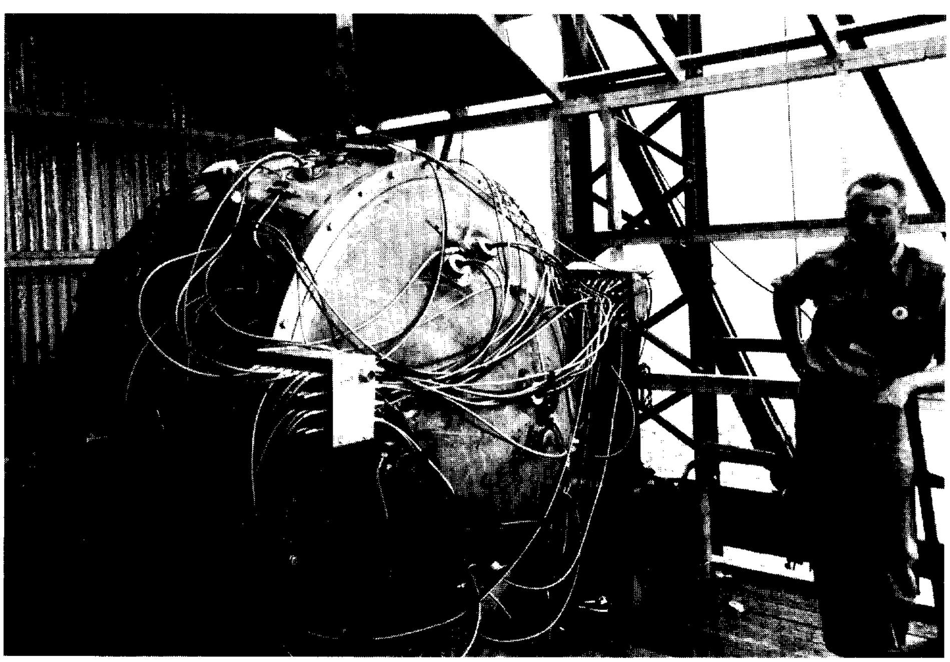
Weapon Design

We've Done a Lot but We Can't Say Much

by Carson Mark, Raymond E. Hunter, and Jacob J. Wechsler

The first atomic bombs were made at Los Alamos within less than two and a half years after the Laboratory was established. These first weapons contained a tremendous array of high-precision components and electrical and mechanical parts that had been designed by Los Alamos staff scientists, built by them or under their direction, and installed by them in much the same way as they might have put together a complicated setup of laboratory equipment. Immediately following the end of the war, a large fraction of those who had been involved with these matters left Los Alamos to resume activities interrupted by the war. They left behind little written information about the manufacture, testing, and assembly of the various pieces of a bomb.

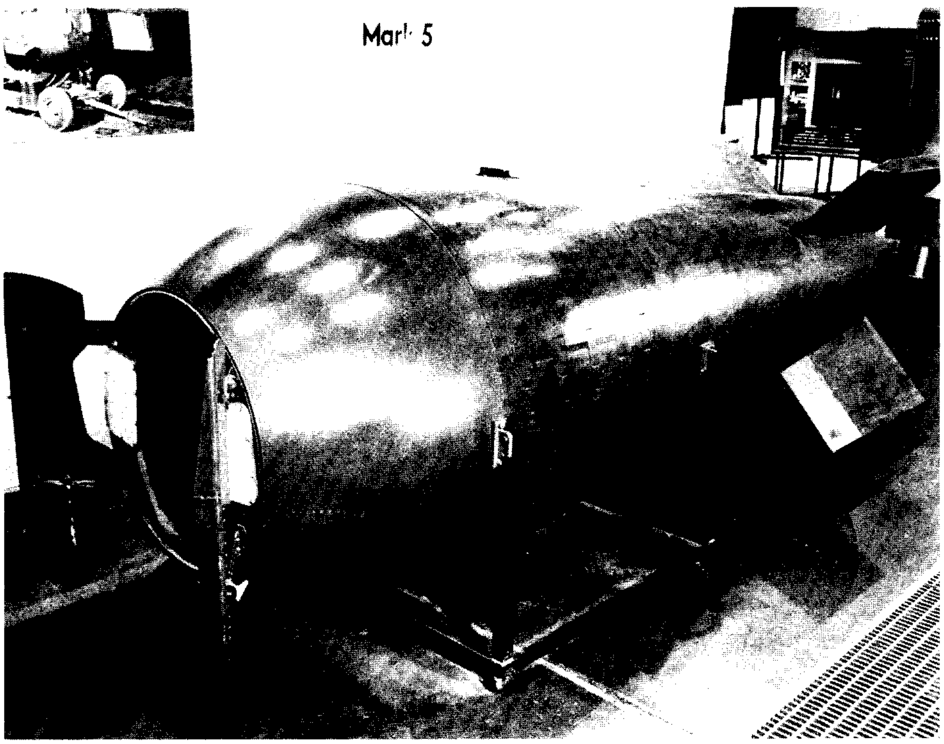


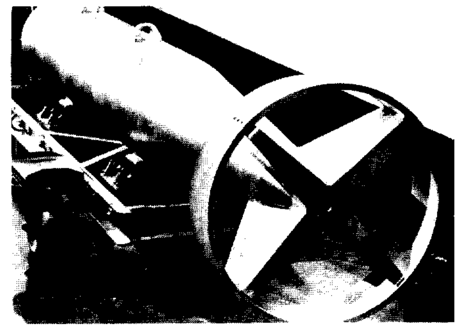
The Trinity device, the first nuclear weapon, atop the 100-foot tower on which it was mounted for the test on July 16, 1945. Norris Bradbury stands next to the device.

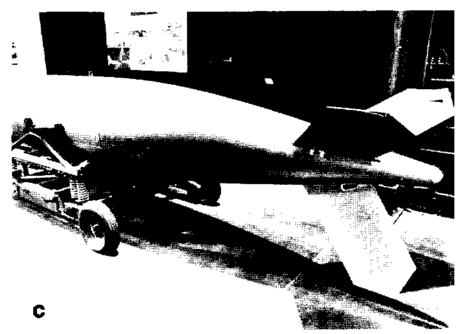
This gap had to be filled by the Laboratory, and particularly by the newly formed Z Division, which was responsible for ordnance engineering. Z Division had been moved to Sandia Base in Albuquerque where it could be in closer touch with the military personnel who might ultimately have to assemble and maintain completed weapons and where storage facilities for weapons and components were to be established.

For several years the Laboratory people at Sandia, and many of those at Los Alamos, were heavily engaged in preparing a complete set of instructions, manuals, and manufacturing specifications, in establishing production lines for various parts, and in instructing military teams in the handling, testing, and assembly processes for weapons having the original pattern. Los Alamos continued to supply the more exotic components, including the nuclear parts, initiators, and detonators required for the stockpile.

At the same time, work at Los Alamos proceeded on developing a completely new implosion system, which evolved into the Mark 4, with improved engineering and production and handling characteristics. Successful demonstration of essential features of the new system, in the Sandstone







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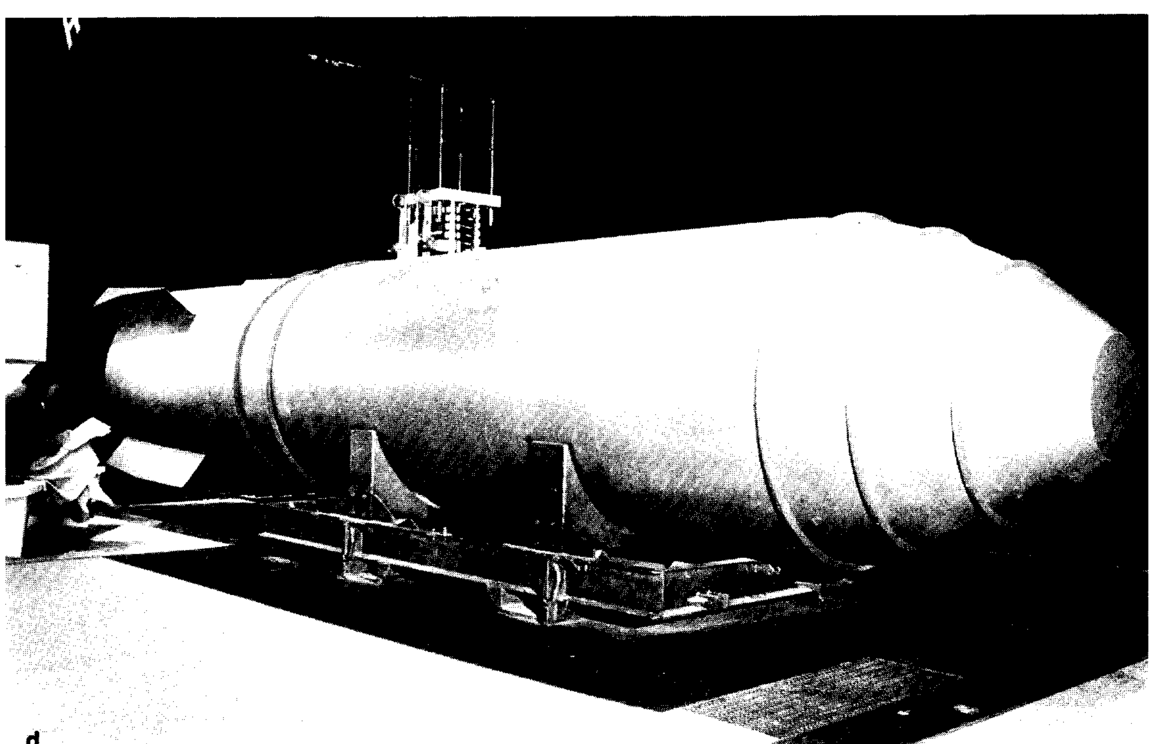

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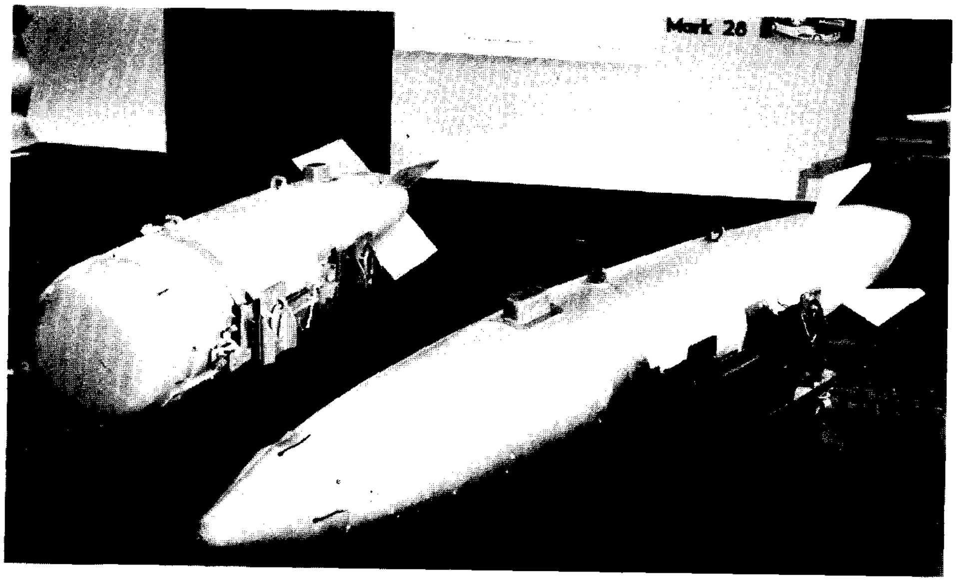

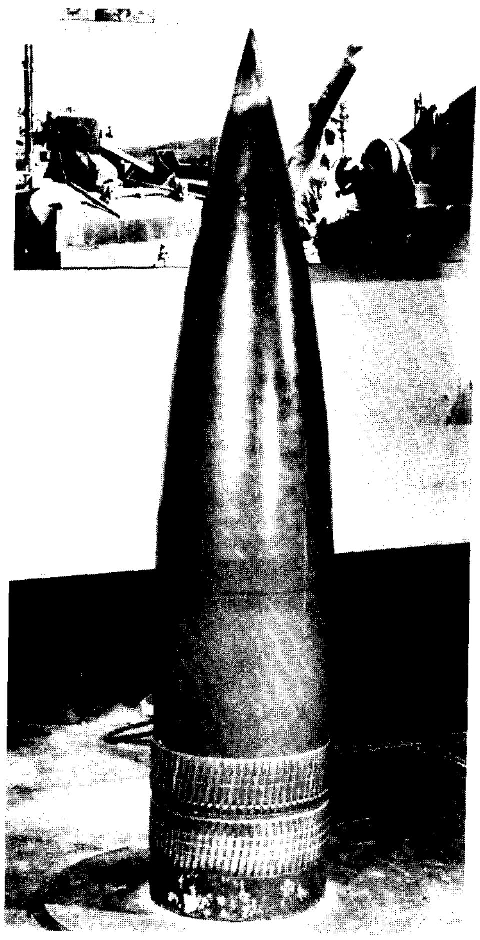

The nation's stockpile of nuclear weapons has included about fifty designed by the Laboratory, each having unique nuclear yield, size, weight, shape, ballistic performance, and safety features. Shown here are a number of early designs. (a) The Mark 5 was a smaller and lighter implosion weapon than previous designs. Its weight was one-third that of the Hiroshima weapon and one-half that of the Nagasaki weapon. The nuclear warhead was loaded through the doors in the casing. (b) The Mark 7, which could be carried on the outside of an airplane rather than in a bomb bay, added nuclear capability to smaller, faster fighter aircraft. (c) The Mark 8, an early penetration bomb, could penetrate 22 feet of reinforced concrete, 90 feet of hard sand, 120 feet of clay, or 5 inches of armor plate before detonating. (d) The Mark 17 was the first deliverable thermonuclear weapon. This massive bomb weighed 21 tons and could be carried in a B-36 after modifications were made to the bomb bay. Pilots who test-dropped the weapon reported that the plane rose hundreds of feet after the weapon was dropped, as if the bomb released the plane rather than the reverse. (e) Two weapons armed with the W28 warhead. The W28 warhead was a high-yield, small-diameter thermonuclear device. (f) The Mark 19, a projectile weapon, added nuclear capability to artillery that previously fired conventional shells. (Photographed at the National Atomic Museum, Albuquerque, New Mexico.)

test series at Eniwetok in the spring of 1948, ended the laboratory-style layout of weapons and opened the way for mass production of components and the use of assembly-line techniques. In addition, the Sandstone tests confirmed that the growing stockpile of uranium-235 could be used in implosion weapons, which were much more efficient than the gun-type weapons in which uranium-235 had previously been used.

In mid 1949 the Sandia branch of the Los Alamos Laboratory was established as a separate organization: the Sandia Laboratories, operated under a contract with Western Electric. New plants set up at various locations around the country gradually took over the production of components for stockpile weapons, although Los Alamos continued to carry appreciable responsibilities of this sort until some time in 1952.

The experience gained in the successful development of the Mark 4 put the Laboratory in a position to move much more rapidly and with more assurance on the development of other new systems. A smaller and lighter weapon, called the Mark 5, was tested successfully in 1951. Further advances followed very rapidly in subsequent test series and have resulted in today's great range of options as to weapon size, weight, yield, and other characteristics. The Laboratory can now prepare a new design for nuclear testing in a form that can readily be transferred to the manufacturing plants for production of stockpile models.

The early concern for safety in handling nuclear weapons, especially during the takeoff of aircraft, led to the development of mechanical safing mechanisms that ensured no nuclear explosion would occur until release of the weapon over a target. These mechanisms eliminated the tricky and somewhat hazardous assembly of the final components of a bomb during flight.

Studies of the possibilities of using thermonuclear reactions to obtain very large explosions began in the summer of 1942—almost a year before the Los Alamos Laboratory was formed. Such studies continued here during the war, though at a necessarily modest rate partly because the Laboratory's primary mission was to develop a fission bomb as rapidly as possible, partly because a fission bomb appeared to be prerequisite to the initiation of any thermonuclear reaction, and partly because the theoretical investigation of the feasibility of achieving a large-scale thermonuclear reaction—at least the "Classical Super" form then considered—was enormously more difficult than that required in connection with obtaining an explosive fission reaction. Studies of possible thermonuclear weapons continued here in the years immediately after the war, but these too were necessarily limited in scope. Only one of the small but capable group working on the Super during the war continued on the Los Alamos staff after the spring of 1946. In addition, the need for improvements in fission weapons was evident and pressing. And, for several years at least, the computing resources available here (or anywhere else in the country) were completely inadequate for a definitive handling of the problems posed by a thermonuclear weapon.

Nevertheless, in 1947 the pattern emerged for a possible "booster," that is, a device in which a small amount of thermonuclear fuel is ignited by a fission reaction and produces neutrons that in turn enhance the fission reaction. In 1948 it was decided to include a test of such a system in the series then planned for 1951. Following the first test of a fission bomb by the Soviets in August 1949, President Truman decided at the end of January 1950 that the United States should undertake a concerted effort to achieve a thermonuclear weapon even though no clear and persuasive pattern for such a device was available at that time. In May of 1951, as part of the Greenhouse test series, two experiments involving thermonuclear reactions were conducted. One, the George shot, the design of which resulted from the crash program on the H-bomb, confirmed that our understanding of means of initiating a small-scale thermonuclear reaction was adequate. The other, the Item shot, demonstrated that a booster could be made to work.

Quite fortuitously, in the period between one and two months preceding these experiments but much too late to have any effect on their designs, a new insight concerning thermonuclear weapons was realized. Almost immediately this insight gave promise of a feasible approach to thermonuclear weapons, provided only that the design work be done properly. This approach was the one of which Robert Oppenheimer was later (1954) to say, "The program we had in 1949 was a tortured thing that you could well argue did not make a great deal of technical sense . . . . The program in 1951 was technically so sweet that you could not argue about that." On this new basis and in an impressively short time, considering the amount and novelty of the design work and engineering required, the Mike shot, with a yield of about 10 megatons, was conducted in the Pacific on November 1, 1952.

As tested, Mike was not a usable weapon: it was quite large and heavy, and its thermonuclear fuel, liquid deuterium, required a refrigeration plant of great bulk and complexity. Nevertheless, its performance amply confirmed the validity of the new approach. In the spring of 1954, a number of devices using the new pattern were tested, including the largest nuclear explosion (about 15 megatons) ever conducted by the United States. Some of these devices were readily adaptable (and adopted) for use in the stockpile.

Since 1954 a large number of thermonuclear tests have been carried out combining and improving the features first demonstrated in the Item and Mike shots. The continuing objective has been weapons of smaller size and weight, of improved efficiency, more convenient and safe in handling and delivery, and more specifically adapted to the needs of new missiles and carriers.

Other developments in weapon design, though less conspicuous than those already referred to, have also had real significance. Some of the more important of these have to do with safety. The rapidly developing capability in fission weapon design made it possible to design a weapon that would perform as desired when desired and yet that would have only a vanishingly small probability of producing a measurable nuclear yield through an accidental detonation of the high explosive. Thus, the mechanical safing systems were replaced by weapons that, because of their design, had intrinsic nuclear safety. Today all nuclear weapons are required to have this intrinsic safety.

Another major development in nuclear weapon safety has to do with the high explosives themselves. Most of the explosives that have been used in nuclear weapons are of intermediate sensitivity. They can reliably withstand the jolts and impacts associated with normal handling and can even be dropped from a modest height without detonating. Still, they might be expected to detonate if dropped accidentally from an airplane or missile onto a hard surface. Since, as noted above, all weapons are intrinsically incapable of producing an accidental nuclear yield, accidental detonation of the high explosive would not cause a nuclear explosion. Detonating explosive would, however, be expected to disperse any plutonium associated with it as smoke or dust and thereby contaminate an appreciable area with this highly toxic substance. To reduce this hazard, much less sensitive high explosives are, where possible, being employed in new weapon designs or retrofitted to existing designs.

A quite different development has to do with weapon security. In the event, for example, that complete weapons should be captured by enemy troops or stolen by a terrorist group, it would evidently be desirable to make their use difficult or impossible. A number of schemes to achieve such a goal can be imagined, ranging from coded switches on essential circuits (so that the weapon could not be detonated without knowing the combination) to self-destruct mechanisms set to act if the weapon should be tampered with. A variety of inhibitory features have been considered, and some have been installed on weapons deemed to warrant such protection.

A final development worthy of attention is the advent of “weapon systems.” This term refers to the integration of a carrier missile and its warhead, that is. to the specific tailoring of the warhead to the weight, shape, and size characteristics of the missile—as in the case of a Minuteman ICBM or a submarine-launched ballistic missile. The missile-cum-warhead constitutes an integrated system that is optimized as a unit. This integration contrasts with the earlier situation in which nuclear devices were to be taken from a storage facility and loaded on one or another suitable plane (or mated to a separately designed re-entry vehicle) to meet the mission of the moment. One should also note that the great improvements realized in missile guidance and accuracy have made it possible to meet a given objective with a smaller explosion and, hence, a smaller nuclear device. A missile can therefore now carry a number of warheads, each specifically tailored to meet the characteristics of the carrier. A consequence of integration is that the weapon system—a carrier with its warhead or warheads—is required to be ready for immediate use over long periods of time.

This change from general-purpose bombs to weapon systems has had significant effects on warhead design and production. For one thing, a very much larger premium attaches to reducing the maintenance activities associated with a nuclear device to an absolute minimum. Today, warheads require essentially no field maintenance and will operate reliably over large extremes in environmental conditions. As a separate matter, since a new carrier involves considerably greater cost and lead-time than does a new warhead, the production schedules (and budget limitations) for the carrier govern the production schedules and quantities of the warheads.

In response to the considerations mentioned here, as well as to new insights in explosive device behavior, a rapid evolution in design requirements and objectives has occurred and may be expected to continue. ■