issuing monthly progress reports.[6] The initial report of the Mechanical Engineering Group, Z-4, noted that work on the Fat Man was directed toward making this bomb a more reliable and serviceable weapon--more of a re-engineering task than a radical redesign of the entire gadget.

("Gadget" was a common term in those days for an atomic device.) The report pointed out that the Mk III had to be assembled component by component, while it was hoped that the new bomb could be put together in fairly large subassemblies In line with this objective, a start had been made in consolidating some of the electrical items into a "cartridge" that could be inserted into the weapon as a unit (in the same manner that a cartridge was inserted in the chamber of a rifle).

A conference between military and Z-Division personnel had meanwhile been held at Wright Field, Ohio, September 21, 1945, to review aircraft capable of carrying the proposed bomb. The B-36 long-range bomber was in the last phases of design and was nearing the flight-test stage, and several jet-propelled medium bombers were being developed. However, the B-36 had a relatively low top speed, and the jet bombers (at that time) were restricted in range, so it was concluded that any immediate redesign of the Fat Man must, of necessity, keep the B-29 in mind as the delivery vehicle.[7]

A Mk 4 planning meeting was held October 4, 1945, at which an optimistic schedule was laid out. The coefficient of expansion of the high-explosive sphere was to be determined by November 1, 1945. The external shape of the bomb and the elements of the firing circuitry were to be settled by December 1, and the sphere assembly and mounting were to be designed by December 15. Drawings of the tail, the cartridge, and the electrical equipment were to be prepared by January 1, 1946. Handling equipment was to be available by February 1; full-scale drops were to be started March 15; a pit and sphere assembly was to be completed by May 15; and the entire bomb was to be ready for stockpile production, with all problems solved, by July 1, 1946. (b)(3)

It is obvious ... that the

estimated date of July 1 for the completed bomb is contingent on the progress made with the pit."[6] However, it was understood that, should the nuclear design be produced, the weapons hardware group was to be ready with the rest of the bomb, and the Z Division swung into high gear.

During design of the wartime Fat Man, there had not been enough time to make a thorough analysis of component functions and their relationships to the overall weapon system. A study was thus started, covering the circuit elements of the bomb and the part played by such factors as simultaneity of switch operation in overall efficiency. Ballistic problems, further described in Chapter III, also were examined. To meet this need, a field-test range was secured, arrangements made for wind-tunnel work, and special telemetry apparatus started into design.

Improvements were made to various elements of the firing system, notably the X-unit, which created the high-voltage surge of current that fired the weapon detonators. The wartime implosion bomb had been equipped with an X-unit whose capacitors were charged to approximately 5600 volts before the bomb was released from the carrying airplane. This not only created a hazard to the bomber crew, but made it necessary to pressurize the X-unit to prevent internal arcing at bomb release altitudes. A safer and simpler X-unit was designed, which was charged after the bomb had fallen to its fuzing altitude, a safe distance from the strike aircraft.

Detonators were modified for easier installation, and much attention was paid to the design of segment molds and the lenses for most efficient implosion of the high-explosive sphere. Extensive tests were made of face pressures between high-explosive segments, and studies were conducted of improved systems of detonator cabling. The protruding Mk III (Yagi) antennas were redesigned to be recessed into the flattened nose of the bomb, thus simplifying weapon handling. So-called "Dipsy-Doodle" flight tests were conducted to determine the effects of signal interruption on the fuzing and firing system, and minor improvements were made to radar units and to the clock box circuits.[6]

The entire Division compiled lists of needed personnel and prepared plans for anticipated space at Sandia and Los Alamos. Many Division members were military representatives of the Special Engineer Detachment of the Manhattan Engineer District that had been formed to assist Los Alamos scientific personnel during the war, and efforts were made to interest these people in transferring to the Z Division in a civilian capacity.

This acceleration of effort continued for several months, only to be slowed down (in the design area) by many circumstances. One of these was Operation Crossroads, the first postwar full-scale test of atomic bombs. This operation took place at Bikini in July 1946, and many people from the Z Division were assigned in the early months of the year to help with the work. A second factor was loss of supervisory personnel. As an example, Dr. Zacharias returned to the Massachusetts Institute of Technology on September 28, 1945 (to be succeeded by Roger S. Warner, Jr., previously in charge of Z-2B, "Production Schedules and Manuals").[6] This was the first of many such moves, as in the next 15 months, 8 out of 10 Z-Division supervisors were to leave and be similarly replaced. A third item was the loss of trained military personnel as postwar demobilization got under way in early 1946 and career officers were returned to prewar commands. Finally, the lack of specific directives for new bomb design and production, and the general dearth of needed facilities impaired the progress of the overall work.

When the Crossroads contingent returned to the Division in the late summer of 1946, work on the Mk 4 was resumed, although at a somewhat slower pace. The Crossroads test had included an atomic device detonated under water, and the success of this explosion against target ships resulted in a demand for a penetrating weapon. The work on this latter device resulted in manpower being diverted from the Mk 4 program.

The passage of the Atomic Energy Act, August 1, 1946, resulted in cancellation by the Military of plans for Sandia buildings and facilities. The newly created Atomic Energy Commission could not immediately act to counter this cancellation, and securing needed space for the Mk 4 effort was delayed. Supply problems were aggravated as a result of the physical separation of parts of the Division from Los Alamos, with the Z-Division Progress Report of October 1946 noting that daily operations were "continually hampered by an inadequate supply of the common every-day types of electrical equipment ... such things as ordinary rosin solder, hook-up wire, etc."[6]

The need for this new weapon was, however, becoming more apparent, with the Division Leader reporting on November 29, 1946: "As we reach the end of the 1561 FM stockpiling program ... we are finding more and more subassemblies which are marginal .... In certain cases where we have taken steps to bolster one weakness, another develops, and so on ad nauseam until we reach the stage where by physical handling and reworking the component is worn out before it reaches the stockpile .... Because of the low confidence I have in the 1561 gadget, I request the Tech Board to permit me to carry through with the Mk IV test program under forced draft."[8]

Consequently, by early 1947, work was again moving forward and progress could be noted.[9] A full-size Mk 4 prototype shape was built and used in the design of handling equipment. The Z-4 group was moved from Los Alamos to Sandia Base, thus consolidating the entire Division at one location.

Mr. Warner became the AEC's first Director of Engineering and was replaced as head of the Z Division by Robert W. Henderson of Z-4. The Armed Forces Special Weapons Project was created to handle military functions relating to atomic energy, with an office being established on Sandia Base to provide liaison with the Z Division.

A date of March 15, 1948, was agreed to at a meeting of Z-Division supervisors on April 16, 1947, for a "proven Mk IV bomb ready to be procured in quantity by Road." (Road was a general code term for production and stockpiling activities, as the fact that the Division was producing atomic weapons was highly classified.) The meeting report also noted: "A tremendous responsibility has been given to Z Division to have this bomb by the above deadline because either the Mark IV is ready by that date or all work must cease and a new project along different lines must begin." (Official recognition was thus taken of approaching new weapons programs.) All groups were requested to determine their manpower needs and to make a realistic estimate of any additional personnel required, "realizing that even after the people have been found, a 45-day delay for clearance will follow."[10]

New employees subsequently were added to the Division. The cartridge design was completed and started into production. A thorough study was made of the proper location of detonator cabling. The sphere design was completed, and the assembly of the sphere to the outer case was checked out. Investigation was made of barometric switch operation, including the proper location of external ports in the outer case to provide pressure sensing as the bomb fell toward the target. It became necessary to seal the outer case to control this pressure sensing, and different sealing methods were proposed and tested. Handling equipment and storage containers were designed and built.

The above effort was compounded by the necessity to provide parallel designs for mockup or dummy units. Detonators, for example, were built with inert charges so that they could safely be used in trial sphere assemblies using, of course, dummy high-explosive segments. Various operational units had to be simulated by dummy weights so that these could be attached to assemblies being given shake-table tests.

The Mk 4 work was later delayed by another full-scale test, Operation Sandstone, which was held at Eniwetok in mid-1948. Mr. Henderson headed up the engineering phase of the operation, and Z-Division personnel were assigned to various Sandstone functions. However, as the year 1947 drew to a close, the following accomplishments related to the Mk 4 weapon could be reported to Congress in reply to a request for the status of nuclear ordnance:

1. Selection of an outer case with improved ballistics;
2. Progress on a new fin design;
3. Development of a new antenna system;
4. Development of a cartridge-type assembly to contain bomb fuzing components;
5. Development of new handling equipment;
6. Preliminary studies of a new radar and electromechanical fuze;
7. Establishment of a mechanical test laboratory; and
8. Extensive work in the field of telemetry.[11]

For some time there had been proposals to separate the Z Division from the rest of the Los Alamos Scientific Laboratory. Los Alamos interests were basically that of an experimental nuclear and scientific laboratory, while the Z-Division work was rapidly assuming the aspects of ordnance design and production. This trend brought about the appointment on

December 4, 1947, of Paul J. Larsen of the Applied Physics Laboratory of the Johns Hopkins University as leader of the Z Division. As one step in the process of creating an independent organization, on April 1, 1948, the Division was named the Sandia Branch of the Los Alamos Scientific Laboratory.[12]

The March 15, 1948, deadline for a completed Mk 4 design had meantime been postponed to October 1, with production predicted to start January 1, 1949. A decision had initially been made that the Mk 4 would use Archie radar units (originally called "Tail-Warning Charlies") of the Mk III Bomb, but an improved design called Abee had been developed and would be available by early 1950.

A major coordinating agency for the ordnance effort was the Sandia Research and Development Board, later to be named the Sandia Weapons Development Board and, still later, the Special Weapons Development Board. This Board was made up of military representatives from the Armed Forces Special Weapons Project and civilian members of the Z Division, and provided a common technological meeting ground. This board greatly assisted in bringing a combined civilian-military judgment to bear on atomic devices, and this composite point of view was to be of the highest value to the Mk 4 and subsequent weapons.

The first Board meeting was held March 12, 1948, with Richard A. Bice, Manager of the Sandia Laboratory Engineering Department (SLE) and Project Engineer of the Mk 4, being named Chairman. Early meetings devoted considerable attention to the Mk 4, with the suggestion being made that a system for inflight nuclear extraction be developed so that, if a mission was aborted, the airplane returning with the bomb could not cause a nuclear detonation during a landing accident.[13]

In the meantime, at Kirtland Field, members of the Tactical and Technical Liaison Committee, established by the Air Force in connection with the atomic bomb, were also studying this subject. On March 26, 1948, the Committee recommended to Air Force Headquarters that both insertion and extraction of nuclear components be provided, pointing out that such design would increase both aircraft and airport safety. The practicality of this insertion and extraction operation had meanwhile been demonstrated by members of the Z Division working inside a parked B-29 at Kirtland Field.[14] This subject was further discussed in the Sandia Research and Development Board meeting of July 20, 1948, in which it was noted that the problem of extraction was of concern, but that it was necessary to freeze the design to permit production to proceed. Accordingly, action on the problem was temporarily deferred.[15]

Meanwhile, international tensions were increasing. The Communists had seized Czechoslovakia and were being belligerent in Berlin, where the Western powers occupied part of the city as an island in the midst of Soviet-held territory. As a result, the Military Liaison Committee urged that production and stockpiling of the Mk 4 be expedited.[16] The Sandia Research and Development Board discussed assignment of priorities for various atomic programs and, in a meeting May 6, 1948, urged the acceleration of the Mk 4 by every means possible.[17] Working at high speed and under overtime schedules, Sandia released portions of the Mk 4 design as they were completed, and by mid-November 1948 the entire weapon was in production.[18]

It was felt that the Mk 4 could be stockpiled by April 1, 1949.[19] The Preliminary Evaluation Report for the weapon, which provided an engineering examination of the bomb and gaged its success in meeting specifications, was issued January 15, 1949. A crash program produced test and handling equipment for military training and for possible emergency use.[20] As a result of this intensive effort, the first Mk 4 Bomb entered stockpile March 19, 1949.[21]

Chapter III - The Ballistics Problem

The problem of Mk 4 ballistics received early attention. The Mk III weapon had a diameter of 5 feet to accommodate its large explosive sphere, and a proportionally short length (~~11 feet~~ 10 feet 8 inches) to enable the weapon to fit into the B-29 bomb bay. A 5-foot-square box tail was initially used, and this design was only marginally aerodynamically stable after the tail structure had been internally stiffened and braced. The ballistics group at Los Alamos suggested that the center of gravity be moved as far forward as possible and that the body and tail be streamlined to the utmost. A tail design to provide lift rather than drag as a stabilizing force was advocated, as well as a structural design to minimize vibration and flutter, the location of internal components for best static and dynamic balance, and the elimination of external projections that might cause turbulence or parasitic drag. The report noted that the Mk III had a low ballistic coefficient, that this figure should be increased to improve stability, but that the stubby shape of the bomb would militate against any large increase.

A meeting of Los Alamos and W-47 representatives was held August 25, 1945, to provide an answer to the ballistics problem. Some attendees felt that if the bomb could be lengthened, a relatively high ballistic coefficient might be attained. (b)(1), (b)(3) [redacted] This was found to be impractical, due to the large diameter of the Mk 4 and the lack of sufficient clearance under the fuselage of the B-29. As one result of the meeting, it was decided to seek external ballistics advice.[22]

Two days later, Z-Division representatives left for the East Coast to visit the Bureau of Standards, the Aberdeen Ballistics Laboratory, and Langley

Field; and to confer with aerodynamicists and ballistics experts. They were informed that the best tail was a design using four equally spaced airfoils, and that these airfoils had to extend some distance out from the body of the bomb since, at high velocities, the air flow broke away from the bomb contour at approximately the maximum diameter of the bomb. It was felt unwise to permit the velocity of the bomb to exceed Mach 1 (the speed of sound), due to buildup of vibration, and it was suggested that a tail shroud be used to retard the rate of fall of the bomb if this velocity was approached in full-scale drops. The use of a blunt rather than a round nose was recommended in an effort to further retard the rate of fall.

A wind-tunnel test program was outlined, to be conducted at Aberdeen. Body shapes without tails would be initially investigated, and the best shapes fitted with simple fins and tested further. If these designs were not completely stable, a circular tail shroud would be added. These wind-tunnel tests would be made at speeds expected to be encountered in actual drops, and stability of the bomb shapes at higher or supersonic speeds would be checked by firing 20-millimeter-diameter models from a gun. It was felt that little could be done to improve the body of the bomb, due to the dimensional limitations imposed by high-explosive sphere and bomb bay, and that efforts should be concentrated on tail modifications.[22]

It had been decided to start full-scale test drops as soon as possible, and an aerial survey of World War II practice ranges in the vicinity of Albuquerque was made September 19, 1945, by members of Z-1. As a result, Range S-1 (which was renamed the Los Lunas Range) was selected for use. This range was located west of the town of Los Lunas and approximately 25 miles southwest of Albuquerque.[23]

In preparation for the work at Los Lunas, recording and communications gear was installed in trailers which could be based at Albuquerque and moved to the range for each test. Plans were drawn up for permanent facilities at Sandia Base, but while these were being constructed it was necessary for the field-test crew to operate out of Los Alamos. Much design and assembly work was done on various pieces of telemetry equipment (called "informers") that would transmit to ground stations data concerning operation of t[illegible]zing and firing circuits, and the changing conditions of vibration, temperature, pressure, and bomb position during the drop. The Z Division designed and built much of this equipment, as it was not commercially available, and it soon became evident that extreme accuracy and highest quality were required. Even so, it required considerable time, ingenuity, and effort before telemetry equipment began to clearly report anything but its own "shake and shiver."[6]

The first practice drop at the Los Lunas Range December 14, 1945, demonstrated that the target was difficult to see from the air. Consequently, 10- x 1000-foot windrows were bulldozed out to the four points of the magnetic compass, and the target was changed from a black-and-orange cross to a white square 50 feet on each side.[6]

The Aberdeen Ballistics Laboratory issued an interim report May 1, 1946. This confirmed the fact that severe separation of wind flow from the bomb body occurred during high-speed tests, and predicted that it might be necessary to design a high drag shape to reduce the bomb drop velocity. It was recommended that the most promising shape be tested in half-scale bomb drops, and a suggestion was made that some models be built with fins canted at an angle so that the stability of the bomb under varying degrees of spin could be observed.[22]

A Z-4 summary of the entire ballistics problem was issued July 26, 1946. This pointed out that the Mk III had a terminal velocity in a speed range most conducive to poor aerodynamic flow and buffeting (Mach 0.7 to 0.97), and it was hoped that the Mk 4 would pass through this turbulent region as rapidly as possible. It was believed impractical to build enough drag into the shape to keep it below this trouble zone without using a parachute or similar device. In order to provide better knowledge concerning bomb trajectory, it was decided to install three Askania Kine-Theodolite cameras at 120-degree intervals around the target. Mitchell motion-picture cameras were employed to measure striking velocity, time of fall, and general trajectory information.[24]

Subsequently, Aberdeen wind-tunnel tests favored an airfoil fin with a small planform or side area. Fourteen ballistic shapes were tested at speeds of Mach 0.6 to 0.8, to determine drag and air-flow characteristics, and resulted in narrowing the number of body shapes to five. These five shapes were then tested on the gun firing range, and the two best selected. Full-scale models of these two were subsequently mocked up and dropped with (as disappointingly reported) "varying stability characteristics."[6]

Full camera coverage at the Los Lunas Range was installed by October 1946. On one memorable test, the bombardier was given a wind reading 180 degrees wrong, and the result was a miss--"over the top of observing personnel"--that undoubtedly helped to keep range workers on the alert. Plans were made to drop some half-scale units at Los Lunas and others at a Naval Auxiliary Air Station on the shore of Salton Sea, California. This latter location had been used by the Manhattan Engineer District for some wartime bombing tests of Project W-47, based at Wendover Field, Utah. The need for this range, later called the Salton Sea Test Base, was created by the desire to have a sea-level target, which would provide a long weapon trajectory (and thus a high bomb velocity), and to test bomb operation in a denser atmosphere. The range had been obtained for the Z Division in March 1946, and initially used for Mk III tests. Subsequently, much preparatory work was done at Salton Sea, with Askania stations being established, targets prepared, field communication wire strung along the ground, and radio transmitting and receiving equipment installed.[9]

A half-scale Mk 4 shape was dropped at Salton Sea April 4, 1947. The test demonstrated that the approaching B-29 bombers were hard to see, and this fact, coupled with inaccurate bombing, complicated tracking and camera work. The B-29's developed mechanical trouble as the high-altitude work continued, and electrical problems were created as the wild life around Salton Sea acquired a taste for the insulation of the ground-laid wires. Test operations were temporarily halted while new B-29's were secured, wiring strung on poles, and a new target array installed.[25]

By the fall of 1947, it was felt that if the roll of the bomb in flight could be controlled, many erratic ballistic actions could be eliminated. One way of controlling roll was to provide a tail that would spin freely, and this was tried. It involved difficult manufacturing problems and was therefore not thoroughly pursued. Another proposal was to use the shroud that had been initially proposed as a means of providing drag. This shroud would add considerable weight to the tail, thus adversely shifting the center of gravity aft, and designs were tested for a lightweight tail cone to counter this added weight.[26]

By early March 1948, drop tests were indicating improved ballistic characteristics. Releases to supply performance data on fin shape indicated that a large-plan fin (with an area increased approximately 25 percent above the plan area of the standard fin) would produce less yaw in flight than the standard fin. Fairly consistent performance was also obtained using a thin fin (with a plan area decreased approximately 25 percent) and a circular shroud. Neither of these two types, however, gave completely satisfactory ballistic performance.[27]

Members of the Armed Forces Special Weapons Project suggested that a group of aerodynamicists might be able to suggest improvements in ballistic characteristics, inasmuch as a great deal had recently been learned concerning actions of bodies passing through the transonic region, which had been pierced by manned aircraft only a few months previously. Consequently, representatives of Northrop, Rand, Douglas, North American, Boeing, Wright-Patterson Air Force Base, Inyokern, and Aberdeen formed an advisory panel which initially met May 26 and 27, 1948. The panel suggested that thin fins with flat sides and wedge cross sections would perform better than fins with curved sides and airfoil cross sections. It was also proposed that the planform of the fin be enlarged and drag introduced by the use of plates or spoilers to hold the velocity of the bomb below the transonic range. Arrangements were made to use the Cooperative Wind Tunnel at the California Institute of Technology, which had a greater velocity range than the Aberdeen tunnel.[28]

The flat-sided wedge fins were subsequently tested at the Cooperative Wind Tunnel and exhibited good stability.[22] Consistently good results were obtained from drop tests and, in mid-September 1948, the large-plan wedge fin was tentatively selected for use.[29,30] Detailed results of tests at the Cooperative Wind Tunnel became available October 1, 1948, and confirmed the results noted above. Perforated tail plates were tested on two bombs; one with a square plate and the other circular. The first gave improved control over pitch and yaw, while the second resulted in decreased control--hardly a conclusive test.

Since there was now a limited amount of time and drop tests that could be made, it was decided to concentrate on trials of a large-plan wedge, a thin-fin shroud wedge, a dorsal wedge, and a large plan with a sloping leading edge. All these, it was felt, would have about the same ballistic characteristics. A closer examination of wind-tunnel data subsequently narrowed the choice to a large-plan wedge or a thin-fin shroud wedge. It was then found that the reliability of the thin-fin shroud declined in high-speed, high-altitude drops, whereas the large-plan wedge did not, and the latter design became the obvious choice.

Aberdeen wartime experience with certain experimental bombs had indicated that a "flap" placed at the rear of a bomb shroud (which presented a greater angle of attack to the approaching air than the fin) would help to stabilize bomb flight, and large-plan wedge and thin-fin shroud tails were prepared with this modification. The first to be dropped was the large-plan wedge. One drop showed such excellent flight characteristics--with pitch and yaw of only about 2-1/2 degrees and a ballistic velocity coefficient only slightly lower than that of the thin-fin shroud--that it was deemed advisable to concentrate on further drops of this type, rather than expending time and energy on the thin-fin shroud, which was difficult to fabricate.[22] Accordingly, the large-plan wedge design was frozen for Road production in December 1948.

(b)(1), (b)(3)

More intensive testing in mid-1950 revealed that bomb instability could occur when the Mk 4 was released at altitudes of 26,000 to 31,000 feet, and it was recommended that releases be made above or below this range.[32] It was theorized that this instability was caused by the development of a large shock wave near the fins and the use of circumferential spoiler bands to create smaller shock waves at the mid-point of the bomb and prevent formation of this one large shock wave, was suggested.[33] Tests subsequently made in the Wright Field wind tunnel showed that the Mk 4 shape with five of these spoiler bands possessed good stability.[34] These wind-tunnel tests were the last performed on the Mk 4 weapon, as it was felt more logical to apply the spoiler bands to the approaching Mk 6 Bomb rather than to retrofit them to the Mk 4.[35] As a result, all ballistic testing on the Mk 4 Bomb came to an end.

Chapter IV - Mk 4 Bomb Description

Since the Mk III Bomb was the immediate predecessor of the Mk 4, a brief review of its major design features is of interest. (b)(3)

The Mod 1 retained the Type A pit, but incorporated an improved fuzing and firing system including the Mk III Mod 2 X-unit (an inductance type), ER-12-10 batteries, and 1E20 detonators. (b)(3)

The original Mk 4 Mod 0 Bomb was similar in many respects to the Mk III Mod 2 (see Figure 2). (b)(3)

The Mk 4 was a free-fall, air-burst, implosion-type bomb 60 inches in diameter and 128 inches long, and weighing 10,900 pounds.[37] (b)(1), (b)(3)

These yields compared to the wartime "Little Boy" and "Fat Man" bombs of 18 and 23 kilotons, respectively.[40] (b)(3)

The external ballistic case was made of mild steel, 3/8 inch thick, and was built in three sections for ease of assembly.[37] The front and rear sections bolted directly onto the fore and aft flanges of the sphere case. The center "belly band" section was split at the top so that it could be spread apart with assembly tools and slipped over the sphere flanges for positioning over the center section of the sphere. Tension bolts pulled the split-band together at the top. A large rubber gasket sealed the surfaces where the steel case met the aluminum sphere case. The forward case supported the antenna nose plate, which could be removed for access to the sphere. The inflight insertion gear was supported by the forward case. The four fins, which were of aluminum sheet-metal construction, were bolted to the rear case.

(b)(3)

The cartridge structure supported the fuzing components, was cylindrical in shape, and used riveted aluminum sheet-metal construction. The X-unit was bolted to the forward end of this assembly, and the entire unit was fastened to the bomb sphere case by bolts through the X-unit flange. Shelves and mounting plates were provided in the cartridge structure for installation of fuzing components.

The fuzing and firing system contained the same general components used in the Mk III Mods 1 and 2, but were mounted in a single cartridge structure. The X-unit used the same basic electrical design as that of the Mk III, but was redesigned to reduce size and weight, and to adapt it to the cartridge structure.

The four radar antennas had cavity-backed slot designs and were mounted on a nose plate at the front of the bomb. Being flush with the outer surface of the weapon, these were superior from the aerodynamic and handling standpoints to the Yagi-type antenna used on the Little Boy and Mk III Bombs.

The clock timers and batteries were provided with heated, insulated covers to protect against freezing during flight to the target. These heaters were powered from the aircraft electrical system through a cable connection at the upper surface of the rear case which was separated when the bomb dropped away from the aircraft. This same pullout cable was used during flight to monitor the electrical components in the bomb.

The "Archie" radars were modified APS-13 "Tail Warning Charlie" radars developed during World War II. They were adapted to the bomb fuzing application by using a different antenna system and modifying the range gate. (b)(3)

The early radars required alteration by soldering iron to change the range setting, but later modifications provided plug-in gate lines.

(b)(3)

[redacted]

(b)(1), (b)(3)

The following aircraft were equipped to deliver the Mk 4. For the Air Force; B-29, B-36D, B-36F, B-47B, B-50A, and B-50D. For the Navy; AJ1 and AJ2. Since the Mk 4 was originally designed for carriage by B-29 and similar land-based aircraft, no provision had been made for resisting catapult loads. With the development of Navy aircraft capable of taking off with the bomb from the deck of an aircraft carrier, some difficulty at the sway-brace locations was encountered. This was overcome by redesigning the sway braces in the aircraft bomb bay so as to distribute the load over a sufficient area to prevent damage to the outer case of the Mk 4.

The Mk 4 Mod 0 Bomb entered stockpile March 1949. It was not equipped for inflight nuclear insertion. It included the Type C pit and had an inflatable rubber gasket to seal the ballistic case. Baro ports were located at the nose of the bomb, and the entire interior of the bomb case was used as a "plenum chamber" to provide static pressure to the baroswitches.

The "Mod-Alt" change system was not in use at this time, and major changes were processed under a "block" change system. All weapons in a given "block" of units incorporated the same changes. In May 1950 the Mk-Mod-Alt weapon designation system was instituted, and the weapon was divided into three major assemblies, bomb, fuze, and capsule.[42] The bomb capable of inflight nuclear insertion became the Mk 4 Mod 1 (previously identified as the Block 7 weapon). It also included a solid rubber gasket for sealing the ballistic case. Since it had a Type C pit, the complete bomb nomenclature was Mk 4 Mod 1-C.

The Mk 4 Mod 2-C Bomb incorporated a baro manifold, which was a circular copper tubing assembly installed in the rear ballistic case.[43] Static pressure was provided from intake ports in the rear cover plate through flexible hose leading to the manifold and additional flexible hose connected the manifold to the baroswitches. The accuracy of the baro system was improved by this change, since it no longer depended on a sealed ballistic case for a static pressure source.

The Mk 4 Mod 2-D Bomb incorporated a Type D pit with a higher yield.[44] Special handling equipment was required for insertion of this capsule into the pit, and included a loading tool and a capsule alignment tool or loading trough. By the end of 1951, all Mk 4's had been retrofitted to the Type D pit.[45]

The Mk 4 Mod 3 Bomb incorporated a lightweight magnesium antenna nose plate for easy manual handling. This permitted simplification of the inflight nuclear insertion gear and speeded the operation. Since this change was incorporated on bombs having either the Type C or D pit, it was identified as the Mod 3-C or Mod 3-D.

The "cartridge" became, under the new system, the Mk 4 Mod 1 Fuze. This included the AR-10A "Archie" radars (four required), BS-4 or BS-5 Baroswitches (six required), M-127 "clock" timers (eight required), Mk 4 X-unit, and lead-acid ER-12-10 batteries. The components were mounted on an aluminum structure for convenient installation

(b)(3)

(b)(3)

[redacted] However, this operation was greatly facilitated by the design of the Mk 4, which provided access to the pit through the bomb nose by removal of the nose plate and sphere access door. The same operation on the Mk III required complete disassembly of the bomb (see Figure 3).

Early Mk 4 weapons required that nuclear insertion be performed on the ground before loading the weapon in the strike aircraft. The insertion gear consisted of an overhead hoist with attachments for removing the high-explosive charges (see Figure 4). Later weapon versions provided inflight nuclear insertion (or extraction) with the airplane airborne, reducing the possibility of a nuclear accident in the event of a plane crash during takeoff or landing. The equipment designed for this operation (see Figure 5) was provided retroactively for all weapons in stockpile. Inflight insertion was not done automatically, but was performed manually by a trained operator working around the nose of the bomb as it hung in the bomb bay of the carrying aircraft.

The fuzing and firing sequence of the Mk 4 was as follows: As the carrying aircraft approached the target, green safing plugs, which had been installed on the ground during bomb preparation, were manually removed and replaced by red firing plugs. These safing plugs, located in the nose of the bomb, provided protection against accidental detonation by interrupting the power lines to the firing set.

When the bomb was released from the aircraft, pullout wires attached to the aircraft structure were withdrawn from the weapon pullout switches and spring-wound clock timers. These "clocks" provided a 15-second time interval before supplying power to the firing set. This time interval allowed the airplane to get beyond radar fuzing range, preventing premature detonation by radars ranging off the aircraft. Closing of the arming switches by the clocks allowed current from the 30-volt battery packs to flow through the X-unit choke and the closed firing switch. This current flow caused a magnetic field to be built up in the choke.

At a predetermined altitude, well above the desired burst height, baroswitches closed, allowing the radars to start transmitting and receiving. At the preset burst height, the ranging of any two of the four radars off the target operated a relay network which opened the firing switch in the X-unit. The rapid opening of this firing switch caused a collapse of the magnetic field in the choke, transferring electrical energy to a condenser. When the voltage in the condenser built up to approximately 4000 volts, the spark-gap switch spontaneously broke down, allowing current to flow through the gap and the detonator circuits.

Bridge wires in the detonators were vaporized by the high-voltage pulse. This detonated the explosive material in the detonators, which in turn ignited the high-explosive charges of the sphere, creating a spherically convergent detonation wave which compressed the nuclear components to supercriticality.

(b)(1), (b)(3)

Chapter V - Mk 4 Improvement

After the Mk 4 entered stockpile, design improvements continued despite the fact that much of the engineering staff was transferred to work on other weapons. A list of desirable modifications was compiled, based on a joint military-Sandia survey, and, after thorough review, was formally issued May 18, 1949, under the title "Desired Military and Technical Characteristics of FM Type Atomic Weapons."[48]

Five areas were listed, including weapon battery, ballistics, inflight nuclear insertion and extraction, lightweight case, and improved fuzing system. Battery improvement, due to the state of the art, was deferred for later consideration; the ballistics story has been developed in Chapter III.

The inflight nuclear insertion and extraction project was already well under way, as studies had started in early 1948, (b)(3) [redacted]

Facilities for supporting the antenna nose plate and sphere access door while the nuclear capsule was being guided into position were also provided. This support device was temporarily bolted to the nose of the bomb while it was in the bomb bay of the aircraft proceeding to target, and was manually operated.[18] A later production version eliminated the support arms for the nose plate and access door, which by that time had been much reduced in weight.

(b)(3)

It was originally felt that the Mk 4 should be protected against flak by an outer case of 1/4-inch-thick armor plate. Those attending the August 25, 1945, meeting that discussed general bomb features had felt that this protection was unnecessary,[22] and as a result the weapon was constructed with a case of 3/8 inch-thick mild steel. The Bureau of Ordnance later noted that aluminum offered somewhat better protection than steel, when equal weights of materials were used, and as a result some reduced-scale aluminum cases of 3/4-inch thickness were designed, built, and drop tested in 1947. However, the fact that strong steel cases were normally used in bomb construction led the Mk 4 designers back to this material.

The Air Force was of course vitally interested in anything that would reduce the weight of the bombs they carried, in order to increase the range and altitude of the carrying aircraft, and this subject was discussed in various meetings at Kirtland Field and the Los Alamos Scientific Laboratory during the fall of 1948.[51] Sandia Laboratory forwarded a memorandum to the Division of Military Application on September 29, 1948, stating that it should be possible to reduce the weight of the Mk 4 by using aircraft-type design in the front and rear case sections, but that this work would delay the Mk 4 stockpile delivery date.[52] It was suggested that some preliminary design be undertaken by aircraft engineers cleared as members of the aerodynamics panel.

This topic was mentioned in the September 30, 1948, meeting of the Sandia Research and Development Board, with Sandia pointing out that the change would necessitate a major change in material sources, tooling, and bomb handling equipment, and that a thorough stress analysis would be required.

Subsequently, considerable correspondence on the subject developed between the Division of Military Application, Military Liaison Committee, AEC, and Sandia, with efforts being made to determine whether or not there was a real need for the heavy case for either flak protection or storage.[53,54,55,56] On December 24, 1948, Sandia informed AEC that a development program for reduction of Mk 4 Bomb weight had been established at Project Roger (the Army's Rock Island Arsenal, which was handling certain weapons production work) and its subcontractor, the American Car and Foundry Company. The purpose of this program was to evaluate and recommend weight reductions based on an aluminum outer case produced by the same tools used for forming the steel casing.[57]

Meanwhile, various pressures were exerted both for and against the design of a lightweight case,[58,59,60] with the matter being decided February 17, 1949, when the Division of Military Application directed Sandia to subcontract the design of an aluminum case.[61] On March 16, Northrop Aircraft, Inc., was invited to design a riveted case,[62] and in May the American Car and Foundry Company was asked to design a welded case.

Ballistic testing of both the riveted and welded cases was conducted in December 1949, and static and dynamic tests were run at Wright Field.[63] These proved that both cases were satisfactory, and, inasmuch as cost and weight comparisons were roughly equivalent, it was decided to procure both types.[64,65,66,67] Production of the riveted design was turned over to Project Royal (the AEC manufacturing facility at Kansas City), and the

American Car and Foundry Company started to fabricate the welded case. A memorandum from Sandia to the AEC April 5, 1950, noted the desirability of minimum weights for all bomb components, and stated that Sandia was investigating the possibility of also reducing the weight of the inner sphere case.[68] However, about this time, the entire weight-reduction program was transferred from the Mk 4 to the Mk 6 design.

(b)(1), (b)(3)

Design and production problems were encountered with the Abee and, for a time in late 1949 and early 1950, consideration was given to a simple barometric fuze. However, the Los Alamos requirement that the bomb detonate at a relatively precise distance above the target inevitably brought the designers back to consideration of a radar fuze.

Meanwhile, some short-range improvements were made to the Archie.[69] Various range (height of burst) modifications had been provided by the use of separate delay lines that were soldered into the instrument for each range. This made it difficult to alter the height of burst rapidly when targets were changed,[70] and in the fall of 1949, a modified Archie (AR-10A) with plug-in delay lines was introduced, eliminating the soldering task. A still more powerful radar (to be called Albert) was proposed, and work proceeded intermittently on this design.

At a meeting of the Sandia Research and Development Board, on September 19, 1949, an addition of a "Black Box" to the radar system was considered.

(b)(1), (b)(3)

Meanwhile, it was becoming evident that the lightweight case and the improved fuze could be put into production simultaneously, and in July 1950 a high-priority or "crash" program called 4-N was established. (b)(3)

Shortly thereafter, however, it was decided to treat the modified Mk 4 as an entirely new weapon, and the program evolved into the Mk 6.

Design attention was also given to improving the pressure-operated or barometric switch which "armed" or placed the radar in operational condition. The original approach had been to consider the interior of the bomb as a plenum or pressure chamber and to measure the pressure as the bomb fell through the air toward the target. Vent holes to the external atmosphere were located in the nose of the bomb, and it became necessary to provide an airtight seal between the sections of the bomb case. It was at first thought that an inflatable rubber tube would serve for this seal,[74] but it was found impossible to maintain air pressure in this tube. In addition, the relatively large volume of the plenum chamber made it difficult to secure rapid responses to changes in external air density, and it was decided to substitute a small-volume manifold constructed from a length of tubing bent into a circular shape and installed under the contour of the bomb skin near the tail. Because of the possibility of the nose ports becoming plugged with ice,[75] they were relocated in the tail plate.[76]

It was found that, as the bomb neared closure altitude, the baroswitch contacts chattered, and the switches were shock mounted to minimize vibration. A new design of baroswitch became available in mid-1950, but it chattered in similar fashion, proving that the cause of the trouble was in the weapon and not the switch. Inasmuch as it was felt that the light case would solve this difficulty, this phase of the project was canceled.

Plans for protecting the Mk 4 in storage were proposed in the fall of 1948, using various combinations of plastic bags and a plywood crate.[77] It was eventually decided to make the entire weapon weathertight, and this reintroduced the case-sealing problem. A solution was found in January 1950, when a solid gasket was put into production.[78]

As the Mk 4 started to move into design history, to be replaced by its successor, the Mk 6, Sandia could point to many notable achievements. Technical problems in the field of aerodynamics had been met and solved, many in areas where there had been no previous experience. Major advances were made in the design and manufacture of telemetry equipment, again in a field where there had been little prior knowledge. Weapon components were designed that were easier to manufacture, assemble, and use, and which possessed a higher degree of reliability. In addition, a whole family of field-test and handling equipment had been designed.

Sandia created the Mk 4 weapon under the impact of a combination of circumstances that might well have daunted larger and more experienced organizations. It was necessary to move to a new location, design and build new facilities, and provide proper personnel housing--all in the face of postwar material shortages. A working force was recruited, despite the general outward wave of migration from the atomic project that occurred at the end of World War II, and despite competition with other employers in a country just starting a gigantic postwar reconversion effort. Sandia operated in a more or less continuous atmosphere of "crash" programs, with new days bringing fresh challenges of both national and international importance.

Perhaps the foregoing can be summed up in the statement that Sandia built a weapon while it was building a corporation. Either job was of sufficient magnitude--the fact that they were both successfully and simultaneously accomplished meant that this new organization of Sandia possessed the competence that was to earn it a respected position in the field of nuclear weaponry. Sandians, both old and new, can be justifiably proud of this achievement.

Glossary of Mk 4 Terms

<u>Aberdeen Ballistics Laboratory</u> -- A Navy laboratory operating a ballistics testing range near Aberdeen, Maryland.

<u>Archies</u> -- Code name for a relatively short-range radar initially developed for installation in the tail of single-seater airplanes to warn the pilot of enemy approach from the rear. Radars emit a pulse of high-frequency energy and measure the time lapse from that transmission to receipt of a reflected electrical "echo" from an object. This time measurement determines the distance of the object from the transmitting antenna of the radar.

<u>Armed Forces Special Weapons Project</u> -- An interdepartmental agency formed to handle military functions relating to atomic weapons. Activated by a memo order from the Secretaries of War and Navy, January 29, 1947. The Air Force was represented in AFSWP after the passage of the National Security Act July 29, 1947.

<u>Askania Camera</u> -- A motion-picture camera that can photograph an object in space and record the angular position of that object in relation to the camera. By having two or more Askanias whose location on the earth's surface is precisely known, the location of the object at any given instant can be determined.

<u>Atomic Energy Commission (AEC)</u> -- A civilian agency which absorbed the functions of the Manhattan Engineer District on January 1, 1947.

<u>Ballistics</u> -- The science which studies the laws governing the motion of projectiles or of bombs dropped from aircraft.

<u>Barometric Switch</u> -- An electrical switch whose contacts are closed or opened by a bellows which contains a charge of air at a precisely calibrated pressure. The increase or decrease of atmospheric air pressure external to the flexible bellows causes the bellows to expand or contract.

<u>Bikini Atoll</u> -- An extension of the Pacific Proving Grounds, approved by the AEC September 11, 1952, to accommodate increased test requirements. Construction was started in late 1952. See Eniwetok Atoll.

<u>Bureau of Ordnance</u> -- A Bureau of the Navy Department concerned with atomic ordnance.

Crash Program -- Term for expedited program.

Crossroads -- Full-scale test operation held at Bikini Atoll July 1946.

Detonators -- Explosive devices which when activated by the X-unit ignite the Detonators of the high explosive sphere. ~~Bridge wires that are subjected to a sudden electrical current, burn rapidly, and act as a match to apply a flame to various points on the outer surface of the high-explosive sphere (which see)~~.

Dipsy-Doodle Flight Tests -- Flight tests in which the airplane follows a roller-coaster type of path, rising and descending through the altitude at which the barometric switches were set to operate, and alternately pointing the radar antennas at the ground (to create an echo, see Archies) and then away from the ground. These tests gauge the effect of interruptions on the circuits of the bomb fuzing system.

Division of Military Application -- An AEC office which functions as liaison between the Military and weapons designers and producers. By provision of the Atomic Energy Act, the Director of this Division is an active member of the Armed Forces.

Eniwetok Atoll -- Original site of the AEC's Pacific Proving Grounds. Located in the Marshall Islands, some 5500 miles west by south from the continental United States. United Nations concurrence was obtained for entry and use. Initial usage was as the site of a ship-based operation. Permanent facilities were constructed for use after Operation Sandstone in the spring of 1948.

Fat Man -- Code name for the implosion weapon dropped on Nagasaki, Japan, during World War II. So named for its short, fat silhouette in contradistinction to the early gun-type weapon, which was called the Thin Man (later the Little Boy). The term was extended to include the general designs of early implosion weapons, such as the Mk 4.

(b)(3)

High-Explosive Sphere -- The ball of high explosive that ~~creates the implosion effect~~ surrounds the nuclear pit and capsule and is designed to produce the implosion effect when detonated.

Implosion-Type Bomb -- A weapon based on the principle discovered by Professor Charles E. Munroe, Washington, D. C. Written up by him in Scribner's Magazine and the American Journal of Science in 1888 and in Popular Science Monthly in 1900. Rediscovered by Egon Neuman of Germany, who secured German and English patents in 1910-11. The Munroe principle notes that an increased explosive effect is created when an unconfined cylinder of high explosive is hollowed out. In 1920 the Journal of the Society of Chemical Industry (London) stated that "no practical use has apparently been made of this discovery." Suggested by S. H. Neddermeyer at Los Alamos as a means for producing the extremely high pressures required on the capsule of an atomic bomb. Not much attention was paid to the suggestion until it received the backing of John von Neumann and George Kistiakowsky. The same principle was used in the Pacific area in World War II as a means of destroying Japanese pillboxes, and for increasing the penetrating effect of rockets.

Kiloton Yield -- A means of measuring the effect of a nuclear explosion by comparing it with the effect of an explosion of TNT. One-kiloton yield is equivalent to the effect of 1000 tons of high explosive.

Kirtland Field -- An Air Force Base located in Albuquerque, New Mexico, and using part of the facilities of the Municipal Airport (Sunport). Kirtland Field was built in 1939 with the help of federal funds. Named for Colonel Roy F. Kirtland, one of the earliest Army aviators.

(b)(3)

<u>Manhattan Engineer District</u> -- A district of the Army Corps of Engineers established in August 1942 under the command of General Leslie R. Groves to develop weapons using atomic energy.

<u>Military Liaison Committee</u> -- A committee established by the Atomic Energy Act of 1946 to advise and consult with the AEC and on behalf of the Department of Defense, on all atomic-energy matters relating to military applications of atomic weapons. Chairman can be any active or retired officer of the Armed Forces. Includes a representative or representatives from each Department of the Armed Forces.

<u>Operation Crossroads</u> -- See Crossroads.

<u>Operation Greenhouse</u> -- See Greenhouse.

<u>Operation Sandstone</u> -- See Sandstone.

<u>Oxnard Field</u> -- Constructed in 1929 as the airport for the City of Albuquerque by Frank G. Speakman. Named Oxnard Field in 1931 for James G. Oxnard, who financed its expansion and who was its owner until May 1942, when the area was taken over by the Government for an Air Depot Training Station.

(b)(3)

<u>Radars</u> -- See Archies. Named for <u>RA</u>dio <u>D</u>etecting <u>A</u>nd <u>R</u>anging.

<u>Salton Sea Test Base</u> -- Located on the site of a Naval Auxiliary Air Station on the shores of Salton Sea, California. Acquired in June 1946 for ballistic tests of the Z Division.

<u>Sandia Base</u> -- Located east of the City of Albuquerque and adjoining Kirtland Field. Encompasses the area formerly occupied by Oxnard Field, plus additional land extending south to the Isleta Indian Reservation and east to the Manzano Mountains. Operated under the tripartite control of the Armed Forces Special Weapons Project.

<u>Sandia Laboratory</u> -- An outgrowth of the Los Alamos Laboratory's Z Division. Originally established as Sandia Branch of LASL; in November 1949 it became an independent entity, Sandia Corporation, with a contract with the AEC and under the managerial direction of the Western Electric Company.

<u>Sandia Research and Development Board</u> -- A joint Sandia Laboratory-military board formed at Sandia Base to provide local guidance on weapons design.

Sandstone -- Full-scale test operation held in the Pacific in April 1948.

Tactical and Technical Liaison Committee -- A committee of Air Force officers established to provide liaison between the atomic project and the Air Force prior to admittance of the Air Force as a member of the Armed Forces Special Weapons Project.

Telemetry -- The science of radio transmission of information to a ground station from an object traveling in space.

Wendover Field -- Located in Utah, west of Salt Lake City. A training location for the Army Air Forces work with wartime atomic bombs.

W-47 Flight Test Group -- The Army Air Forces group stationed at Wendover Field during World War II. Part of this group was transferred to Kirtland Field after the war and helped in the bomb drops at Los Lunas.

Yagi -- A radar antenna developed by a Japanese scientist.

X-Unit -- ~~A high-voltage transformer.~~ A device used to provide high voltage to the weapon detonators.

Z Division -- A Los Alamos Laboratory division established in July 1945 to handle development work on atomic bombs. Part of the Z Division was moved to Sandia Base at the close of the war, and became the nucleus of Sandia Laboratory. Named for Jerrold Zacharias, first leader of the Division.

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17. SRD Minutes, RS 3466/50124, Sandia Research and Development Board, 6th Meeting, dtd 5/6/48. SC Archives.

18. (b)(1), (b)(3)

19. SRD Report, RS 3466/33041, Sandia Corporation to Distribution, subject, SL-11, Monthly Progress Report 11/18/48-12/18-48. SC Archives.

20. SRD Report, RS 3466/33076, Sandia Corporation to Distribution, subject, SL-71, Monthly Progress Report 1/18/49-2/18/49. SC Archives.

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23. SRD Ltr, Dale R. Corson to Capt. T. O. Jones, dtd 10/1/45, subject, Use of Bombing Range. SC Archives, microfilm reel MF-SF-SC-13.

24. CRD Ltr, RS SMD-13, C. E. Runyan and L. H. Cherry to Z Division Group Leaders, dtd 7/26/46, subject, Review of Z-4 Ballistic Test Program. SC Archives, microfilm reel 700.

25. SRD Report, RS 3466/4246, Z Division to Distribution, subject, LAMS-574, Monthly Progress Report 4/21/47-5/20/47. SC Archives.

26. SRD Report, RS 3466/4252, Z Division to Distribution, subject, LAMS-637, Monthly Progress Report 9/20/47-10/20/47. SC Archives.

27. SRD Report, RS 3466/27837, Sandia Laboratory to Distribution, subject, SLMS-3, Monthly Progress Report 4/18/48-5/18/48. SC Archives.

28. SRD Report, RS 3466/27839, Sandia Laboratory to Distribution, subject, SLMS-6, Monthly Progress Report 5/18/48-6/18/48. SC Archives.

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(b)(3)

31.

(b)(1), (b)(3)

32. SRD Ltr, Sandia Corporation to Field Manager, AEC-Sandia, dtd 7/21/50, subject, Dud Behavior of Mk 40 Bomb Due to Ballistic Characteristics. SC Archives, microfilm reel MF-SF-SC-28.

33. CRD Ltr, C. H. DeSelm, 1211, to All Concerned, dtd 5/18/50, subject, Minutes of the Meeting Concerning the "41" Light Case Program on May 2 and 3, 1950. SC Archives, microfilm reel MF-SF-SC-44.

34. CRD Ltr, RS 1210/5141, R. A. Bice, 1210, to R. W. Henderson, 1200, dtd 8/1/50, subject, "41" Case Design. SC Archives, Folder M-4.

35. SRD Ltr, R. P. Peterson and R. W. Henderson to R. E. Poole (all SC) dtd 9/8/50, subject, Spoiler Bands for Mk 4 Bomb, SC Archives, microfilm reel MF-SF-SC-35.

36.

(b)(3)

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38. (b)(1), (b)(3)

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41. (b)(3)

42. SRD Report, RS SC1448(PL), Basic Parts List for the Mark IV Mod 1-C Bomb, dtd 5/25/50. SC Central Technical Files.

43. SRD Report, RS SC1474(PL), Basic Parts List for the Mk 4 Mod 2-C Bomb, dtd 6/23/50. SC Central Technical Files.

44. SRD Report, RS SC1997(PL), Basic Parts List for the Mk 4 Mod 2-D Bomb, dtd 8/27/51. SC Central Technical Files.

45. SRD Report, RS SC2299(S), Analysis of the AEC Mk 4 Stockpile as of 12/31/51, dtd 4/52. SC Central Technical Files.

46. (b)(3)

47. (b)(3)

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49. (b)(3)

50. (b)(3)

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52. SRD Ltr, Paul J. Larsen to Brig. Gen. James McCormack, Jr., DMA, dtd 9/29/48. AEC Archives, Mk 4, LASL.

53. SRD Minutes, RS 3466/60030, Sandia Research and Development Board to Distribution, 13th Meeting, dtd 12/16/48. SC Archives.

54. SRD Ltr, Armed Forces Special Weapons Project to United States Atomic Energy Commission, dtd 10/21/48. AEC Archives, Mk 4, LASL.

55. SRD Ltr, Armed Forces Special Weapons Project to United States Atomic Energy Commission, dtd 11/4/48. AEC Archives, Mk 4, LASL.

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57. SRD Ltr, Paul J. Larsen to Carroll L. Tyler, SFOO, dtd 12/24/48. AEC Archives, Mk 4, LASL.

58. SRD Ltr, Field Command to Armed Forces Special Weapons Project, dtd 1/19/49, subject, Development of Lightweight Case for Mk 4 Bomb. Air Force Special Weapons Center Files, General Correspondence, Field Office for Atomic Energy, 8/12/48-10/27/49.

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60. SRD TWX, Division of Military Application to Santa Fe Operations Office and Los Alamos Scientific Laboratory, dtd 1/29/49. AEC Archives, Mk 4, LASL.

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63. SRD Report, RS 3466/25050, Sandia Corporation to Distribution, subject, Monthly Progress Report, December 1949. SC Archives.

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69. SRD Minutes, RS 3466/60049, Sandia Research and Development Board to Distribution, 17th Meeting, dtd 2/17/49. SC Archives.

70. SRD Ltr, Field Command, Sandia Base, to Director, Sandia Laboratory, dtd 8/29/49, subject, Archie Ranges. SC Archives, microfilm reel 743.

71. (b)(3)

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