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LOS ALAMOS SCIENTIFIC LABORATORY

of

THE UNIVERSITY OF CALIFORNIA

Report written:
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[redacted] A.

NUCLEAR WEAPONS

ENGINEERING AND DELIVERY

Volume 23

Los Alamos Technical Series (U)

Compiled by:

Norman Ramsey
Raymond L. Brin

CIRCULATION LIMITED

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CHAPTER 1

HISTORY OF PROJECT A

N. F. Ramsey

1.1 INTRODUCTION

The history of Project A is essentially the history of the combat use of the atomic bomb and of the preparation and planning to make possible this use. Project A was responsible for the unification and direction of all activities concerned with the use of a nuclear explosion as a bomb to be delivered to the enemy (as opposed to the experimental firing of such nuclear explosion on a test site). This assignment included: responsibility for design and procurement of components required to convert a nuclear explosion into a combat bomb; coordination with Air Forces activities, including the modification of suitable aircraft; supervision of field tests on bombs without active material; planning and establishment of the necessary advance base where the final bombs would be assembled; assembly of active bombs and loading into the aircraft; supervision of all tests and actions pertaining to the bomb while aboard the aircraft but prior to release, etc. Many of these responsibilities were shared with other groups anddivisions at Project Y (Los Alamos), but the basic responsibility for unifying all these activities was that of Project A.

Project A, as such, was not established until March, 1945. However, the activities that later became the responsibility of Project A were initiated long before this time in a different organizational form but with many of the same men in responsible positions. During the earlier period, most of what were later defined as Project A problems were known as delivery problems, i.e., problems concerned with the successful delivery of an atomic bomb against the enemy. For this reason, a history of Project A should begin with a history of the delivery program at Project Y prior to establishment of Project A.

1.2 HISTORY OF DELIVERY PROGRAM PRIOR TO ESTABLISHMENT OF PROJECT A

Prior to the establishment of Project A, the delivery program was primarily the responsibility of Captain W. S. Parsons, U.S. Navy, who headed the Ordnance Division at Project Y, and N. F. Ramsey who was in charge of the Delivery Group. These responsibilities were, however, completely shared with Commander Francis A. Birch who headed the Gun Group, K. T. Bainbridge who, until the establishment of Project A, was responsible for the design of the implosion model, R. B. Brode who was in charge of the Fuzing Group, and George W. Galloway who headed the Engineering Group.

The first major activities of any kind concerned with the delivery program began in June, 1943 when Ramsey, at Parsons' request, surveyed the Air Forces aircraft to determine approximate sizes, shapes and weights of bombs that could be carried in such aircraft. [redacted]

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As a result of this survey, it was apparent that the B-29 was the only United States aircraft in which such a bomb could be conveniently carried internally, and even this plane would require considerable modification so that the bomb could extend into both the front and rear bomb bays by being close under the main wing spar. Except for the British Lancaster, all other aircraft would require such a bomb to be carried externally unless the aircraft were very drastically rebuilt.

On August 13, 1943, the first drop tests of a prototype atomic bomb were made at the Dahlgren Naval Proving Ground to determine stability in flight. These tests were on a 14/23 scale model of a bomb shape which was then thought probably suitable for a gun assembly. [Essentially, the model consisted of a long length of 14-inch pipe welded into the middle of a split standard 500-pound bomb.] It was officially known at Dahlgren as the "Sewer Pipe Bomb". For security reasons, Ramsey, who was in charge of these tests, presented himself as a representative of Section T, NDRC, and much of the construction work on the model was conducted at the Applied Physics Laboratory, Silver Spring, Maryland. The first test at Dahlgren was an ominous and spectacular failure. The bomb fell in a flat spin such as had rarely been seen before. However, an increase in fin area and a forward movement of the center of gravity provided stability in subsequent tests.

In the months following August, further tests of 14/23 scale models of current and ever-changing gun models were made at Dahlgren. The modifications resulting from these tests were, in turn, incorporated into the design. Also during this time, preliminary models of a proximity fuze, which were constructed at the University of Michigan at Brode's request, became available. These were extensively tested at Dahlgren beginning on December 3, 1943.

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In September, 1943, the fast-implosion model was proposed by John Von Neumann as an alternative to the slow implosion. As it became clear that this model was a promising one, preliminary planning for converting it into a bomb was begun. A preliminary estimate of 59 inches diameter and 9000-pound weight was made by Von Neumann and Ramsey, and on this basis the Bureau of Standards bomb group was asked to design suitable fairing and stabilizing fins for such a bomb.

In the Fall of 1943 it became apparent that plans for full-scale tests should be started. In view of the critical shortage of B-29's it was first proposed that a British Lancaster be used for the test work, even though a B-29 would almost certainly be used as the combat ship. The Air Force, however, wisely recommended that a B-29 be used for the test work as well, both to avoid non-standard maintenance and to accumulate experience in B-29 operations with such a bomb. In order that the aircraft modifications could begin, Parsons and Ramsey selected two external shapes and weights as representative of the current plans at Site Y (Project Y). One of these was 204 inches long with a maximum diameter of 23 inches and was a model for the current gun assembly. The other was 111 inches long and 59 inches in diameter, corresponding to a fast-implosion assembly. For security reasons, these were called by the Air Force representatives the "Thin Man" and "Fat Man", respectively; the Air Force officers tried to make their phone conversations sound as though they were modifying a plane to carry Roosevelt (the Thin Man) and Churchill (the Fat Man). Models to these dimensions were ordered from Detroit. Modification of the first B-29 officially began November 29, 1943. Colonel R. C. Wilson was Army Air Forces Project Officer for all aspects of the program, Colonel D. L. Putt at Wright Field was in charge of the division under whose supervision the modification was done, and Captain R. L. Roark was Project Officer in charge of modification.

Tests with the modified aircraft and full-scale dummy bombs were begun at Muroc, California on March 3, 1944. Brode's fuzing group, Bainbridge's instrumentation group, and the delivery group participated in these tests. Coordination of the activities of the different groups in these and subsequent field tests was a responsibility of Ramsey's delivery group. The purpose of the tests was to check the suitability of the fuzing equipment, the stability and ballistic characteristics of the bombs, the facilities then available for field work, and the suitability of the aircraft to carry and drop the bombs. After four weeks of delay, due to torrential rain on the Mojave Desert and aircraft troubles, a series of tests was completed. The negative results of most of these tests thoroughly justified preliminary tests at such an early date. The fuzes proved to be unreliable and, on the basis of these results, an investigation of the possibility of adapting an AFS-13 fighter tail-warning radar to this use was begun. The Thin Man proved to be very stable in its flight, but the Fat Man -- with a tail that the Bureau of Standards bomb group thought would be extremely stable --, proved to wobble badly with its axis departing 20° from the line of flight. Although the B-29 release mechanism worked satisfactorily for the Fat Man, it failed completely for the Thin Man. Four of the units were bad hang-ups with delays up to 10 seconds, and the final drop was 20 minutes premature while the plane was still climbing to altitude. The bomb in this case fell onto the bomb-bay door which was badly damaged, when the door had to be opened to jettison the bomb. With this accident, the first Muroc tests were brought to an abrupt and spectacular end.

Between the end of the first tests and June 1944, all groups worked to correct the faults demonstrated in the first tests.

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Detailed designing of this shorter model was begun during this period under the supervision of E. M. McMillan and F. A. Birch. Because of the contrast in dimensions with the Thin Man, this model finally acquired the appropriate name of Little Boy. At the same time the detailed designing of the 1222 form of Fat Man assembly was begun.

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Tests at Muroc were resumed in June, 1944. These tests confirmed previous results in that the first form of fuze being developed at Michigan was not satisfactory. The first two APS-13's became available to Project Y during the test, and two haywire drop tests (genuine baling wire was actually used) were made with a field adaptation of this equipment to fuzing. The earlier of these provided the first completely satisfactory fuzing test; and, although the second failed, it was probable that the failure was in some of the hastily prepared auxiliary equipment. The Fat Man, its tail assembly modified from the original circular shroud to a square shroud 59 inches on a side, still proved unstable. As a desperate last resort, Captain David Semple, Project Bombardier, suggested a drop be made with internal 45° baffle plates welded into the inside of the shroud as a field modification. To everyone's surprise, this modification was successful, the bomb being completely stable in its flight and the ballistic coefficient being improved rather than decreased as anticipated. No release failures were experienced in the tests.

Adm Ashworth says this was Parsons suggestion. 9/11/78

From the end of these tests until October, 1944 when similar field tests were resumed, a strenuous program of design and procurement was under way at Site Y to obtain units that could be used as components of an actual atomic bomb rather than units that were merely ballistic models. Three basically different models were on hand at this time. One was the Little Boy model of the U^{235} gun assembly, another was the 1222 Fat Man model of implosion assembly, and the third was a model which evolved into the finally adopted 1561 Fat Man implosion assembly. The latter arose from a redesign for the purposes of simplifying the assembly problem (the assembly of 1222 required the insertion of more than 1500 bolts) and of improving the flight characteristics (by using an ellipsoidal shape for the outer armor). The model finally adopted comprised an inner spherical shell, consisting of two polar caps and a segmented central zone which could be bolted together; this was surrounded by an ellipsoidal armor to which a stabilizing tail, including the necessary drag plates, was attached. The auxiliary fuzing and electrical detonating equipment were mounted in the space between the inner sphere and the outer ellipsoid.

In August of 1943, Colonel R. C. Wilson and Colonel M. C. Demler visited Site Y and recommended that the Air Forces begin immediate training of a combat unit for the delivery of the atomic bomb. It was agreed, therefore, that Site Y (by September 1, 1944) should freeze the external shapes of the three models and other requirements affecting aircraft, so that modification of a production lot of fifteen B-29's could be started. These aircraft were modified at the Martin-Nebraska Plant at Omaha, and the first aircraft became available in October, 1944. Sheldon H. Dike and Milo M. Bolstad were the Project Y representatives during these and subsequent modifications. The special modifications for carrying and releasing the bomb were designed to incorporate the British F and G release mechanism currently used for the British 12,000-pound bomb. This mechanism required only a single lug on the bomb. At this time, Wendover Army Air Base, Wendover, Utah was designated as the center at which training of the new Atomic Bomb Group would be undertaken and at which future field tests would be held. The Second Air Force under General Uzel G. Ent, and later under General Robert B. Williams, was designated as the parent organization of this group. Colonel Paul W. Tibbets was designated commanding officer of the combat group (509 Composite Group), and Captain Charles Begg was in command of the First Ordnance Squadron, Special. Colonel Clifford J. Heflin was commanding officer at Wendover, Major C. S. Shields was in charge of the light Test Section, and Captain Henry Roerkohl was in charge of the Ordnance Test Unit.

The first tests at Wendover in October, 1944, inaugurated a period of tests first intermittently, then monthly, and finally almost continuously, which continued until August, 1945. Initially, the only groups concerned were the Fuzing Group under Brode and Doll, and the Delivery Group led by Ramsey. Subsequently, however, other groups participated in the Wendover tests: the Gun Group headed by Birch, the High Explosives Assembly Group headed originally by Bainbridge and later by Bradbury and Warner, the Electrical Detonator Group headed by Fussell, and the Ballistic Group under M. M. Shapiro. At the end of November, 1944, Commander F. L. Ashworth joined the Project and relieved Ramsey of the responsibility of direct supervision of the field operations, since, by then, important parts of the Delivery Program had, of necessity, to be under way concurrently at Wendover and Site Y. In these, tests units approaching more and more closely the final model were tested for ballistics information, for electrical fuzing information, for flight tests of electrical detonators, for test of the aircraft release mechanism, for vibration information, for assembly experience, for temperature tests, etc. In addition, a number of additional test drops were made at Inyokern, between February 20, 1945 and August, 1945 under the supervision of Charles C. and Thomas Lauritsen, William Fowler, and Commander Hayward, U. S. N.

From October, 1944 until the formal establishment of Project A, the main activities in the Delivery Program were a continuation of development, design, production, and test of bombs, approaching more and more closely the final model. During this period, the 1222 model was definitely abandoned in favor of the 1561 model of the Fat Man. Due to poor flying qualities of the first batch of B-29's and to certain weaknesses in the special project modifications, a new batch of fifteen aircraft was obtained in March and April of 1945. These aircraft, with fuel-injector engines, electrically controlled propellers, very rugged provisions for carrying the bomb, and no armament except the tail turret, proved to be extremely satisfactory. Colonel R. C. Doubleday was Army Air Forces Project Officer at the time of this last modification. In addition to the Wendover tests during this period, numerous physics and engineering tests on complete units were made at V-Site (Los Alamos) initially under the direction of the Delivery Group and of Bernard Waldman and, later (after the formation of Project A), under N. E. Bradbury and Roger S. Warner, Jr. Considerable planning for the establishment of an overseas operating base was done during this period.

1.3 HISTORY OF PROJECT A AT SITE Y

Project A was formally established in March, 1945. Incorporating many groups also assigned to other divisions, its purpose was to unify the activities of those groups concerned with the preparation and delivery of a combat bomb. Captain W. S. Parsons was

Officer in Charge of Project A, N. F. Ramsey was his deputy for scientific and technical matters, Commander F. L. Ashworth was operations officer and military alternate for Captain Parsons, Commander Norris E. Bradbury and Roger S. Warner, Jr. were in charge of Fat Man Assembly, Commander Francis A. Birch was in charge of Little Boy Assembly, R. B. Brode was in charge of fuzing, L. Fussell, Jr. was in charge of the electrical detonator system, Phillip Morrison and Marshall G. Holloway were in charge of the pit (active material and tamper), Luis W. Alvarez and Bernard Waldman were in charge of airborne observations of the combat explosions, George W. Galloway was in charge of engineering, Lt. Col. R. W. Lockridge was in charge of supply, Maurice M. Shapiro was in charge of ballistics and Sheldon H. Dike was in charge of aircraft problems. In addition the following persons were consultants to Project A: William G. Penney on damage problems, H. A. Bethe on general theory, and L. H. Hempelmann on radiological problems. In July, when other personnel moved to Tinian, Sam J. Simmons and Lt. Commander T. J. Walker assumed the responsibility for the Wendover tests. The technical policy committee responsible for initiating technical actions for Project A by means of recommendations to Captain Parsons, was the Weapons Committee, consisting of N. F. Ramsey (chairman), Commander Norris E. Bradbury (Chairman after Ransey's departure), Roger S. Warner, Jr., Commander F. Birch, R. B. Brode, L. Fussell and Phillip Morrison.

Project A at Site Y and Wendover was concerned chiefly with three matters:

(1) The completion of design, procurement and preliminary assembly of units that would be complete in every way for use with active material.

(2) Continuation of the Wendover test program to confirm, insofar as possible without using active material, the adequacy in flight of the components and assembled units.

(3) Preparation for overseas operations against the enemy.

In view of the shortness of the available time, the major designs were necessarily used with as few alterations as possible. The chief design activities during this period were the numerous and urgent ones of supplying the many details necessary for successful operation and of rectifying faults that became apparent in tests. [redacted]

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This was also the period of maximum test activity at Wendover. The unfortunate failure of the Raytheon Company to meet its delivery schedule on X-Units (electrical detonators) added markedly to the difficulty of the test program. This failure reduced the number of tests that were possible on the X-units, prevented efficient testing (since many tests had to be repeated twice, one at an early date with all components except an X-unit and once at a critically late date with an X-unit), and greatly complicated the scheduling of tests since there was at no time a backlog of X-units. The tightness of schedule resulting from this is best illustrated by the fact that it was not until the end of July that sufficient X-units had been tested to confirm their safety with HE; the first HE-filled Fat Man with an X-unit was tested at Wendover on August 4, 1945; the next HE-filled Fat Man with an X-unit was tested at Tinian on August 8, 1945; and the first complete Fat Man with active material was dropped on Nagasaki on August 9, 1945. Despite these difficulties, however, a total of 155 test units was dropped at Wendover or the Salton Sea between October and the middle of August 1945. Much information gathered in these tests were incorporated into the design of the bombs.

Planning for overseas operations was one of the principal activities of Project A during this period. Initial planning and procurement of some kits of tools, etc., began in December, with these activities continuing at an accelerated rate through July. In February of 1945 Commander F. L. Ashworth was sent to Tinian to make a preliminary survey of the location and to select a site for our activities. By March, the construction needs for the Tinian Base were frozen as follows: four air-conditioned 20' x 48' steel rib buildings of the type normally used in the Navy for bomb-sight repair (two for the fuzing team, one for the electrical-detonator team, and one for joint use by the pit team and observation team), three air-conditioned 20' x 70' assembly buildings for which the materials were accumulated at Inyokern, five 40' x 100' steel arch rib warehouse buildings, one building of the same type house as a modification shop, three 10' x 10' x 5' magazines, seven 20' x 50' x 10' magazines, and two special loading pits equipped with hydraulic lifts for loading bombs into the aircraft. A third such pit was constructed at Iwo Jima for possible emergency use. Materials for equipping the buildings and for handling heavy equipment in assembly, tools, scientific instruments, and general supplies, were all included in special kits prepared by the different groups. A kit for a central stock room was also started, but the materials were not shipped by August 4, 1945 (at which time further shipments to Tinian were stopped by the end of the war). Construction of the Tinian base began in April under the supervision of Colonel E. E. Kirkpatrick.

Beginning in May, so-called "batches" of kit materials and of components for test and combat units were transported by ship to Tinian. A total of five batch shipments were made. In addition, a number of air shipments in five C-54 aircraft attached to the 509th Group was made for critically needed items. The availability of these C-54's for emergency shipments contributed greatly to the ability of Project A to meet its schedules in combat use of the atomic bomb.

CHAPTER 2

DESIGN AND ASSEMBLY OF PIT FOR MODEL 1561 FAT MAN *

M. G. Holloway and R. E. Schreiber

2.1 THE PIT

This chapter describes the design and assembly of the Pit, the responsibility for which was primarily assigned to the G-Engineer Group. DOE b(3)

The general arrangement and appearance of these parts is shown in Figure 1.

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* This Chapter was previously issued as LA 619(1946)

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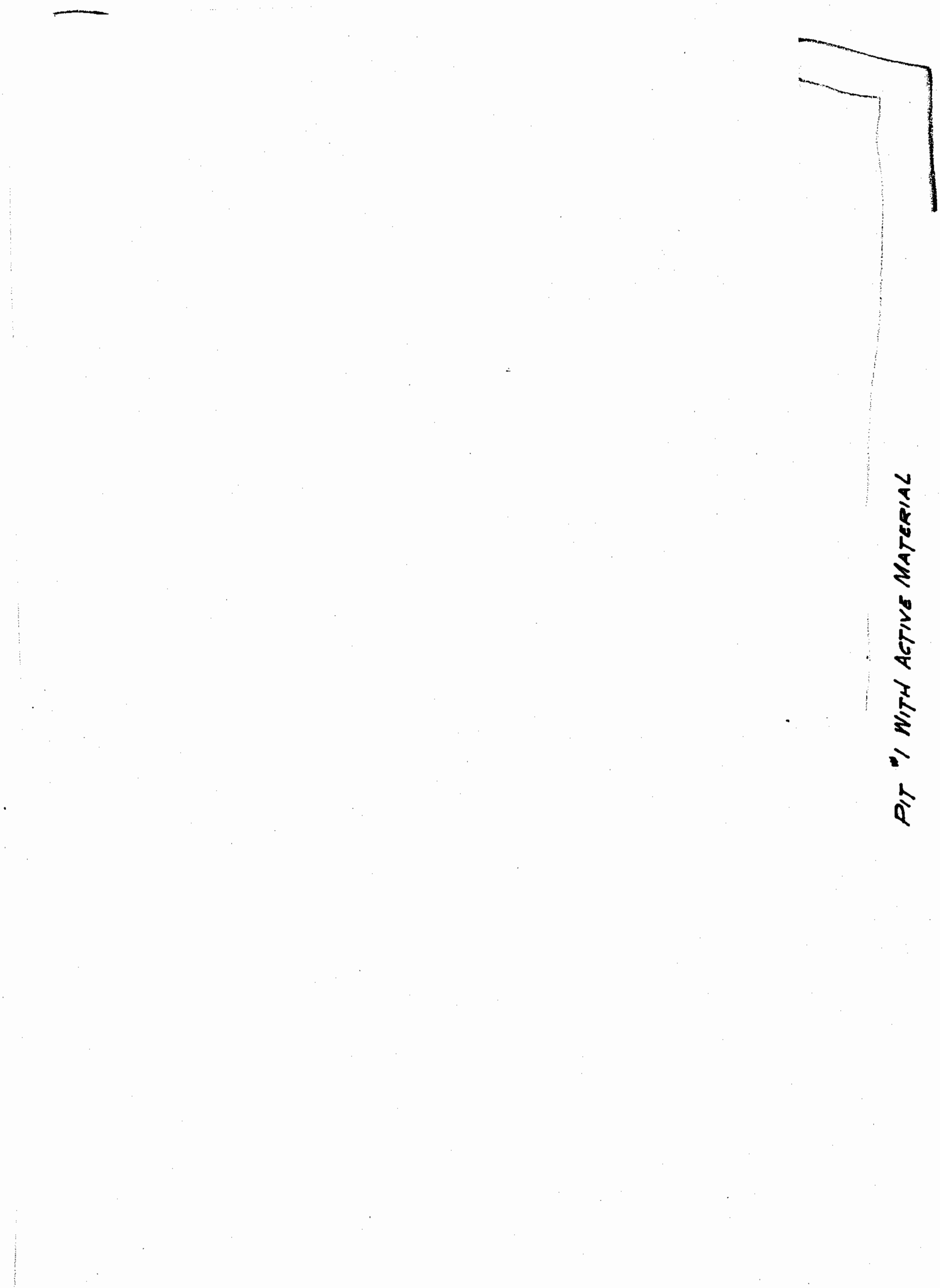

Figure 1

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Details of the Trinity 49 sphere will be given in Section 2.2 of this Chapter.

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The machine shops were very cooperative in fabricating parts; in particular, recognition should go to R. Vergoth and Walter Arnold [for their work in fabricating the Tu tamper.]u Credit should be given to Taylor Finlayson, not only for setting up the radiography but also for his careful work in the radiography [of all the Tu tampers.]u

The assembly of the pit, for insertion into the HE at V-Site, was done in the old Ice House (T-28) by L. B. Thompson, R. W. Thompson, T/4 Stanley Hanna, T/3 Herbert M. Lehr, and M. G. Holloway. The pit was delivered to V-Site by L. B. Thompson and R. W. Thompson, who personally inserted the aluminum screw that fills the threaded hole provided for the eye bolt. Figure 3 shows a pit assembled, ready for insertion into the HE.

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The Trinity Pit, (or Pit No. 1) was made up of the components listed in the standard form.

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It was necessary to use shavings as samples, since one hemisphere was completely finished on its delivery to Los Alamos. While positive identification of the alloy could not be made from shavings, it was possible to compare the two samples with fair certainty.

2.2 MECHANICAL AND NUCLEAR TEST OF THE 49 AND INITIATOR BEFORE INSERTION INTO THE HE

In advance of the Trinity operation, it was necessary to make measurements to insure that the 49 and initiators met the specifications laid down by the Cowpuncher Committee. These specifications concerned the fraction of a critical mass that was to be used and neutron backgrounds. There was the additional requirement that it be possible to load the 49 into the HE assembly without having the core become supercritical.

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Such a sphere was made and was tested at Omega for fraction of critical mass and for safety by Slotin and collaborators. Slotin had for this test the pit to be used at Trinity and a mock HE assemblv for surrounding the pit.

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The field measurements are all relative to similar measurements made at Site Y. The general philosophy was that of measuring with a definite method and equipment at Site Y and repeating those measurements at Trinity. A set of eight Ra-Be sources was purchased and carefully intercalibrated. These sources eliminated to a great extent the effects of any possible differences in sensitivities of detectors.

Descriptions of the various types of counting are given in the "Manual of Field-Check Counting", to be found in LA-619. C. P. Baker,

R. E. Schreiber, P. Morrison and B. McDaniel, with the help of R. Wilkinson of G-10, did experiments leading to the setting up of the field-check procedures described in the Manual.

Considerable concern had been expressed about the possible changes that might take place in the 49 and initiator between the time of loading into the HE and the time of the shot. (This interval was about two and a half days.) It was thought that a measurement of the neutron flux in the HE might give some hint of, at least, gross changes in the core. [redacted] DOE b(3) The activity of the manganese wire was a measure of the neutron activity of the core. Slotin and Morrison made measurements in the mock HE assembly at Omega which indicated that this method would give reasonable counting rate.

It was also necessary to get some facilities set up at Trinity for those operations that the G-Engineers would have to conduct there. Holloway and T/3 Lehr therefore made a survey trip to Trinity and placed construction orders with the various organizations concerned.

Some time before the Test Shot, the G-Engineers (including personnel who would be absent from the Test Shot because of their departure for Destination) carried out their part of a dry run. This precaution was extremely useful in that it pointed out flaws in the method and equipment and helped tremendously in the coordination with other parts of the Test Shot Organization, particularly with the HE groups.

The 49 sphere and the three initiators for the "hot" run arrived at

Trinity about 1800, 12 July, 1945, accompanied by Slotin and Morrison in the company of security guards under the command of Lt. Richardson. The active material was taken to McDonald's Ranch House, located about two miles from the tower (see Figures 4 and 5).

In the evening, the 49 and initiator carrying case was opened and the various components tested for surface contamination. No contamination was found. Preliminary neutron counts were made on the 49 he misphere and on the initiators to see if any changes had occurred during the trip. Nothing startling was found.

According to Bradbury's schedule, the pit was to be loaded with 49 and initiator the afternoon of 13 July. Consequently, the final measurements and checks began on the morning of 13 July. The results of these are shown in the check list and forms G-1 and G-2 of the Manual of Field-Check Counting (see LA-619). Everything appeared to be satisfactory. The counting operations were carried out by Morrison, Schreiber and Daghlian.

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following are taken from notes made at the time of the above operation:

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The mechanical tests consisted of measuring the dimensions of the initiator and the 49 hemisphere to see if they could be assembled into the pit. In addition, inspection of the coatings for mechanical faults were made.

The results of the mechanical inspection were recorded on Form G-1 and G-2, where the results of nuclear tests were also recorded. Some of these tests were done at Site Y and some at Trinity.

Figure 4

Showing McDonald's ranch house
at Trinity Test Shot, July, 1945.

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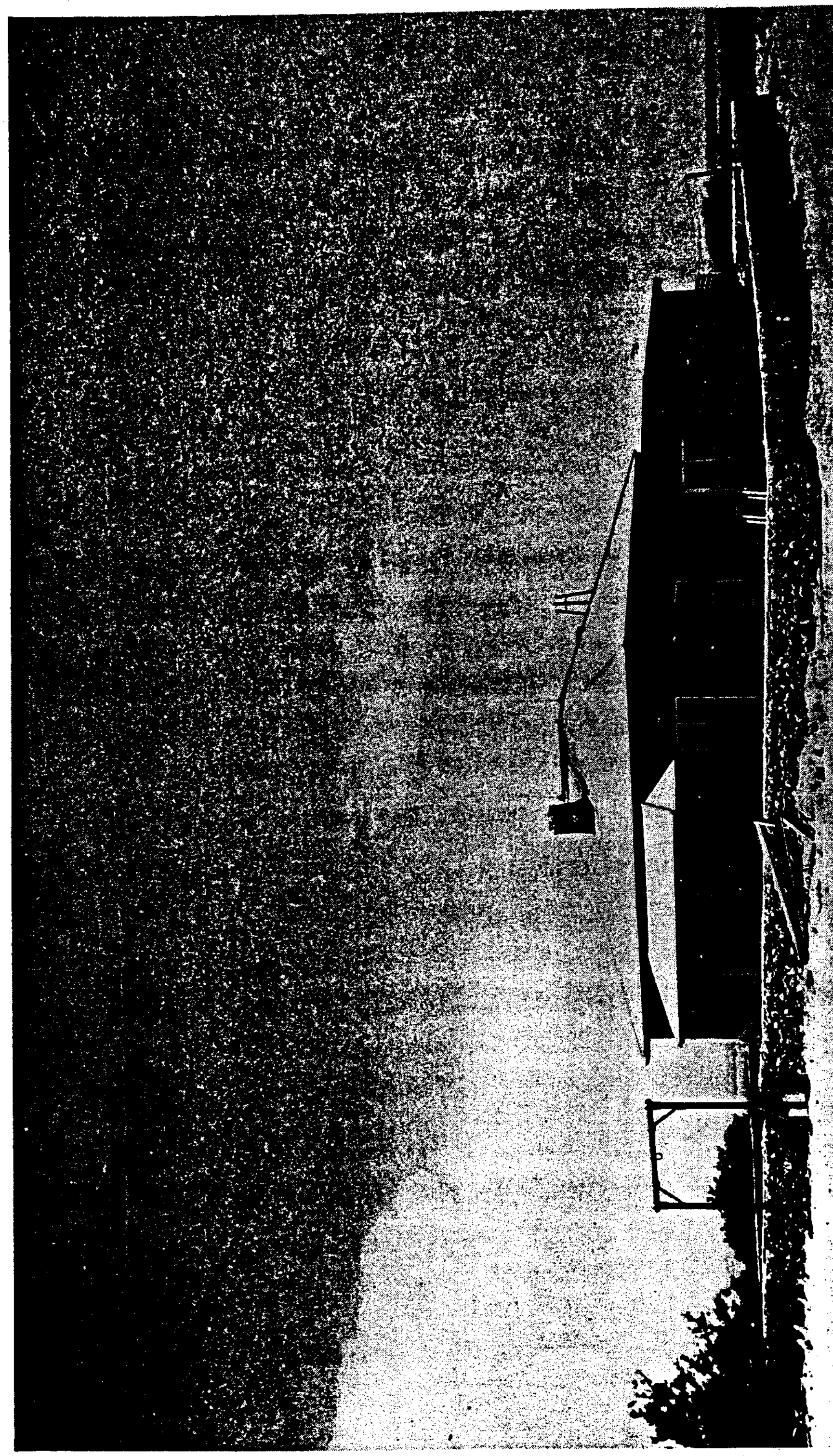

Figure 4

Figure 5

Showing arrival of 49 sphere and
three initiators at McDonald's ranch house,
12 July 1945.

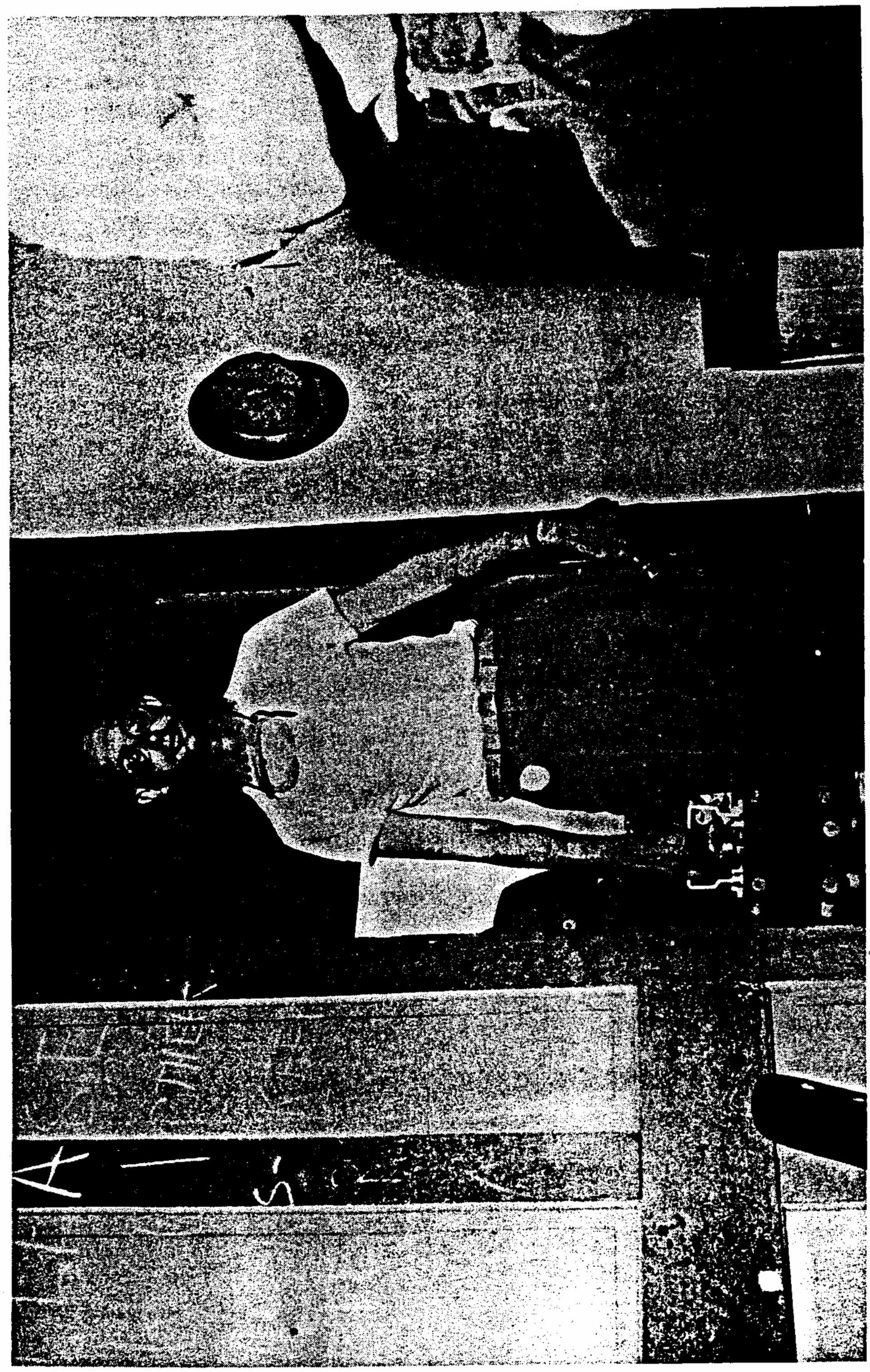

Figure 5

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Figure 6

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Figure 7

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Figure 7

Figure 8

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Figure 8

The field-check counting procedures are given in the "Manual of Field-Check Counting", (see LA-619). A general outline of the operation carried out at McDonald's ranch house, which was the pit-assembly building at Trinity, is given in the check list. The equipment and supplies needed for the insertion of the active material is given in the "List of Equipment for insertion of Pit Plug at HE Building", and the operations in the HE building (which, at Trinity, was the tent at the base of the tower) are given in the "Manual" and "Check List" for the HE building.

The organization of the G-Engineers group at Trinity is given in the "Assignment of Responsibilities for First Trinity Shot". This organization sheet not only fitted the work to the most recent activities of the personnel, but made clear the duties of every person.

2.3 INSERTION OF THE 49-INITIATOR ASSEMBLY INTO THE HE ENCLOSED PIT HE ASSEMBLY BUILDING

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[redacted] The operations were somewhat elaborate since this was the first time that the active material had been inserted into a sphere of HE. While it was felt that the HE mock-up made by Slotin was good, it was believed wise to use some caution in the assembly operation with HE. Several neutron counters were therefore set up beside the HE sphere to ensure that any unforeseen large rise in neutron emission would be noted.

One of these neutron monitors was a standard Chicago-type counter and chassis employing an enriched (82 per cent) B^{10} counter. The counter proper was enclosed in a shell of paraffin about one inch thick to increase the sensitivity of the counter. The other monitor was a McDaniel portable neutron counter which also used an enriched B^{10} counter encased in paraffin. This latter type of monitor proved to be quite useful.

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As mentioned previously, it was also necessary to insert the hypodermic tubing in a crack in the HE so that any changes in neutron emission during the period between the closing of the HE and the final firing could be detected.

The following is a running account of the activities of the G-Engineer Group at the tower. Figures 9 to 24, inclusive, illustrate the various operations.

The plug was brought into the tent at 1518, 13 July 1945. The plug had risen in temperature from 39°C to 46.5°C during the two-mile ride from McDonald's to the tower and in the short wait outside the tent,

At the time the G-Engineer group entered the tent, the modified polar cap was being placed over the exposed HE. (This modified polar cap was an ordinary polar cap that had a large hole cut out of the top. The cap prevented injury to the HE by persons working on the loading of the pit.) Next, the Explosives Group placed

Figure 9

Showing an active-material carrying case almost assembled. The opened cylindrical cavity is for an initiator case. The round dial on top is a thermometer.

Figure 9

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Figure 10

Showing a disassembled active-material carrying case. The spherical cavity is for the 49 sphere.

Figure 10

[redacted]

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Figure 11

Showing the "oil-can geometry"
and the 220 geometry.

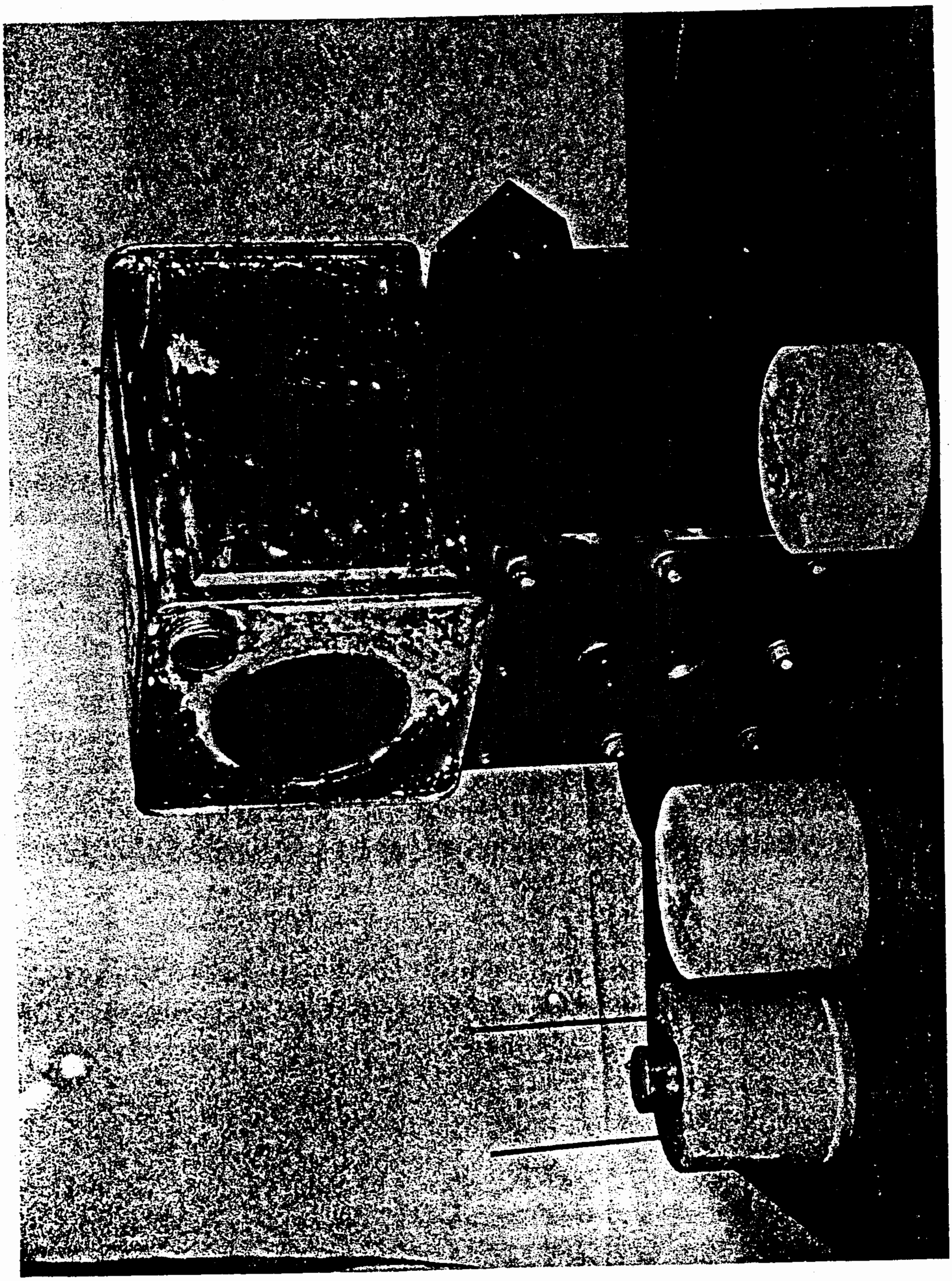

Figure 11

Figure 12

Showing the 220 polythene geometry and amplifier. A "25" fission counter tube is in the polythene block.

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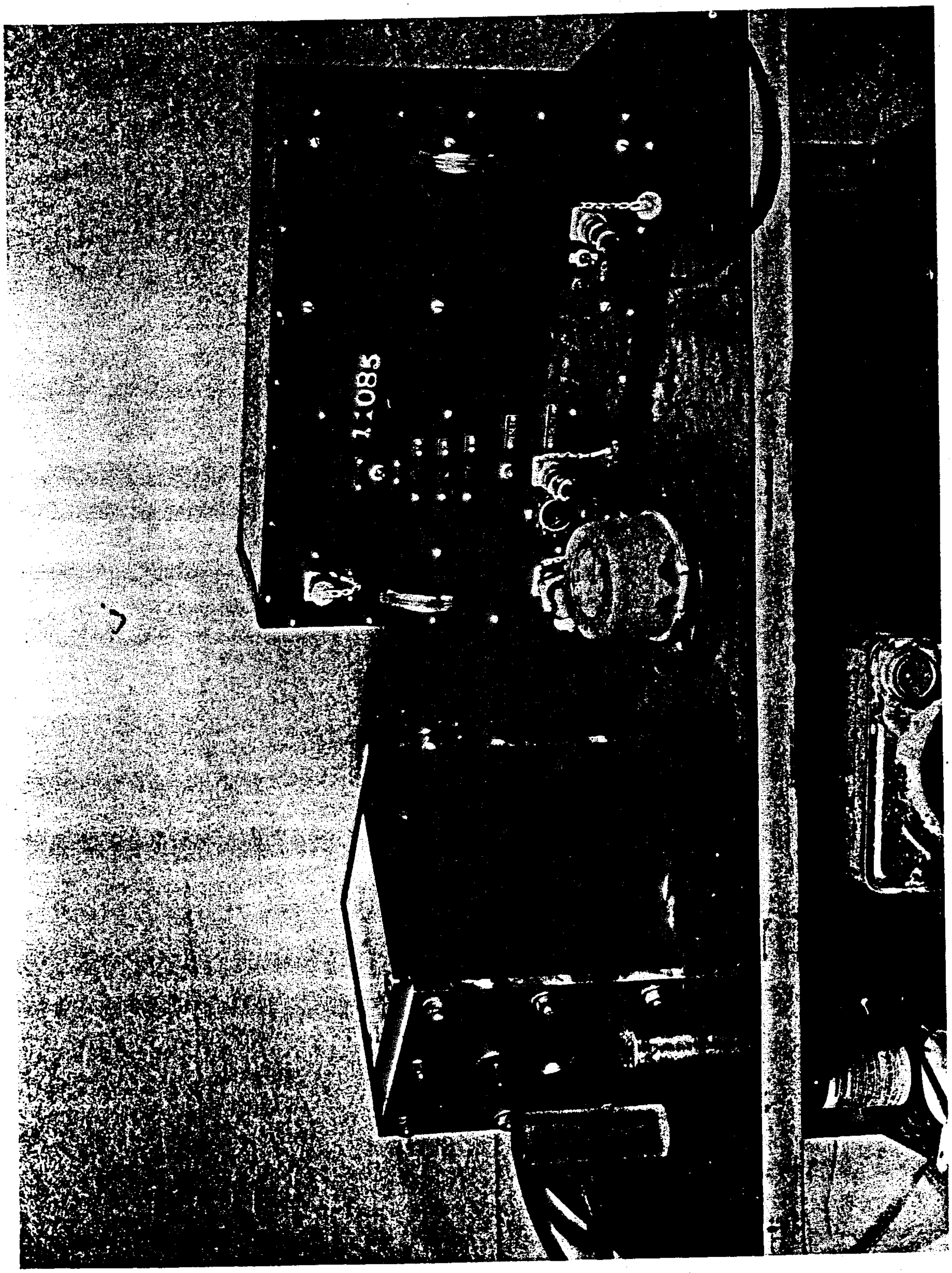

Figure 12

Figure 13

Showing a 220 amplifier connected to a G-M counter. The cylindrical lead shield is a so-called "Columbia shield". The lead "counting plate" is on top of the lead shield and one of the standard sources is being counted.

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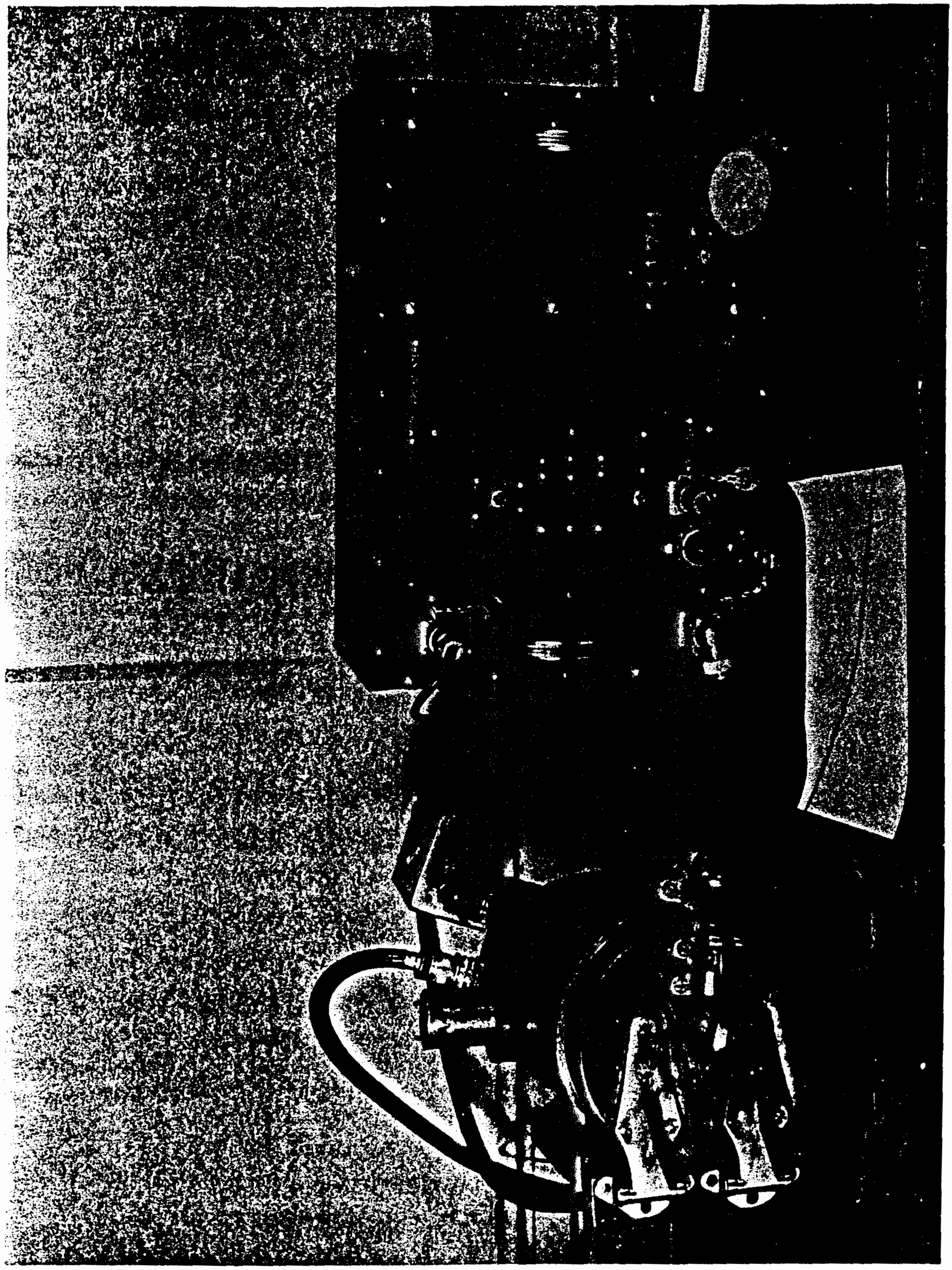

Figure 13

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[redacted]

Figure 14

Showing a McDaniel portable neutron counter. The material enclosing the counter tube at the right is 1"-thick polythene.

Figure 14

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Figure 15

DOE
b(3)

[redacted] UNCLASSIFIED

Figure 15

Figure 16

DOE
b(3)

[redacted] UNCLASSIFIED

UNCLASSIFIED

Figure 16

DOE b(3)

[redacted]

Figure 17

Figure 17

[redacted]

DOE
b(3)

Figure 18

Showing the modified polar cap in place.

UNCLASSIFIED

Figure 18

DOE b(3) DOD b(3)

Figure 19

Showing the insertion of the "funnel". With the exception of about one-half inch at the bottom of the cavity, all of the HE was at this time covered with metal so that it was protected during the operations of the G-Engineer Group.

DoE b(3)

Figure 20

Showing the G-Engineer Group cleaning the interior of the HE cavity and the surface of the pit.

DOE
b(3)

[redacted]

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DOE
b(3)

DOE
b(3)

UNCLASSIFIED

[redacted]

Figure 23

Showing Commander Bradbury taping the hypodermic tubing in place just before the two HE charges were placed in the cavity.

the "funnel" in place

DOE b(3)

The grounding cables were tested with a Simpson meter.

DOE b(3)

An attempt was made to remove the screw with the usual large screwdriver. However, the screw was so tight that it was necessary to use a large beryllium bronze wrecking bar (courtesy Commander Bradbury) to remove it.

DOE b(3)

An inspection of the opened up pit showed no burrs, damage or misalignment.

DOE b(3)

Meanwhile, the Chicago neutron counter in its paraffin sheath was taped to the top of the modified Canton crane and connected to the counter chassis. Power was turned on the monitors, and both were tested by bringing the Hansen mock-fission neutron source near them. The source was then taped on a side of the HE assembly away from the monitors.

DOE b(3)

Figure 24

Showing one step in the insertion of the two HE charges. The weight of the charge is supported by a vacuum cup attached to the Canton crane.

[redacted] UNCLASSIFIED

Figure 24

DOE
b(3)

UNCLASSIFIED

[redacted]

DOE b(3)

Several counts of neutron activity were made as it was lowered.

DOE b(3)

At this time a thunderstorm was approaching and the weather prediction was for a bad storm. The tent began to flap so badly that at 1624 hours the G-Engineers left the tower base, and went to McDonald's

DOE b(3)

ranch house. The weather soon cleared and the group returned to the tower at 1701 hours.

DOE b(3)

(The tube was taped at the top, middle and bottom, with the crimped end in contact with the pit.) A piece of piano wire was inserted into the hypodermic so that a chance blow would not crush it.

DOD b(3)

All handling of HE was done by the Explosives Group under the direction of Bradbury and Warner. [The inner charge was picked up by means of a vacuum cup hooked to the Canton crane.] The hose between the vacuum cup and the Mega vac pump was not vacuum hose and was so flattened by the external atmospheric pressure that the G-Engineers held their collective breaths. As a safety measure, glass cloth webbing was tied around the charge and over the crane hook so that, if the vacuum cup failed, the HE charge could not fall.

DOE b(3)

The Chicago neutron-counter tube had been removed from the top of the Canton crane and placed at the side of the HE assembly.

DOE b3

The lens charge was lowered into position in the same manner as the inner charge, and produced no observable change in the counting rate.

The mock-fission source was then removed.

DOE b(3)

[redacted] With the paraffin sheath removed, the counting rate was so low that no good measure could be made of it in the time available. The time was then 1745 hours.

The Explosives Group removed the modified polar cap and replaced it with the standard polar cap. After the cap was bolted down, the piano wire was removed from the hypodermic (which now protruded through a small hole in the polar cap). At 1807 hours, a manganese alloy wire was inserted into the hypodermic. The work of the G-Engineers Group was now almost finished.

Five manganese activations were made before the shot. The last any member of the G-Engineers Group saw of the gadget was at 1626, 15 July 1945, when the final activated manganese wire was removed from the gadget on top of the tower.

On 14 July, the G-Engineer Group packed their equipment at McDonald's ranch and loaded it into a truck for removal to the base camp.

CHAPTER 3

MECHANICAL DESIGN OF MODEL 1561 FAT MAN

A. H. Machen

3.1 INTRODUCTION

This Chapter is concerned with the design of the case, the equipment supports, the lugs, and other external parts of the 1561 model Fat Man. The design of the pit containing the active material for this bomb is discussed in the preceding chapter of this Volume; and the design of the high-explosive components is discussed in Volume XI of the Los Alamos Technical Series.

Figure 1 is an artist's drawing of an early form of the Fat Man model. From that Figure, it can be seen that the model consisted essentially of a large sphere containing the explosives and active material, mounting provisions for auxiliary electronic equipment, an outer armor steel cover, lift lug, and a stabilizing tail assembly. This Chapter will discuss these components of the assembly. A collection of the mechanical drawings of the final form of the 1561 model Fat Man that was used in combat may be found in LA-392.

3.2 DESIGN OF THE SPHERE

Design of the sphere was started with the following specifications:

(1)

(2) A size within the limits of the bomb bay of a B-29

DOE
b(3)

Figure 1

airplane with a fall angle of five degrees;

(3) Provision of detonation holes for more than one detonation pattern.

The first model was the 1222 (Figure 2). Its spherical case was divided by great circles into twelve equal pentagons bolted together by edge flanges; machining these pentagons to a close enough tolerance to permit bolting-up into a complete sphere turned out to be highly impractical. DOE b(3)

This model was further complicated by a steel case consisting of twenty triangles secured to the sphere by some eleven hundred bolts screwed into holes radially drilled and tapped into the flanges of the pentagon. A steel lift-lug pad, designed to distribute the lug load out into the spherical case, was provided and secured to the sphere at the apex of the top five pentagons. DOE b(3)

A complete departure from the 1222 pentagon structure was made in the 1291 model (Figure 3) using the same polar cap and belt-band design that was used in the final model. The 1291 model consisted of three spherical zone segments bolted together by 18 bolts screwing into tapped flanges to form a belt section of the sphere. The sphere was completed by two polar caps bolted to the tapped flanges of the belt section. DOE b(3)

Figure 2

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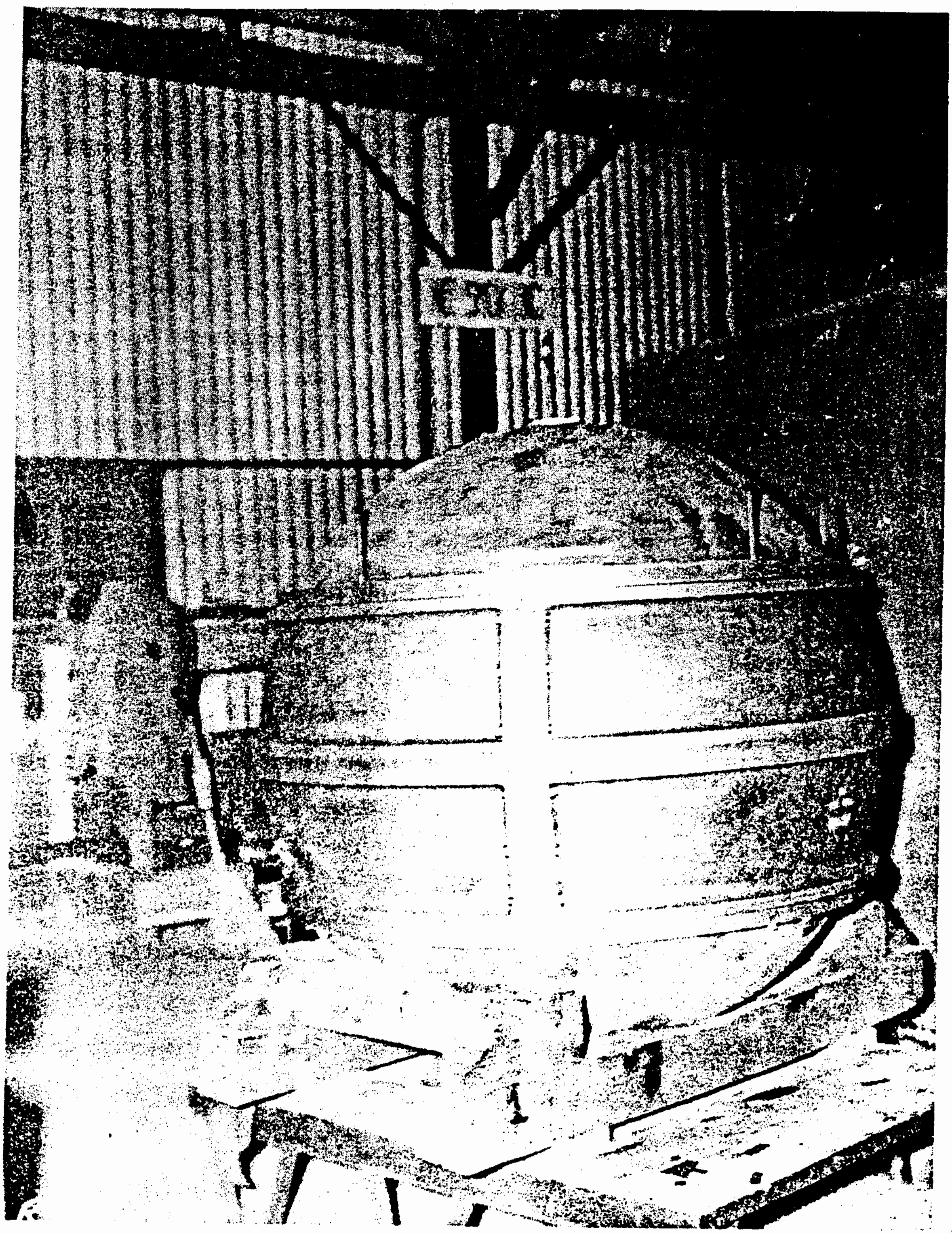

Figure 3

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Redesign of the 1291 brought forth the 1560 (Figure 4). The 1560 belt section was made up of five spherical segments. Instead of being tapped, the flanges were drilled through for the use of steel aircraft bolts with elastic stop nuts.

DOE b(3)

Assembly was made with the polar caps top and bottom which, after assembly was completed, necessitated rotating the sphere through ninety degrees to place the lift-lug on top. For this purpose, pads were cast into the belt segments to which trunnions could be bolted (Figure 4).

DOE b(3)

At this time, some thought was being given to a method of holding the detonator in the holes, insuring they would bottom solidly on the charge and still permit some shifting of the explosives without damaging them. Several types of retainers were designed and made, including spring-loaded cups that covered the hole, with a spring bearing on the detonator.

DOE b(3)

Basic sphere designs were frozen with the 1561 model, and subsequent work dealt with refinements and changes to facilitate mounting of ever-changing instrumentation. Retainer cups were

Figure 4

DOE
b(3)

Figure 5

DOE
b(3)

staked into holes drilled in the case for fast, easy mounting of the 110 wire harness clips necessary to hold the coaxial detonator cables (Figure 5).

3.3 MOUNTING OF ELECTRONIC INSTRUMENTS

The mounting of the instruments in the early stages of 1222 design presented few problems. For example, the firing circuit was a small box weighing a few pounds, whereas the final unit was a cast dural tub, weighing about 300 pounds. All of the instruments of this first unit were supported on a single tubular mount attached to the aft side of the sphere (Figure 6), and it was not until after the start of the 1560 model that any of the instruments were placed forward of the sphere. By this time, all the space within the ellipsoidal covers, fore and aft, was occupied by firing and fuzing circuits. The tubular mounting brackets were used fore and aft on the 1222, but discarded on the 1560. A dural cone was designed that would tie into the polar cap bolts, supporting the 300-pound firing circuit box in front and a panel of fuzing instruments aft without danger of vibration. Fast, accurate assembly was kept in mind throughout this design; although the bomb could be a hand-tailored job in most respects, speed was very important in the assembly of the hot model.

A mounting plate was provided for the firing-circuit charging equipment. This plate, mounted in the nose of the front ellipsoid, was accessible through the removable nose plate, and provided a means of battery installation after assembly of the bomb (Figure 7). All instrument plates required constant attention, since changes and rearranging of parts made new layouts necessary to check clearances

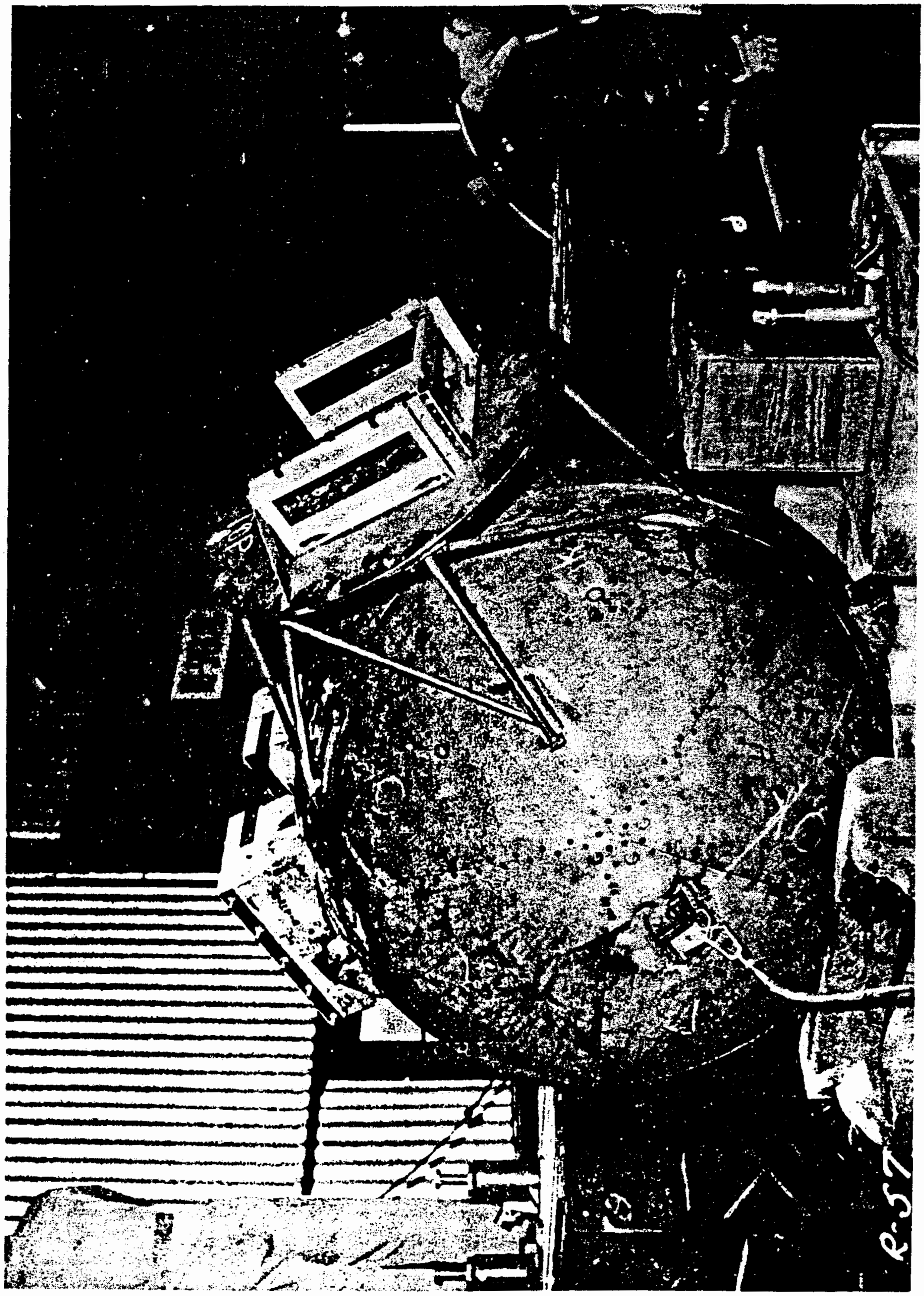

Figure 6

Figure 7

DoE
b(3)

and hole locations.

3.4 OUTER COVERS

From an assembly standpoint, early design of the outer bomb case was as impractical as was the sphere. The original case was composed of 18 steel triangles, formed to a spherical radius, and these were attached to the sphere by Allen head bolts tapped into the pentagon flanges; mating of 1100 attaching holes by any means other than line-drilling on assembly could not be done. Thus, there was no possibility of prefabricating parts. A cone supporting the tail and housing the instruments was made from five rolled segments of half-inch aluminum plate butt-jointed and spliced with splicing strips on the inside (Figure 8). Several methods of attachment of the cone to the sphere were tried, the first being radial drilling at the point of tangency and tapping of the sphere; this, again, was not a production method, and was discarded in favor of a splice plate. The dural cone was used only on the 1222; with the design of the 1291, work was started on steel ellipsoid covers. Attachment of the two ellipsoids to the sphere was considered the major problem; it was decided to eliminate all mating problems by making the attachment a tension union. Lugs were cast into the belt segments of the sphere and, in this manner tension bolts could be bolted through bathtub fittings (welded to the ellipsoid) and through the lugs, thus tying the sphere and the two ellipsoids together (Figure 9). The first ellipsods were of mild steel. However, it was stated in the specification that the cases for the final bomb were to be of homogeneous armor. These ellipsoids were hot-formed in four sections and arc-welded together. This method of

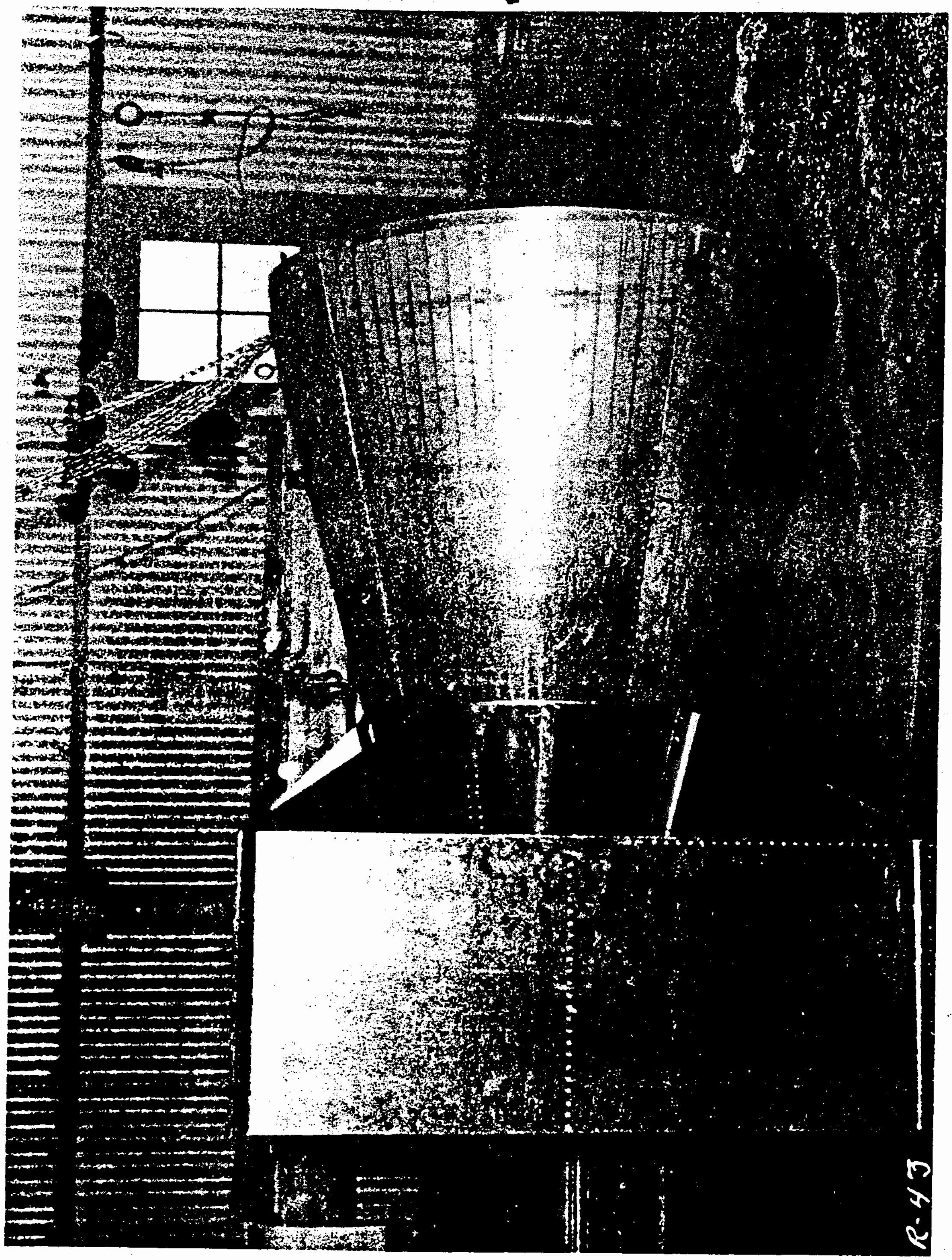

Figure 8

Figure 9

manufacture was satisfactory for mild steel, but the heat-treating of the homogeneous armor warped the cases to the extent that assembly was impossible. It was only toward the end of the program that it was possible to get reformed armor cases that could be assembled. No material change was ever made in the design of the ellipsoids, the only changes made were modifications such as pull-out wire holes, provision for mounting antennas, sleeves for impact fuses, and modifications to permit sealing of the entire unit.

3.5 LIFT LUGS

Lug design was confined to single-point suspension on all bomb models subsequent to June 1944. Tests were first made with a British-designed lug, used with an adapter plate designed to distribute the load out into the pentagons of the 1222 sphere (Figure 10).

A similar lug, designed for the 1291, bolted to a pad cast into the top segment of the sphere. Tee slots were cut in the pad to provide an adjustment in lug location for changes in center of gravity.

The 1560 and 1561 used the same lug as the 1291 (Figure 11) with the exception of a bronze insert on the under side of the crossbar designed to forestall any chafing on the bomb release. The lug was bolted directly through the sphere without provision for adjustment, the center of gravity having become pretty well fixed on the 1561.

3.6 TAIL ASSEMBLIES

Design of the tail was dependent on actual ballistics tests and, as those tests were made, the tail was modified to fit the aerodynamic data obtained. Proposals for design included several types of cylin-

Figure 10

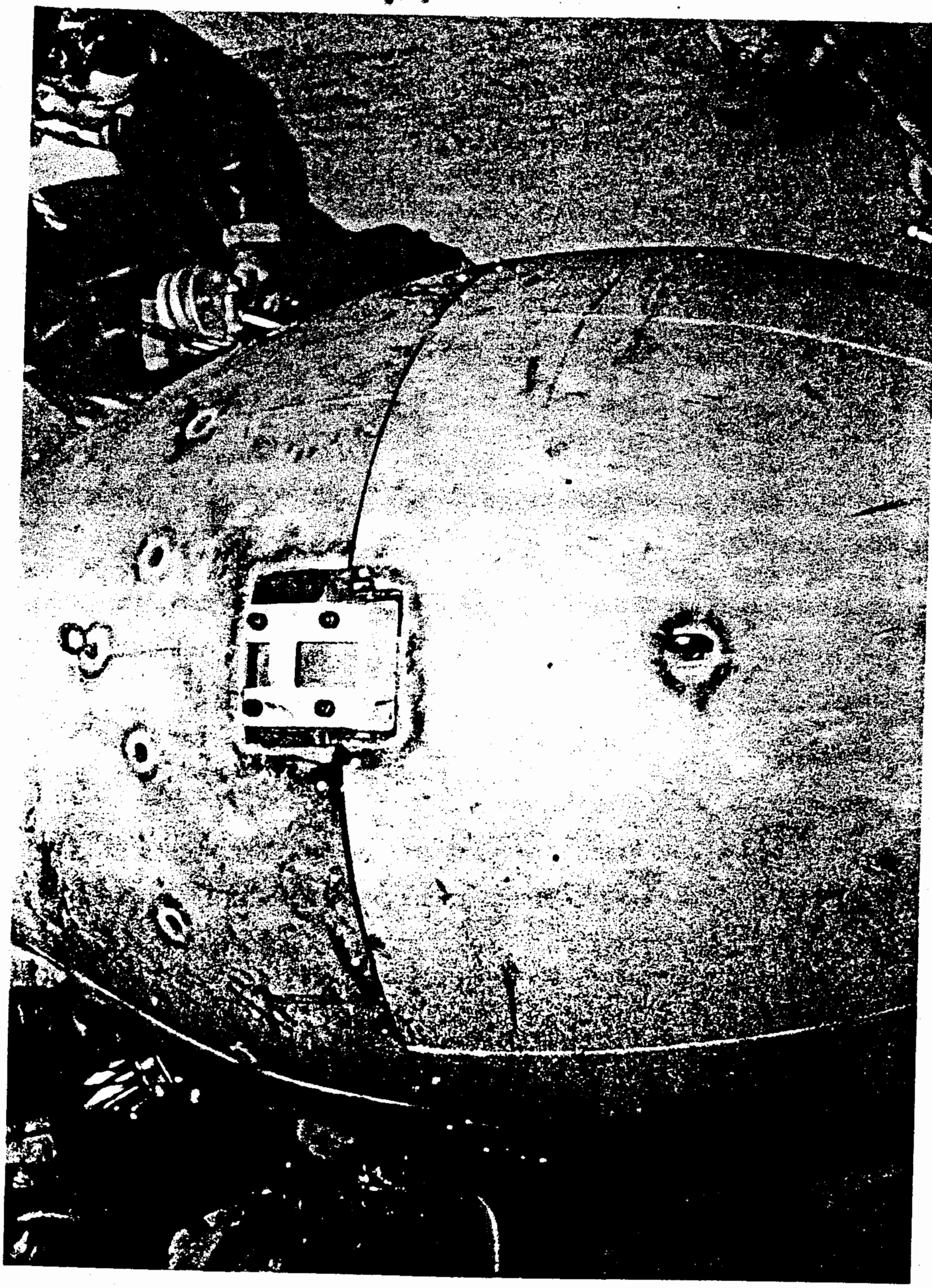

Figure 11

drical tail, but the prototype was a box shape, designed to keep the bomb from rotating.

The first drop tests of the 1222 model disclosed considerable yaw; and it was found that the flight of the bomb could be greatly improved by increasing tail drag somewhat. The tail was therefore redesigned to include parachute ribs--flat aluminum plates running diagonally through the tail (Figure 12). There was no way of predetermining the proper angle for these ribs, so they were arbitrarily set at 45° to the flight of the bomb, and further drop tests were made. Flight characteristics were found to be good. However, tests were still in progress at the end of the war to determine the possibility of reducing the angle of the drag plates by an amount such that complete stability would be retained with less drag and hence greater bombing accuracy.

A study of the structure aroused concern over the possibility that vibration might be set up in the tail vanes themselves. To overcome this, a rolled bulb section was riveted to the leading edges and bent-up angles to the trailing edges. These changes eliminated any chance of damage by vibration.

Attachment of the tail on the 1222 model was made by bolting the tail cone directly into holes tapped in the dural cover cone. The same mating problem was encountered in this method of attachment as in the ellipsoids, and was solved in the same manner. On the 1561, lugs were fixture-welded to the ellipsoid and bolted to the mating tail cone, making attachment of the tail a quick simple operation using five tension bolts.

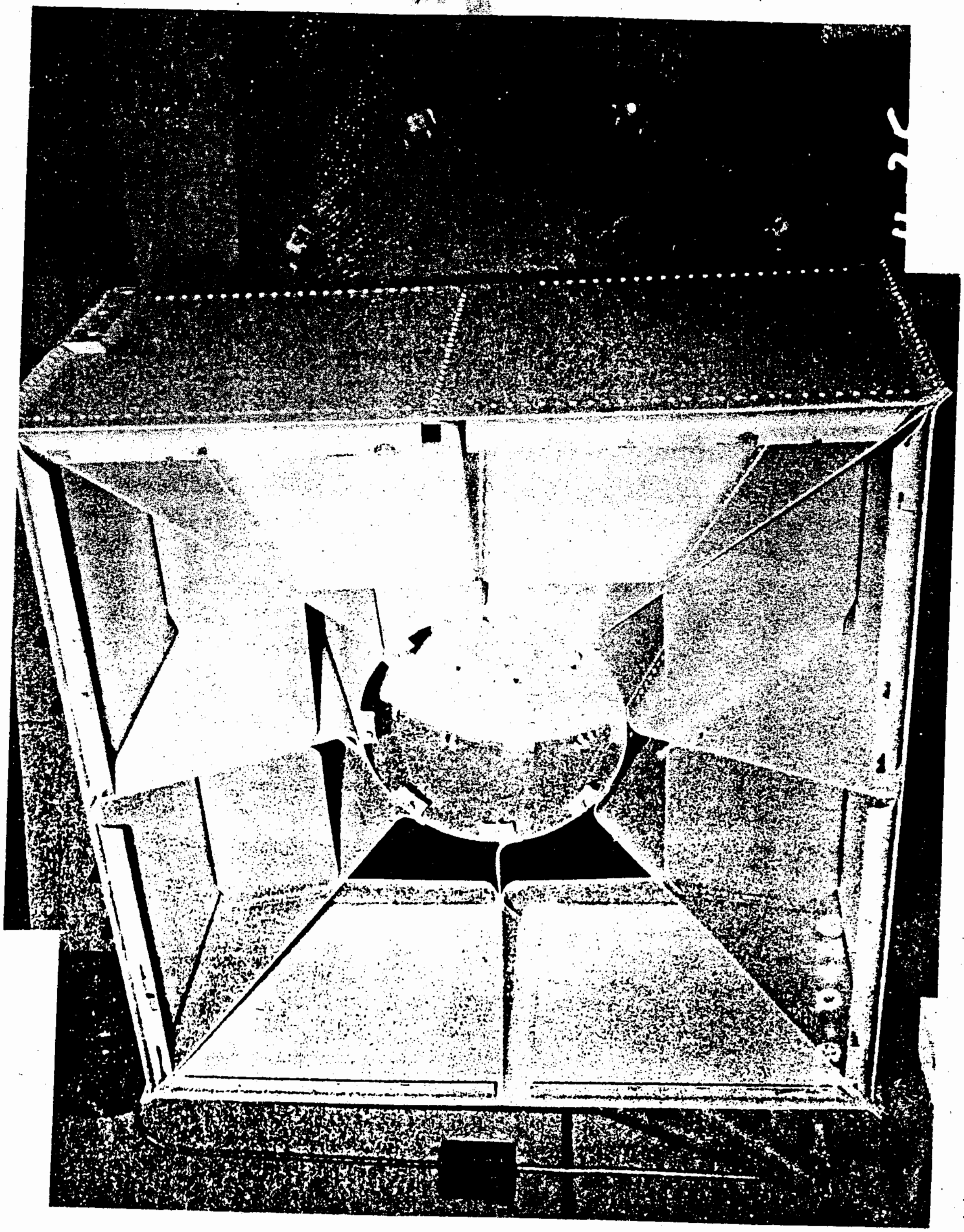

Figure 12

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[redacted]

3.7 MECHANICAL DRAWINGS OF 1561 MODEL FAT MAN

The most suitable and complete means of describing the detailed design of the 1561 unit used at Nagasaki is in terms of the mechanical drawings used in the manufacture of this unit. Since, however, there is a total of more than one hundred such drawings for the complete unit, these will not all be reproduced here. A complete file of these drawings is maintained by the Engineering Group at the Los Alamos Scientific Laboratory, and a collection of photostats of these drawings is deposited in the Los Alamos Document Room as Report LA-392.

[redacted]

CHAPTER 4

ASSEMBLY OF THE 1561 FAT MAN

V. A. Miller

4.1 INTRODUCTION

This Chapter is devoted to a history of the development of buildings, equipment and procedures for the assembly of the 1561 Fat Man bomb. Since that bomb was an entirely new type, no standard equipment or operation procedures were available; consequently, buildings and equipment had to be developed as a result of problems and experience encountered in the early stages of the bomb design. This Chapter will discuss the design of assembly buildings, the supply problems for Wendover and the overseas destination, assembly handling equipment, and the transportation of the bomb.

4.2 BUILDING DEVELOPMENT

The original assembly building at Wendover was a Butler building, 40 by 80 feet. It was equipped with two 1-ton chain hoists and two 6-ton chain hoists. The building had an addition approximately 15 by 15 feet with a 6-ton traveling hoist on one end that was closed off from the other portion of the building and used as a paint shop and delivery room of completed test models. This building was not air-conditioned and since it was also used as a modification building, it was very inadequate for the construction of any but concrete bomb models. The building was used until April of 1945 when a building was completed for assembling HE models.

This latter assembly building was designed by the First Ordnance Squadron, Special Aviation, to meet the requirements deemed necessary at that time. The building was constructed with three rooms in line with a delivery apron at one end. The three rooms were: (a) An air-conditioned assembly room where the HE blocks were loaded in the sphere and all components assembled; (b) An air-conditioned HE uncrating and inspection room; (c) A charge room.

The assembly room was equipped with two 1-ton overhead chain hoists and one 6-ton overhead chain hoist that traveled out over the delivery apron. In the main points of design, this building was adequate, but the chief fault was that the assembly room was too small for the equipment required in assembly.

In February, 1945, a meeting was held at Site Y to formulate plans for the assembly buildings to be used at the overseas project. Those present at this meeting included: Commodore (then Captain) W. S. Parsons, USN; N. F. Ramsey; R. S. Warner, Jr; George W. Galloway, Representatives from First Ordnance Squadron, Special Aviation, R. B. Brode and G. B. Kistiakowsky. It was decided at this meeting that the assembly procedure should be entirely carried out with overhead chain hoists (this was later changed, see Section 4.5 of this Chapter). With this objective in mind, the building specifications called for an air-conditioned assembly room with two 1-ton chain hoists and one 6-ton chain hoist, an air-conditioned HE uncrating and inspection room, a charge and tool room, and a concrete apron with a 6-ton chain hoist for delivery and receiving.

These specifications were sent to the Navy architects at Los

Angeles and plans were drawn up. In March and April of 1945, a test building was constructed at the Naval Ordnance Test Station at Inyokern, California. Photographs and floor plans of this building are shown in Figures 1, 2, 3 and 4.

Inspection of the completed building by representatives from Site Y revealed several faults: The steel columns were not structurally sound nor properly braced; the assembly room was too small for the equipment required for assembly; the doors were warping badly, reducing the effectiveness of the air-conditioning.

To correct these faults, certain recommendations were sent to the overseas project, resulting in changes in the buildings under construction there. The assembly room was extended five feet into the tool room, and all the main columns were doubled in strength and X sway bracing was installed. It was found that, due to the high humidity at the overseas base, the doors did not warp as they did in the test building at Inyokern; therefore, these doors were not changed. Another change incorporated in the overseas assembly building was the shortening of the chains on both 6-ton chain hoists so that, at the highest position of the bomb on the hoist, the chains were clear of the sphere surface. (The reason for this chain-shortening is discussed in Section 4. 5 of this Chapter.)

The building in the revised form proved satisfactory. With the advent of trap-door assemblies, however, the HE room became obsolete.

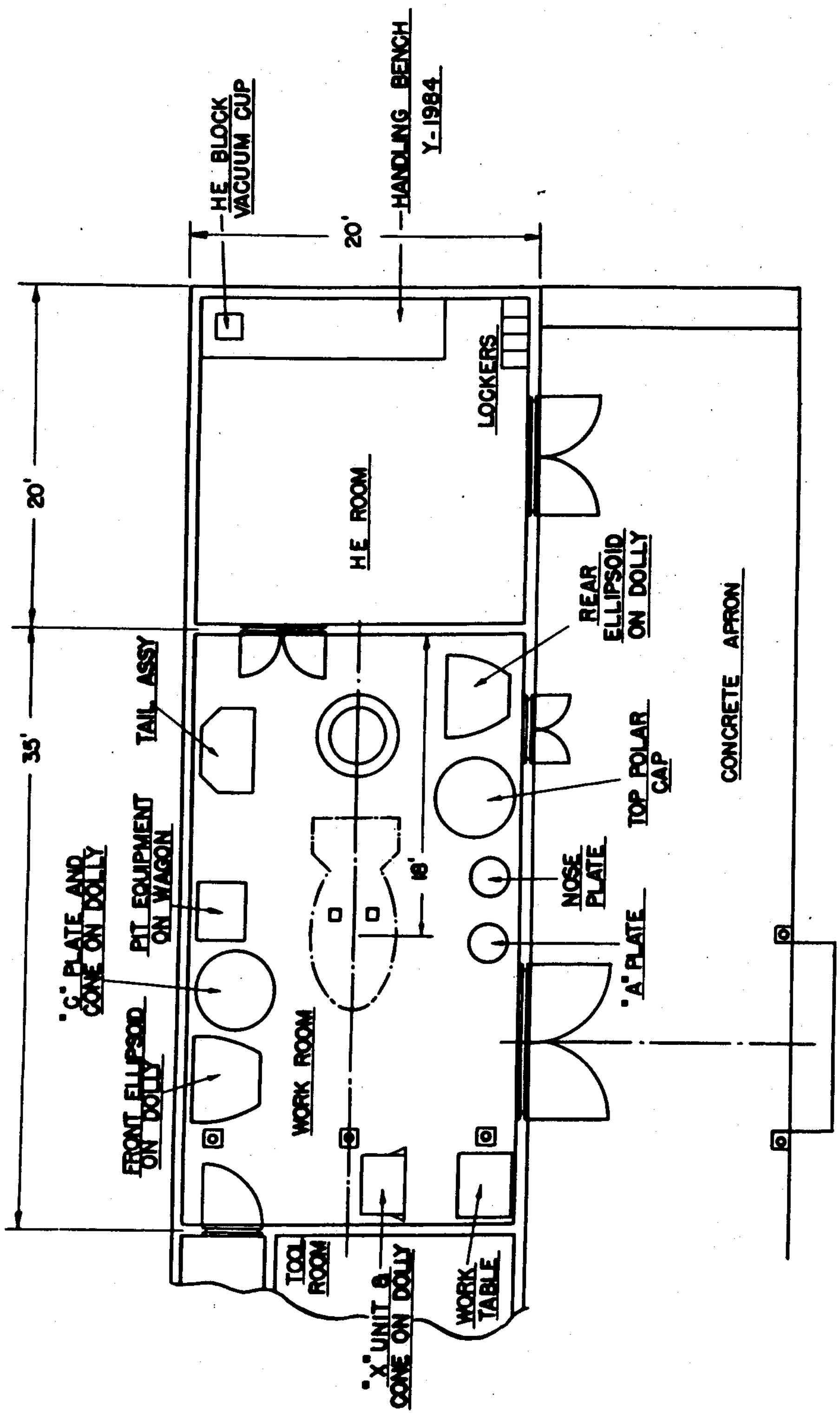
HE BLOCK
VACUUM CUP
HANDLING BENCH
Y-1984
20'
20'
LOCKERS
HE ROOM
35'
REAR
ELLIPSOID
ON DOLLY
CONCRETE APRON
TAIL ASSY
TOP POLAR
CAP
PIT EQUIPMENT
ON WAGON
"C" PLATE AND
CONE ON DOLLY
18'
NOSE
PLATE
"A" PLATE
FRONT ELLIPSOID
ON DOLLY
WORK ROOM
TOOL
ROOM
"X" UNIT &
CONE ON DOLLY
WORK
TABLE

Figure 1

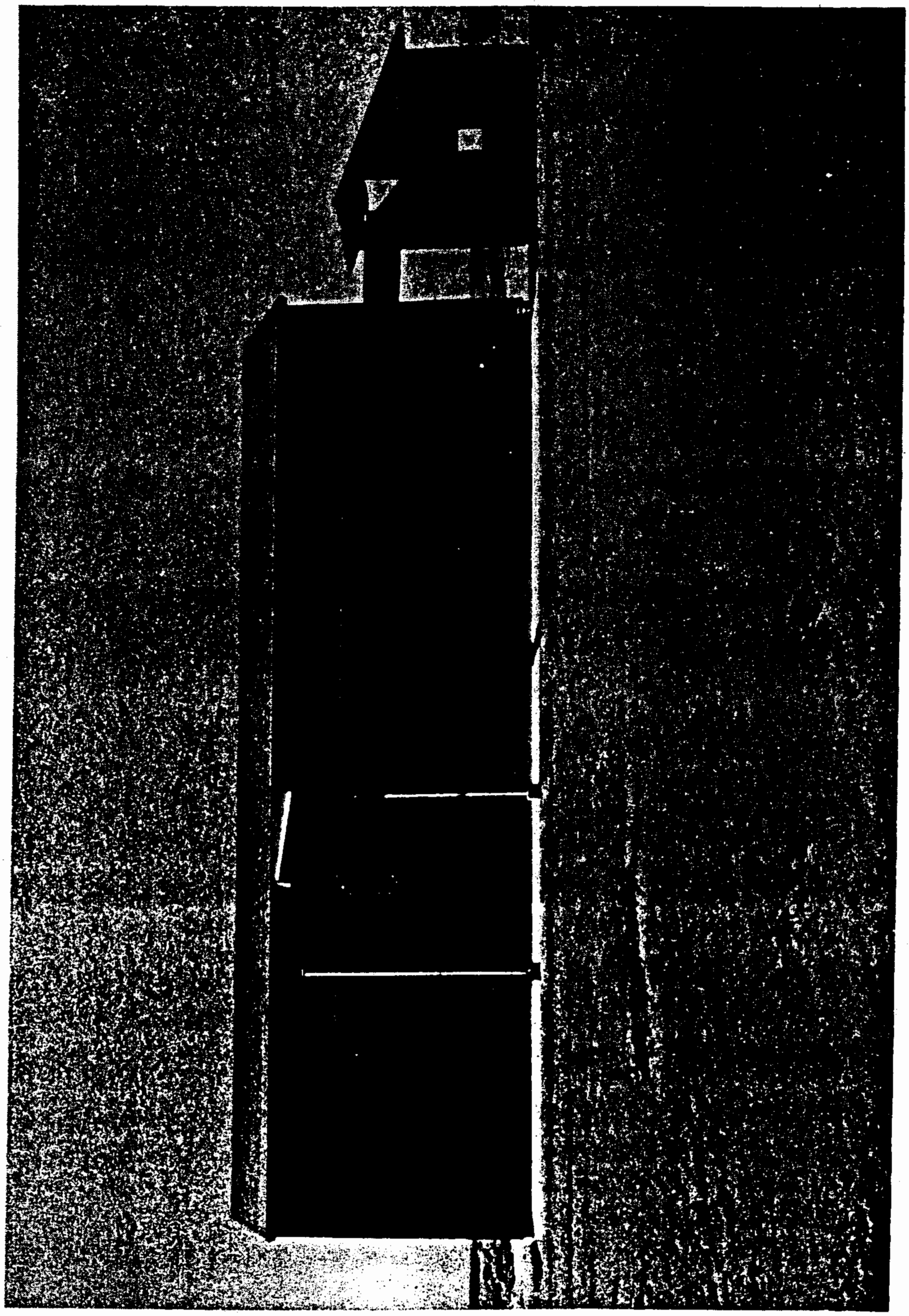

Figure 2

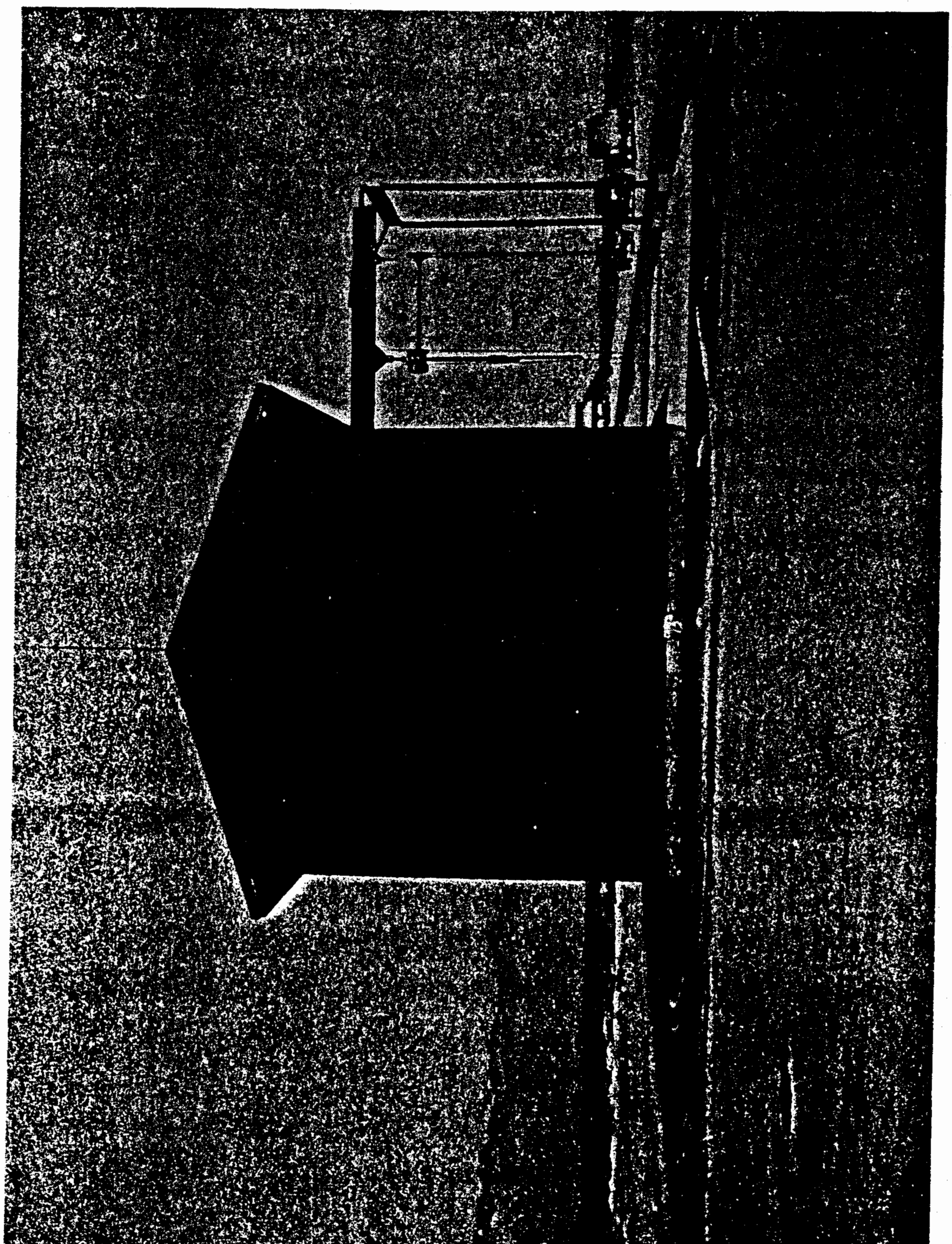

Figure 3

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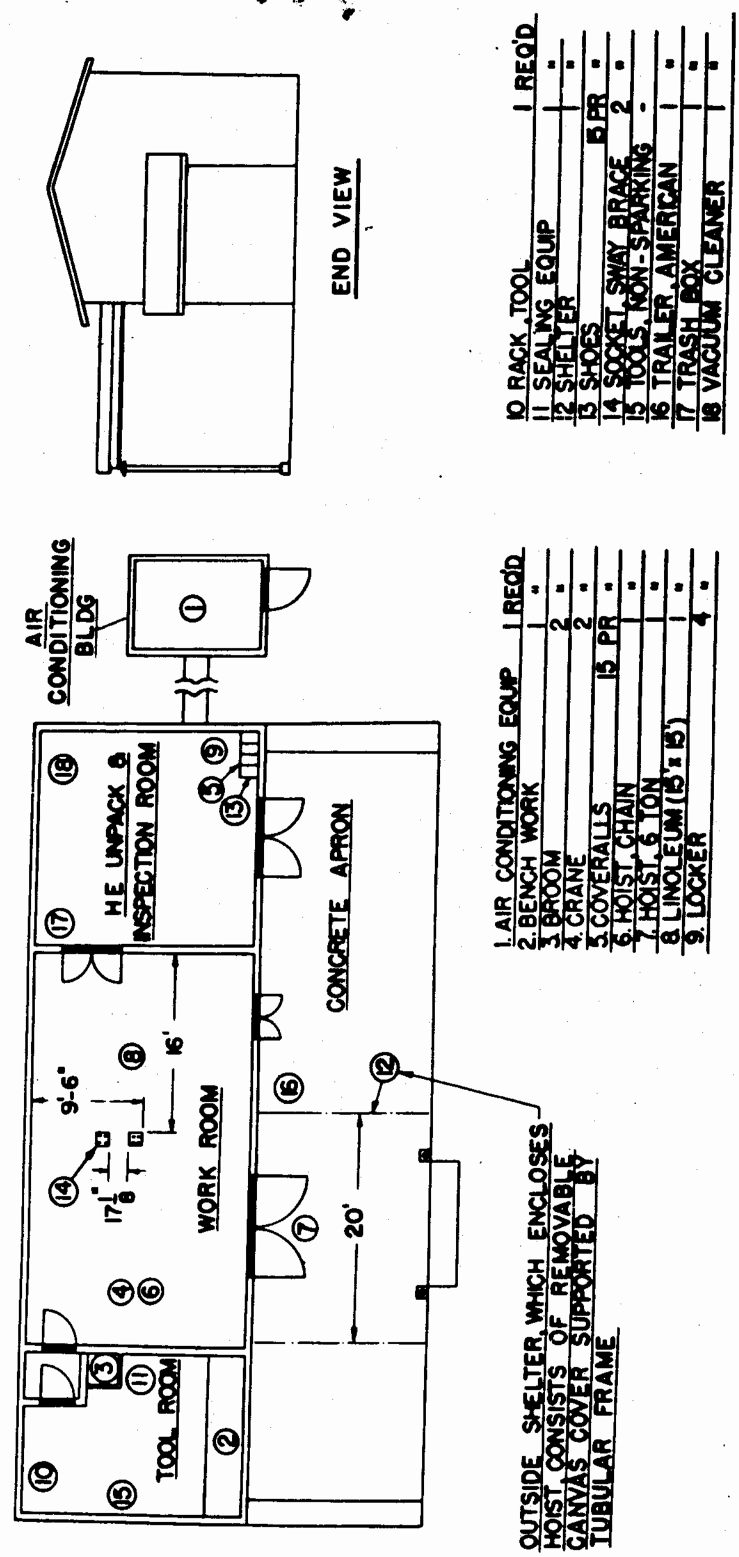
AIR CONDITIONING BLDG
END VIEW
H.E. UNPACK & INSPECTION ROOM
WORK ROOM
TOOL ROOM
CONCRETE APRON
9'-6"
16'
20'
17 1/8"
1. AIR CONDITIONING EQUIP 1 REQ'D
2. BENCH WORK 2 "
3. BROOM 1 "
4. CRANE 2 "
5. COVERALLS 15 PR "
6. HOIST CHAIN 1 "
7. HOIST, 6 TON 1 "
8. LINOLEUM (15' x 15') 1 "
9. LOCKER 4 "
10 RACK, TOOL 1 REQ'D
11 SEALING EQUIP 1 "
12 SHELTER 1 "
13 SHOES 15 PR "
14 SOCKET SWAY BRACE 2 "
15 TOOLS, NON-SPARKING - "
16 TRAILER, AMERICAN 1 "
17 TRASH BOX 1 "
18 VACUUM CLEANER 1 "
OUTSIDE SHELTER WHICH ENCLOSES HOIST CONSISTS OF REMOVABLE CANVAS COVER SUPPORTED BY TUBULAR FRAME

Figure 4

4.3 SUPPLY PROBLEMS AT WENDOVER

The supply problem at the Wendover test station was one of the major difficulties in the development of the 1561 Fat Man bomb. This situation would be true in any case where parts are designed in one location, manufactured in another, and tested in a third; in this case, it was even further complicated by the requirements of the Security Office. Also, due to a constantly changing design, the steady flow of new parts was very difficult to accomplish and, in some instances, the supply broke down completely.

For the procurement of parts, three major organizations were involved: D. P. Mitchell's organization at Site Y, Lt. Col. R. W. Lockridge's organization, and Army Supply channels. In addition to these groups, the Engineering Department maintained a representative in the Los Angeles area to expedite procurement of difficult and special parts. Many times in the bomb development, a shortage of critical parts was averted by such an expeditor.

Two representatives of the Engineering Department made a complete inventory of the Wendover supply, in order that parts destined for overseas shipments and parts needed for test assemblies could be located rapidly. After this inventory was completed, parts were binned in the warehouse and very little trouble was encountered after that.

4.4 DESTINATION SHIPMENTS

In March, 1945, work was started by R. S. Warner and G. W. Galloway, Chief Engineer, toward the formation of a shipping catalog

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and shipping crates for all component parts of the 1561 Fat Man bomb and 1852 Little Boy bomb. This catalog stabilized and crystallized all groups into thinking and actually planning for overseas shipments that were scheduled for May, 1945. The catalog later was found to be inadequate for overseas shipments due to last minute changes in design and late procurement; but it was invaluable in the beginning to coordinate all thoughts in the direction of one purpose, to use tactically a weapon on the Japanese Empire.

At this time, Site Y representatives made a trip to Mare Island Navy Yard to study crating and packing problems for overseas shipment.

From information obtained at the Mare Island Navy Yard, crates were designed and drawings completed for all major components. The engineering procurement representative took these drawings to Los Angeles and, in the time of one week, procured sample crates and shipped them disassembled by air express to Wendover.

These crates were assembled at Wendover by Engineering personnel from Site Y and were used as a sample shipment to Mare Island Navy Yard. This accomplished a two-fold purpose.

(1) It tested the design of crates as to their durability and strength.

(2) It gave the shipping experts at Mare Island an opportunity to gain first-hand information on the parts that they had to pack for overseas shipments.

When the question of overseas shipments or batch shipments arose, the Weapons Committee at Site Y set up requirements as to the number of 1561 FM bombs and 1852 LB bombs required per month. Since certain groups could not meet the requirements as set forth by the Weapons Committee, R. S. Warner, Jr., prepared batch-shipment lists based on the concerned groups' ability to prepare, test and assemble component parts. These lists were then further detailed into work lists by a member of the engineering department for use by the First Ordnance Squadron, Special Aviation, of the 509th Composite Group at Wendover. The specific purpose of this group was to fabricate test models of the 1561 FM bomb and the 1852 LB bomb and also to prepare and crate assemblies and parts for batch shipments.

A large amount of planning and effort was put forth by R. S. Warner, Jr., and by the Engineering Department in starting and maintaining a continuous flow of batch shipments to Mare Island where Lt. Col. R. W. Lockridge's organization was supervising the packing, loading and the computing of necessary statistics. To enlarge on the amount of work that was required to get the first batch shipment on its way, the amount of work in cataloging and preparing crates has been previously mentioned, but the amount of work in actually collecting parts, modifying parts, test assembling and actual crating, required a great deal of effort. At the time of the first batch shipment, the First Ordnance Squadron was involved in a very extensive program and was able to furnish only a limited number of men for batch-shipment work; therefore, most of the work fell to engineering personnel from Site Y to actually collect, assemble and crate parts for the first shipment. The first batch was completed on scheduled time at Wendover on April 30, 1945. This batch was used primarily to thoroughly test the complete shipping channels and packing methods from Wendover and Site Y to the final overseas destination.

In early March it became evident to the Engineering Department that a modifications building for the reworking of parts to latest changes would be necessary at Wendover. In view of this, plans were started and equipment ordered to build and equip a Butler building of 40 feet by 80 feet at Wendover. This building was completed in time to use for the second batch shipment that was shipped from Wendover, May 31, 1945. With the completion of the modifications building and the arrival of the replacement unit, under Captain Roerkohl, for the First Ordnance Squadron which was destined for overseas duty, the work of modification, test assembly and crating was taken over by the replacement unit with supervision from the Engineering Department at Site Y. This unit became very proficient in the preparation of batch shipments and, as the third and fourth shipments were reached, they were functioning smoothly.

To sum up this short discussion of the supply problem at Wendover, it is evident that a great deal of thought, planning and effort was put forth by all concerned in order that a smooth and efficient supply channel could be established between Site Y, Wendover, and Tinian. Credit for this smoothly functioning organization should be given to R. S. Warner, Jr., the Engineering Department, Lt. Col. R. W. Lockridge's shipping organization and Captain Roerkohl's Army unit at Wendover.

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4.5 HANDLING AND ASSEMBLY EQUIPMENT

The assembly of the 1561 Fat Man bomb by means of specially designed handling equipment had been developed from a very crude and unreliable method to a more systematic and safer procedure.

The equipment and assembly method was developed late in the design of 1561 Fat Man bomb and was first fully utilized in assemblies at the overseas project.

In order to clarify the foregoing statements, the problems and solutions of assembly will be given in this portion of the chapter on assembly of 1561 Fat Man.

It was not until July, 1945, that a 1561 Fat Man bomb was assembled completely. Prior to that time bombs had been assembled almost complete, but never complete with the high explosive components. At the beginning and through a major portion of test assembly work at Wendover, most thought was given to the actual design and testing of bomb components, and very little to actual assembly procedures. It was not until April, 1945, that considerable thought and work was started towards assembly equipment and methods by the Engineering Department.

The first method of assembly and the one utilized until June, 1945, was briefly as follows: A dray held the sphere for block loading; a spreader bar was used to rotate the sphere; all equipment was assembled in the sphere by overhead chain hoists; ellipsoids were assembled by chain hoists; and the tail in the final step was held in position for assembly by an overhead chain hoist.

DOE
b(3)

DOE b(3)

With this method of assembly the overhead chain hoists were dangerous due to long lengths of chain striking the detonators in the sphere when it was being held for assembly. The sphere being free to swing and the ellipsoids being suspended from one point, caused an unbalanced condition that led to a great deal of forcing by pinch bars and a high amount of physical force. This method of assembly was quite all right for bombs that were loaded with concrete, no detonators and no wires, but it was very inadequate for assembly of complete bombs.

The first work in the designing of handling equipment was started with the idea of eliminating the overhead chain hoists entirely and using an A-frame instead. The A-frame was designed to hold the sphere steady by means of removable sway-bracing that fit on the flange of the sphere (Figure 5). By using the A-frame, the sphere could be loaded in the dray, the A-frame rolled over the sphere, and then picked up. With the sphere in this position and with the sway-bracing in place, the "X" unit was held in position with a jib hoist (Figure 6) and the sphere wired. The "C" plate was also held in place for assembly with the jib hoist. With "X" unit and "C" plate in place, the bomb was completely wired ready for ellipsoid and "A" plate assembly.

Considerable thought was given in the assembly method for the

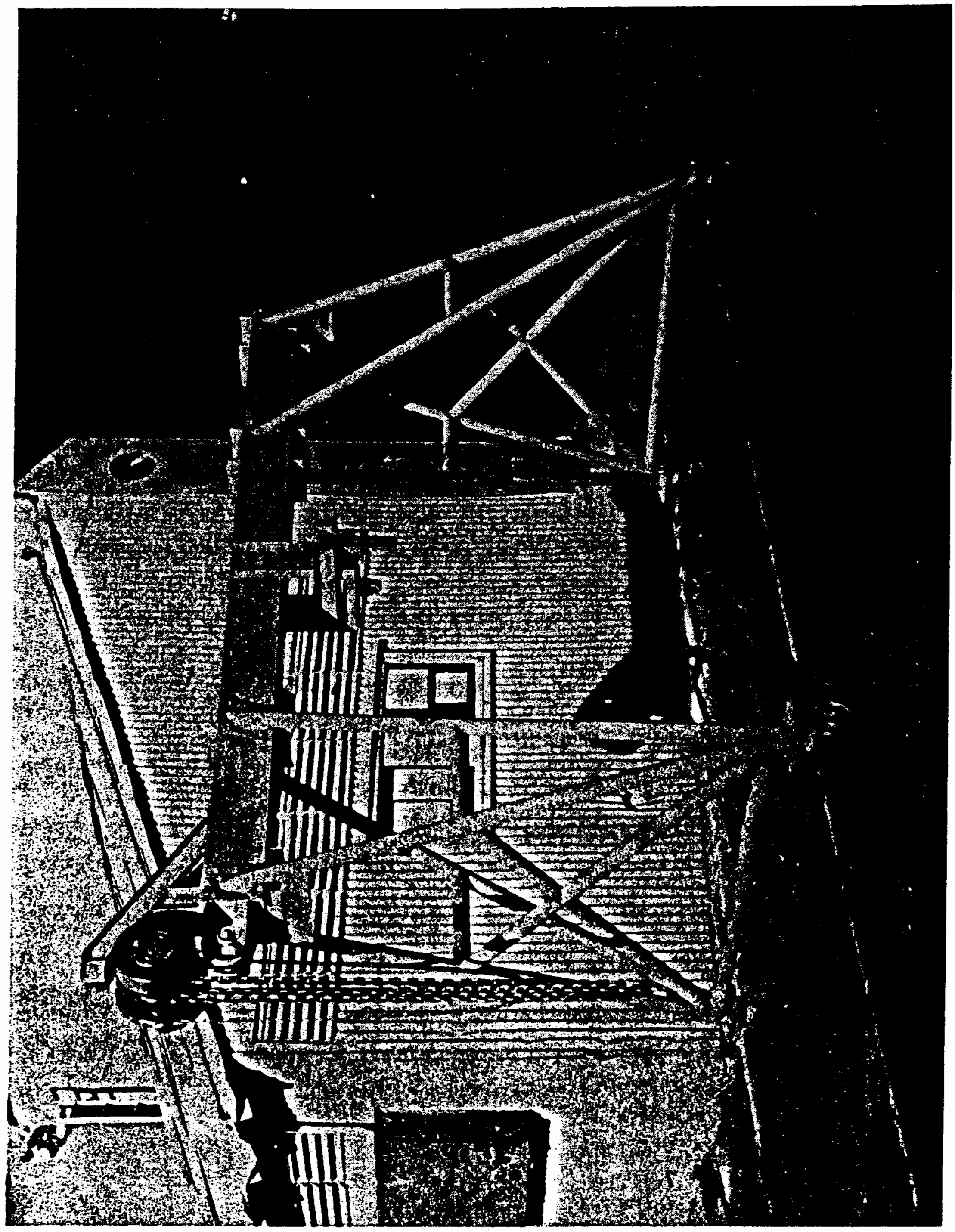

Figure 5

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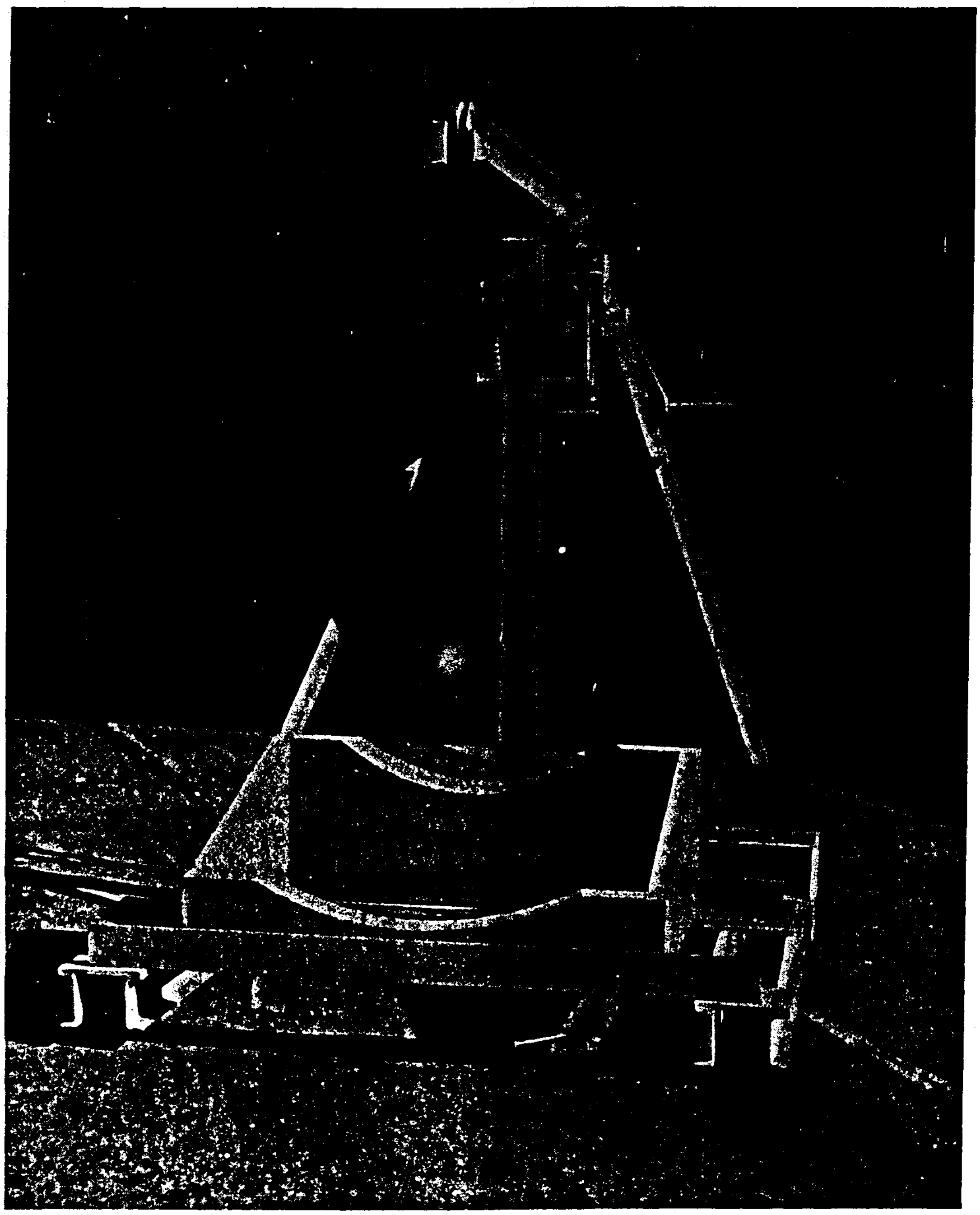

Figure 6

ellipsoids, and the first and final decision was to use an adjustable dolly that would hold the ellipsoid in the proper assembly position. The first type of dolly that was designed for the front ellipsoids is shown in Figures 7a and 7b. The earlier type was later replaced by one with greater adjustability and maneuverability, which dolly was used for both ellipsoids in Figure 8. With still another modification, the dolly was made to hold the ellipsoids rigid, as shown in Figure 9.

The ellipsoids, mounted on the dollies, are run into position on the sphere and bolted in place. The tail of the bomb is then positioned with the jib hoist, and the assembly is complete.

Utilizing the above outlined procedure, the assembly could be accomplished without the use of hoisting equipment other than that mentioned. The method, however, proved impractical due to thelimited floor space, mentioned in the previous discussion on assembly buildings.

From the overhead chain hoist method and the method outlined above, a compromise was reached for the final assembly procedure. The latter assembly procedure utilized the overhead chain hoists, two 1-ton hoists and one 6-ton hoist, together with ellipsoid dollies, floor sway-bracing (Figure 10), X-unit dolly (Figure 11), "C" and "A" plate handling fixtures (Figuresl2 and 13), sphere tongs (Figure 14) and ellipsoid guide pins.

A detailed assembly procedure as used in July, 1945 for the 1561 bomb will be found in LA-392.

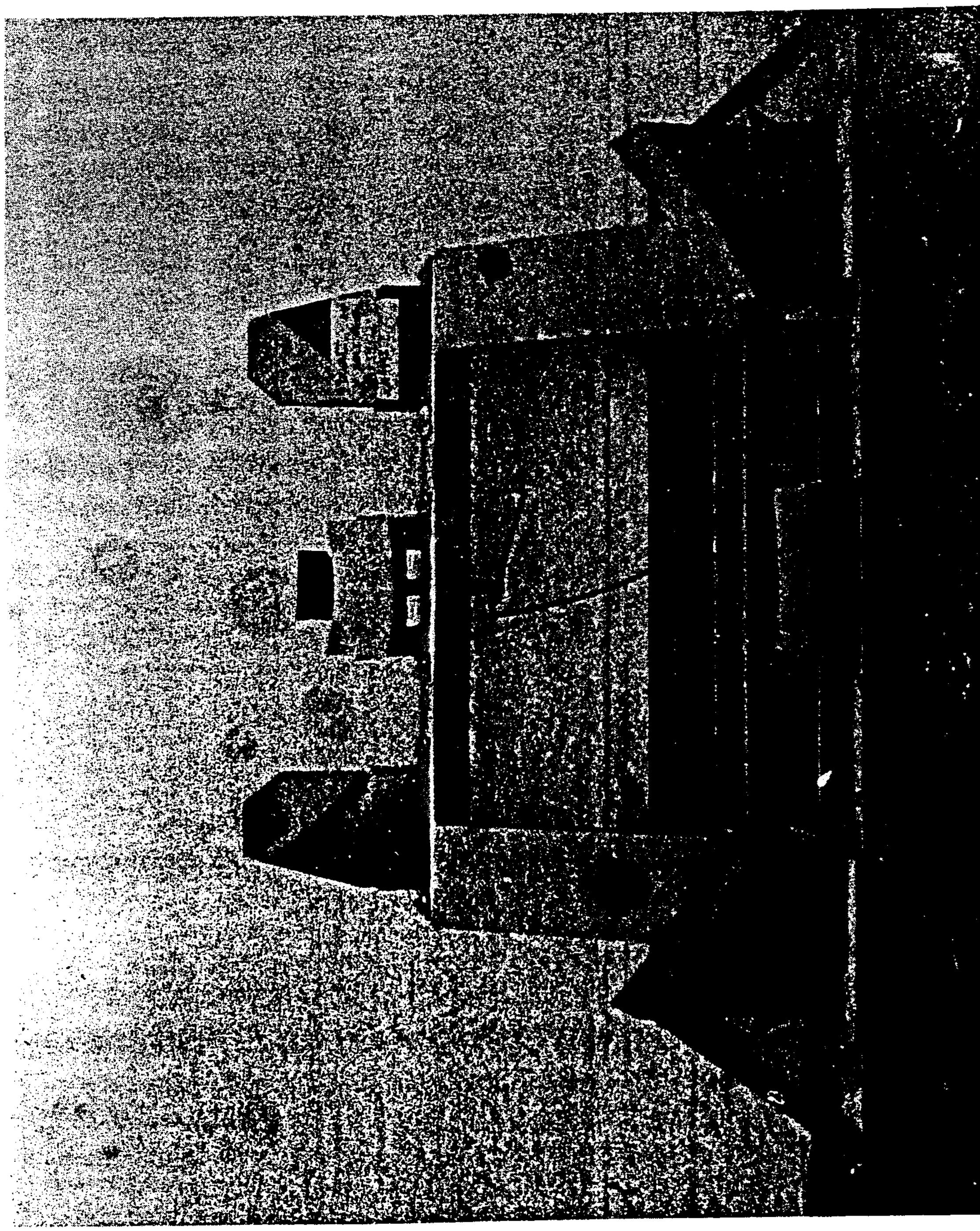

Figure 7a

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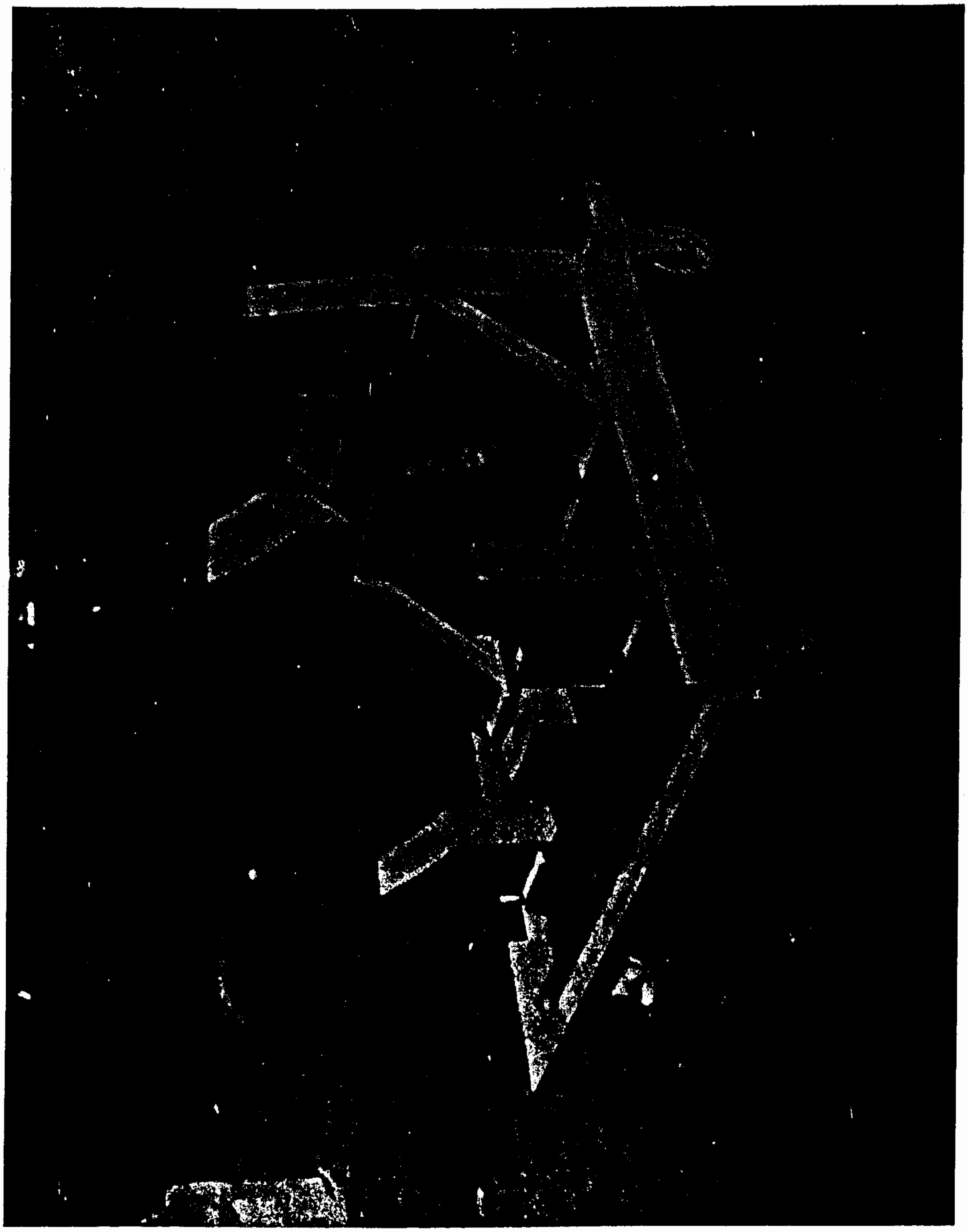

Figure 7b

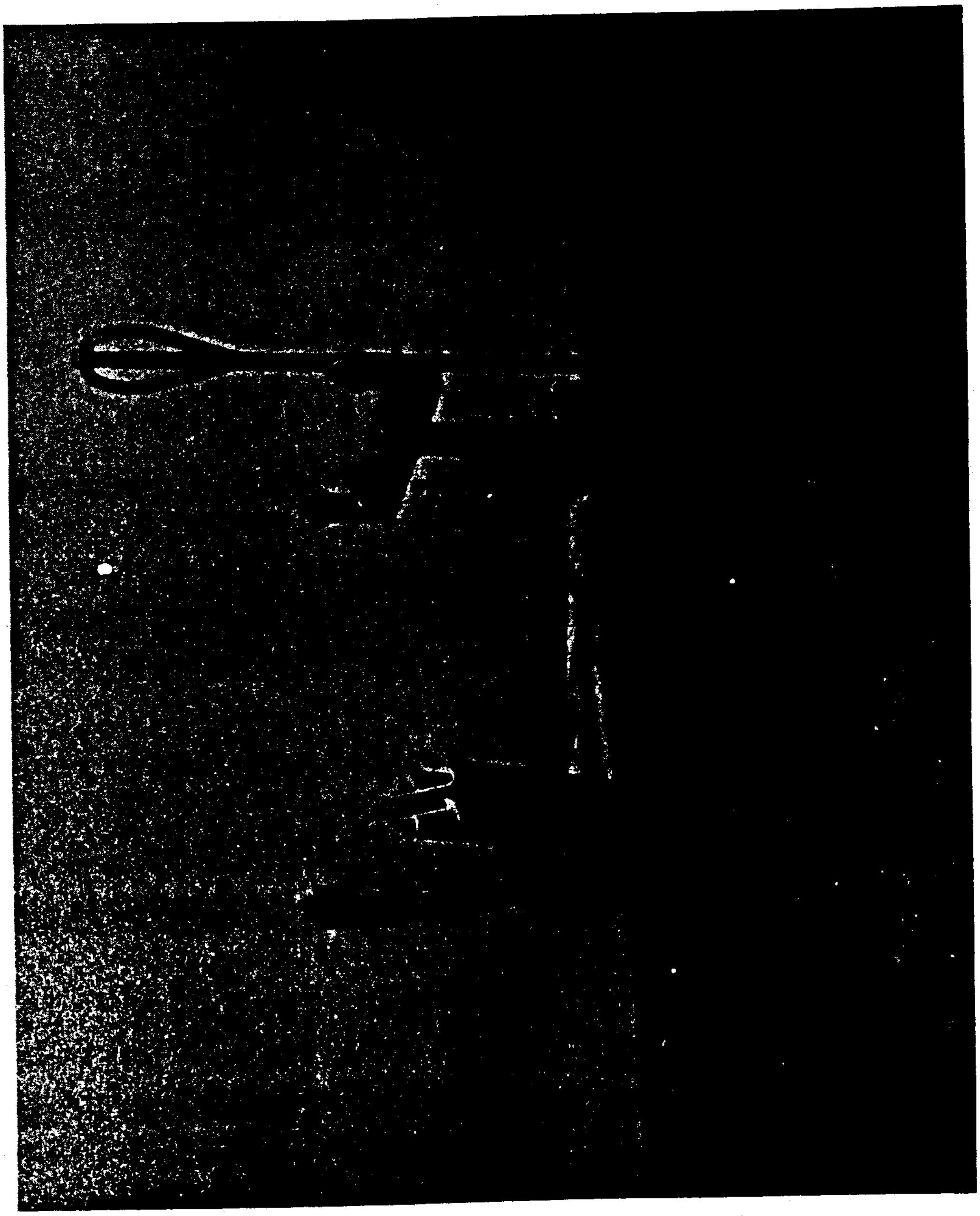

Figure 8

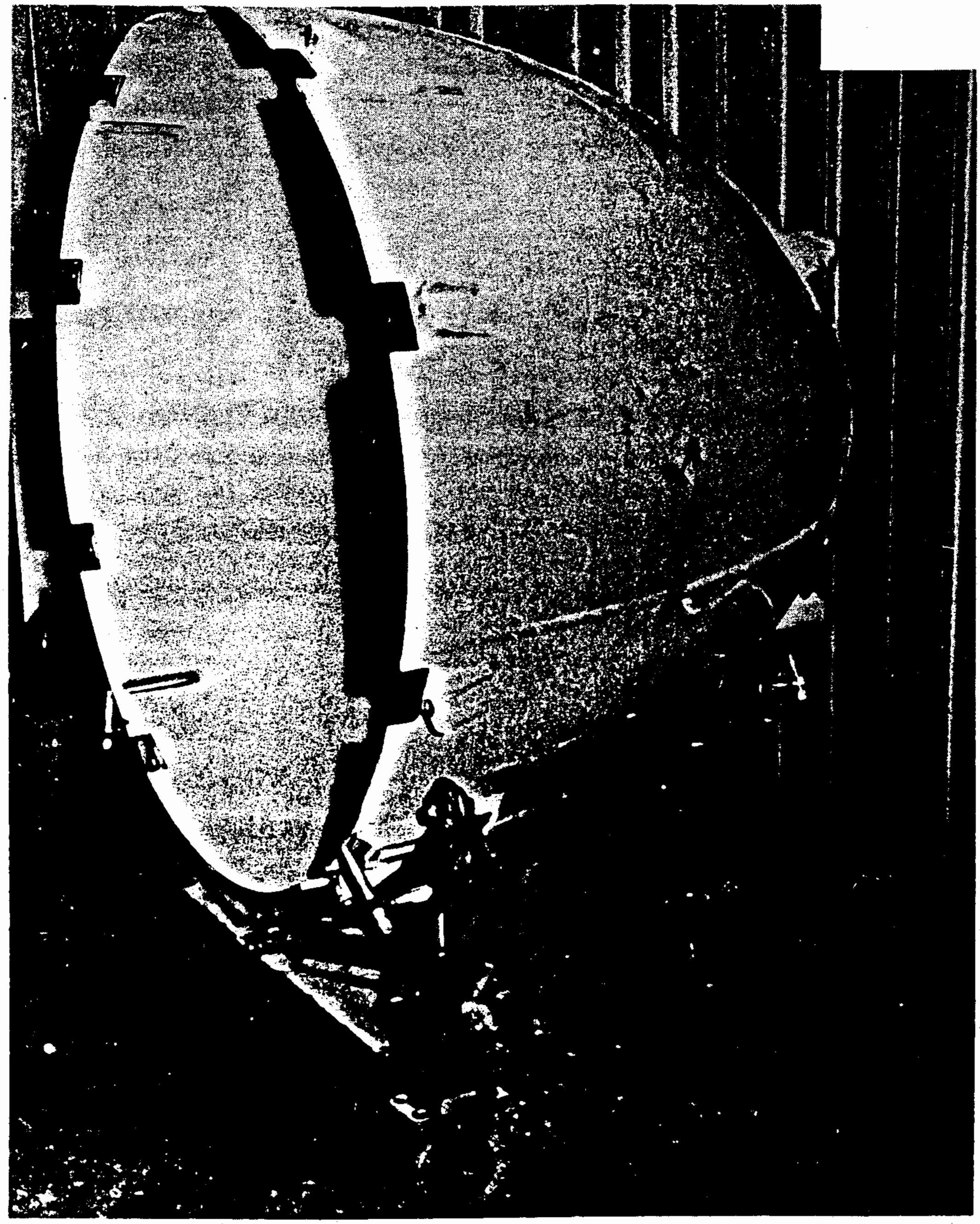

Figure 9

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Figure 10

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Figure 11

DOE
b(3)

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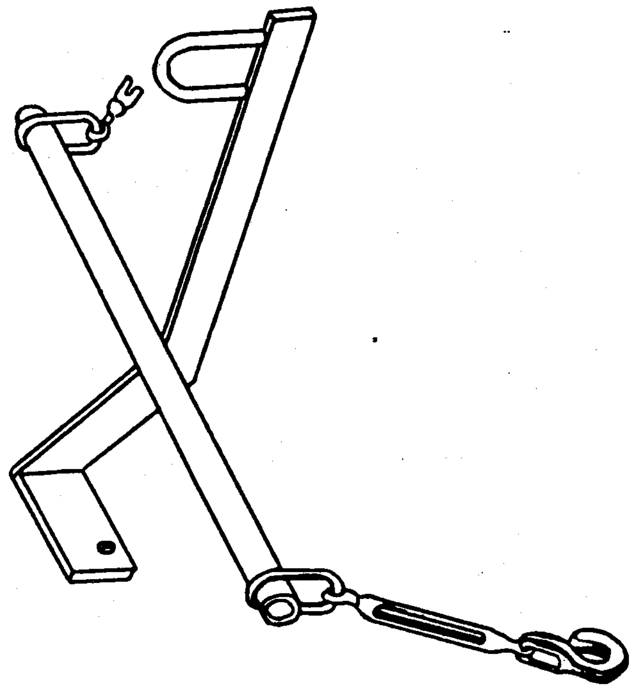

Figure 12

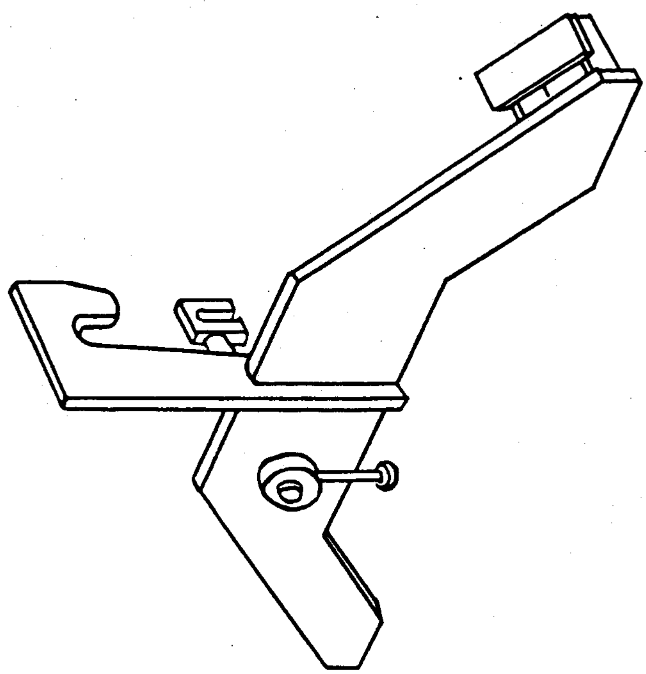

Figure 13

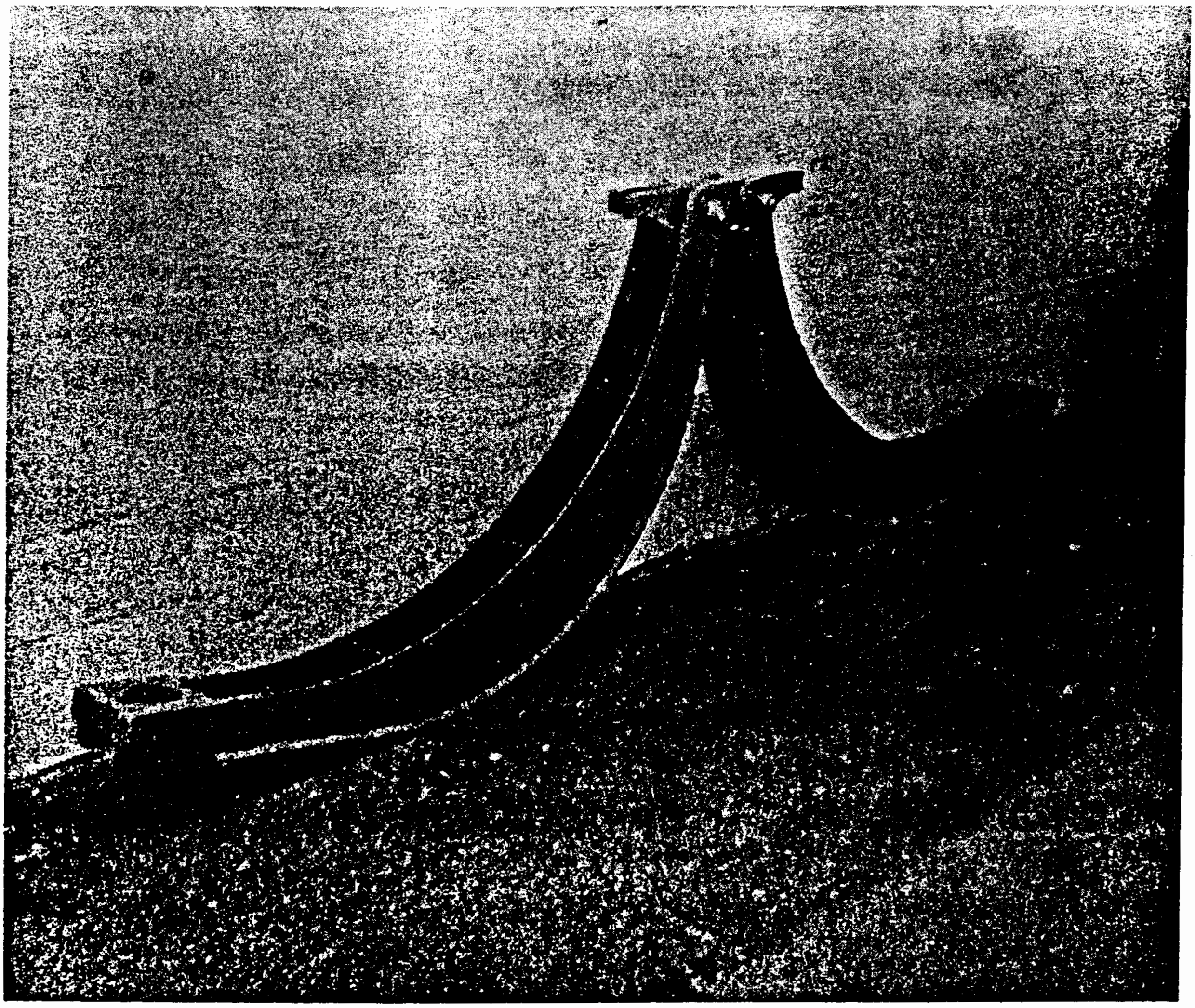

Figure 14

4.6 CONCLUSION

In concluding this chapter, a few comments and notes are in order.

The description of the sphere HE loading and preparation of trap door assemblies will be found in Volume XI.

The author, at this time, wishes to express his appreciation to R. S. Warner, Jr., and A. B. Machen for their helpful suggestions and cooperation in compiling of data for and the writing of this chapter.

The author wishes to give credit to the Project Y Engineering Department, since no one man was responsible entirely for certain developments, a complete list of the Engineering Department personnel as of June, 1945 is given.

ENGINEERING DEPARTMENT

(June 1945)

Civilian	Military
	Navy
Allman, James	Miller, Victor A., Lt. (j. g.)
Batteiger, John C., Jr.	Special Engineer Detachment (SED)
Cline, Grant J.	Baumgarten, Aaron T/3
Davis, Thomas V.	Bond, Avery P.
Galloway, George W.	Carlson, Loren A.
Hayes, Robert O.	Calhoun, Robert J.
Harris, Virgil A.	Cushman, Charles P.
Ives, Wallace W.	Dirksmeyer, Anthony T T/4

Civilian

Lyon, Merrill K.

Machen, Arthur B.

Nicovich, Philip A.

Runyan, James E.

Robinson, Charles F.

Russ, Harlow W.

Russo, Benjamin J.

Riede, John

Siglock, Robert

Selleck, R. W.

Theis, William T.

Warner, Avery L.

Military

Easton, Glen D.

Hicks, Mark W., T/5

Hain, Emory M., T/5

Johnson, J. R., T/3

Jockle, Philip E., T/5

Jennerjohn, Dale P.

Kimball, Arthur R.

Mitts, James E., T/4

Mills, Vernon M., T/4

Owens, Philip P.

Ruder, Jack H., T/4

Russell, Jack P.

Stack, Francis C., Pfc.

Schultz, Raymond, Pfc.

Schmidtke, Richard P.

Whiston, Donald H., Pfc.

Walters, William P.

Young, William S., T/3

Zindler, Herbert P.

Zoerb, Raymond, T/5

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CHAPTER 5

ATOMIC-BOMB PROJECT AIRCRAFT

S. H. Dike

5.1 AIRCRAFT USED FOR ATOMIC-BOMB DELIVERY

The first bomb dropped in connection with this project was released from a TBF at Dahlgren Naval Proving Ground, Virginia, on August 13, 1943. This test, witnessed by N. F. Ramsey, was for ballistic data only. The first drop made in connection with fuze research was made from an SNB-1 (AT-11) at Dahlgren on December 3, 1943.

In the early days, several types of aircraft were considered for carrying the atomic bomb. The shape of the bomb then was very different from either of the two final types. The British Lancaster and our own B-29 were the two planes most seriously considered for the final delivery job. In the early summer of 1943, the B-29 was a new airplane; its performance was still more or less unknown and production rates were not definitely planned.

It was decided in November, 1943, to modify a B-29 at Wright Field for project use. Accordingly B-29 No. 42-6259 was procured. This was the 69th Wichita production airplane.

At that time, there were two distinct types of bombs which Project Y wished to drop. These were known as the "Fat Man" (Figure 1) and the "Thin Man" (Figure 2). The "Thin Man" became obsolete later in the program and evolved into the "Little Boy".

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Figure 1

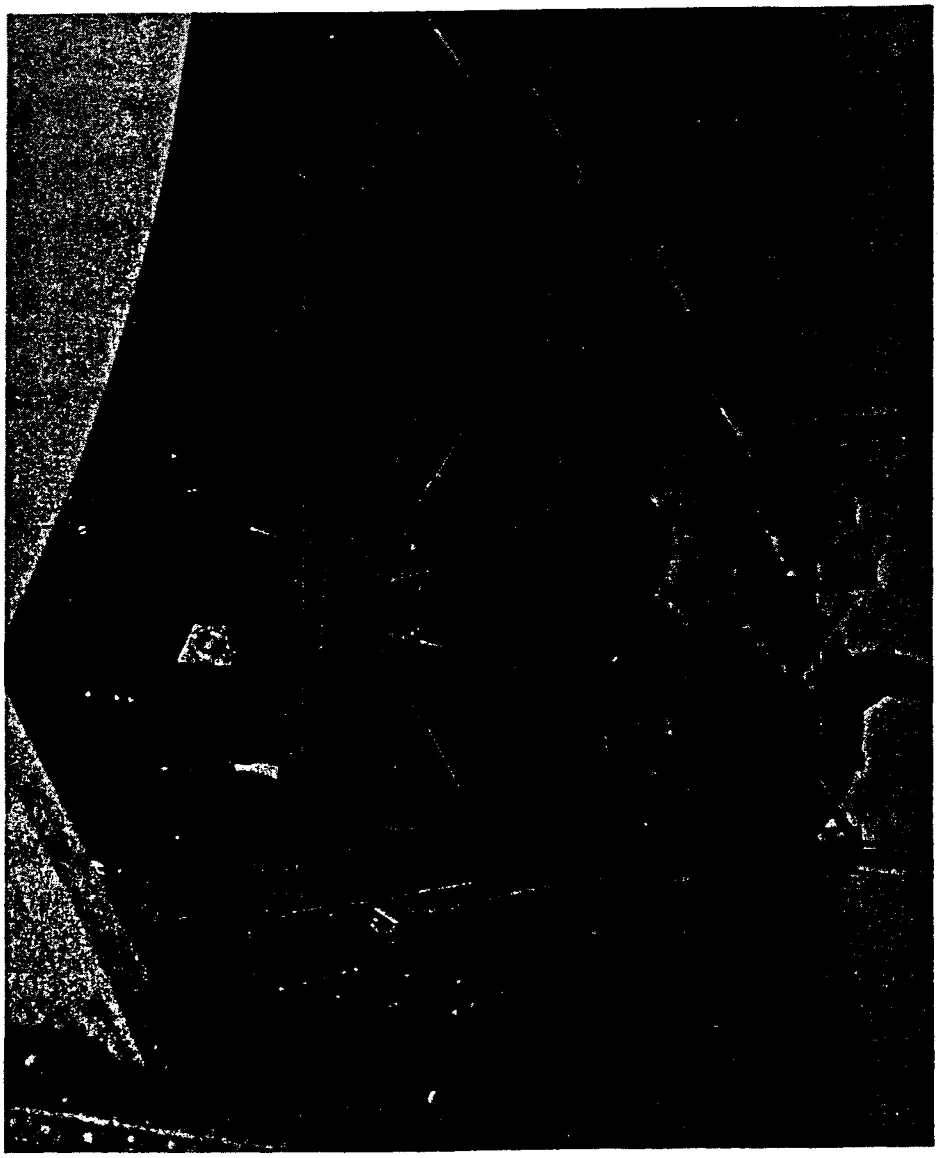

Figure 2

The first "Fat Man" shape was changed considerably, but overall external dimensions remained about the same.

During December, 1943 and January, 1944, the necessary modifications were made at Wright Field under the supervision of Major (then Captain) R. L. Roark. A large part of the mechanical-engineering design was done by Mr. Charles Speer, a civilian Engineer at Wright Field. The crew assigned to the B-29 included Major C. S. Shields, (pilot) and Captain Dave Semple, (Bombardier). Captain Semple followed the modifications concerning the release and bombing circuits.

The modifications of the first B-29 included: changes in the bomb doors; installation of a carrier frame, sway-bracing; and release for the Fat Man bomb model; installation of release and sway-bracing for the Thin Man bomb model; and installation of the special wiring circuits required by the Fuzing Group. Several Eyemo Cameras were installed in the bomb bay for photographing the release and initial bomb flights. The release used was a modification of a standard glider tow release; two of these, tied together mechanically, were used. The bombs were fitted with two suspension lugs.

The modifications were completed in early February, 1944, and the B-29 was flown to Muroc Army Air Base, California, to undergo the first series of tests, arriving there February 20, 1944. Two test drops were made on February 28 with standard inert bombs for ground crew camera practice. The first drop of the Thin Man model bomb from a B-29 was made on March 3, 1944.

Failures in the bomb-release system occurred during the first series of tests. It was erroneously believed that, once the toggle of the glider tow release was pulled past dead center, the weight of the bomb would open the release. This was later proven not to be the case. In order to effect proper release, sufficient force must be applied to actually pull apart the jaws of the release. The insufficient spring force provided in the early tests led to repeated hangups of several seconds in the release. It was at first thought that the firing solenoid was not operating properly. Various remedies were attempted. On one occasion the cable operating the release was tied to a length of pipe fastened to a standard B-7 shackle. During that test, either the nut on the stud holding the cable to the length of pipe backed off due to vibration or the differential contraction between the aircraft and the cable (due to temperature) allowed sufficient slack to occur in the cable so that premature release took place at 24,000 feet while still climbing to the desired altitude. The unit fell on the bomb doors. The doors were then opened and the bomb tore free, considerably damaging the doors. A landing with the doors open was made at San Bernardino Air Depot where the damaged doors were forced closed and a sheet of aluminum riveted across to hold them. The ship returned to Muroc and soon after flew to Wright Field for repairs. Thus ended the first series of tests.

New doors and three new engines were installed at Wright Field. The fault with the release system was found and installation corrected. Several releases were made on the ground.

The second series of tests was made at Muroc in June, 1944. No malfunction of the release system occurred, with the exception of a grounded bomb-door safety switch on one mission. This caused the bombing-circuit fuses to blow. Attempt was made to replace the fuses in the bomb bay in flight but they would not stay. It was necessary to bring the unit home and land. An unfused by-pass circuit around the door safety-switches was then installed, which circuit could be closed by means of a switch should the door switch failure occur in the future. The door switch installation on the early aircraft was poorly designed. It is believed no failures of door switches ever occurred in subsequent project aircraft where the door switch installation was considerably improved. However the by-pass circuit was included in the first group of project B-29's, and in the second group, which was used overseas, the bombing circuit was permanently wired around the door safety-switches.

After the June, 1944, tests it was learned that the weight of the final unit might be considerably greater than was at first thought. It was decided to use a more substantial release. In a meeting at Wright Field, Colonel Butler promoted the British type F release with the type G attachment; that release was accepted by the Project and its installation was started in the B-29 presently in use.

During a visit to the Project in August, 1944, by Colonels Wilson and Demler, it was decided that additional aircraft should be modified for use. Accordingly, Mr. Charles Speer was sent to the Glenn L. Martin-Nebraska Company, Omaha, Nebraska, to supervise the preparation of the engineering on the modifications required. S. H. Dike represented the Project at Omaha and engineered the special wiring and other additional provisions. The first modified aircraft was 42-65209; 17 aircraft were modified in all.

In August, 1944, the Air Force decided to form a squadron specially trained for delivery of the atomic bomb. This squadron was formed around the 393rd Bomb Squadron V.H. then based at Fairmont, Nebraska, and was moved to Wendover Field, Utah, in September. 1944. The Martin-Omaha aircraft were delivered to this field.

Tests were run at Wendover Field in September, 1944, using the original Project B-29, No. 42-6259. The last project flight with this aircraft was made by Major Charles Sweeney, pilot and Major Thomas W. Ferebee, bombardier. The main gear wheel well doors were damaged on this flight and the plane was never used again. It was later turned over to the training command.

Tests continued under a Test Section headed by Major Sweeney. Most used aircraft were Nos. 42-65209, 234 and 235. All of this first series of aircraft were not satisfactory from our modification point of view. Several serious errors in location of release and sway-bracing were apparent due to inadequate layout made at the factory. This was not the fault of the Martin engineers: they were prevented from doing their best by unnecessary security. Furthermore, no attempt was made to make parts interchangeable from one aircraft to another. Thus, each aircraft was different from the other and in some cases critical dimensions varied by inches among various aircraft. The major part of the engineering and modification man-hours went into the installation of bomb bay heaters which were never used.

It became apparent that the present Project B-29's were becoming obsolete, since new developments made the B-29's then coming out of the factories much better. Fuel injection engines were a proved advantage. Pneumatic bomb doors would soon become standard. Fuel flowmeters were available. Electric propellers were being tried on the B-29. It was desired to have these and many other of the latest improvements on the Project B-29's before going overseas. With this in mind, Colonel P. W. Tibbets and S. H. Dike flew one of the Project aircraft to Wichita to talk to the Boeing Company about taking the Project planes to a modifications center, such as Oklahoma City, to have the latest modifications installed. In a discussion with Mr. Harold Zipp, Chief Engineer at Wichita, it was decided that the man-hours involved would about equal those of modifying a new series of aircraft for project use. Colonel Tibbets and Mr. Dike then flew to Wright Field, to get a directive started, and on to Washington to get the authorization sent to Wright Field so that the work could begin.

A meeting was called early in February, 1945, of the Project people concerned with aircraft requirements in order to bring up to date the various modifications that would ultimately be required. S. H. Dike then went to Omaha and revised and re-engineered the so-called Silver Plate modifications. Many items were deleted, others were added, and still others revised. The bomb-carrying provisions were completely redesigned and better tolerances of workmanship were set up and followed. A major part of the carrier, sway-brace, and special bomb rail design were supervised by M. M. Bolstad. Electric propellers were side-tracked from the B-32 program and installed under supervision of Curtis Wright Engineers. All fire control except that of the tail turret was deleted. Fuel injection engines and a fuel manifold system were installed.

The first aircraft modified in the latter series was No. 42-65384. This and the next aircraft (42-65385, 386, 387 and 44-27295) were turned over to the Test Section headed by Major C. S. Shields at Wendover. These five aircraft performed the major part of the test work carried on by the Project. 15 aircraft in all were sent overseas. These were Nos. 44-27296 thru 304, 353, 354, 44-886291, 292, 346 and 347. Aircraft No. 44-27292 was the "Enola Gay" which carried the first atomic bomb.

5.2 AIRCRAFT MODIFICATIONS

The modifications required by the Project in these aircraft can be divided into the following categories:

1. Means for hoisting, holding, sway-bracing and releasing either of two bomb shapes
   - a. Special carrier frame and release mounting;
   - b. Sway-bracing;
   - c. Special forward rails;
   - d. Rework of tunnel to allow installation of release;
   - e. Guide rails for F. M. tail shroud;
   - f. Hoists, cables, equalizer pulleys and blocks;
2. Special wiring
   - a. Fuzing, detonator, and blast gage control and test circuits;
   - b. Keying and release signals;
3. Provisions for special observer

a. Table, chair, oxygen outlet, interphone stations, etc;

b. Provision for test box controls;

4. Bombing circuit

5. Mechanical bomb release controls

6. Provisions for special observational equipment

a. Special antenna;

b. Photocell installation;

c. Equipment rack installation.

All of these modifications are called out on the two master engineering drawings. (These are Martin drawing numbers A-149, Sheet 1A, and A-150, Revision J.*) Reference to these drawings will indicate what other drawings are concerned with the modification in question. The accompanying photographs, Figures 3 through 12, show the majority of these modifications. The numbered arrows, when shown, refer to the Martin drawing number for that part or installation.

Expanding the outline above in somewhat greater detail, the Project modifications are given in the following.

5.2-1 Means for Hoisting, Holding, Sway-Bracing, and Releasing Either of Two Bomb Shapes

(1) Special carrier frame and release mounting.

A carrier frame was installed high in the forward bomb bay. Upon the longitudinal beams of this frame a steel mount was fastened for holding the British Type F bomb release with Type G attachment. Figure 3 shows this frame in place. Note that it is fastened to the standard bomb rails at the rear of the bay and to a pair of special rails at the forward end of the bay. The release mount as shown in

*None of the Glenn L. Martin drawings referred to herein are included in this Chapter.

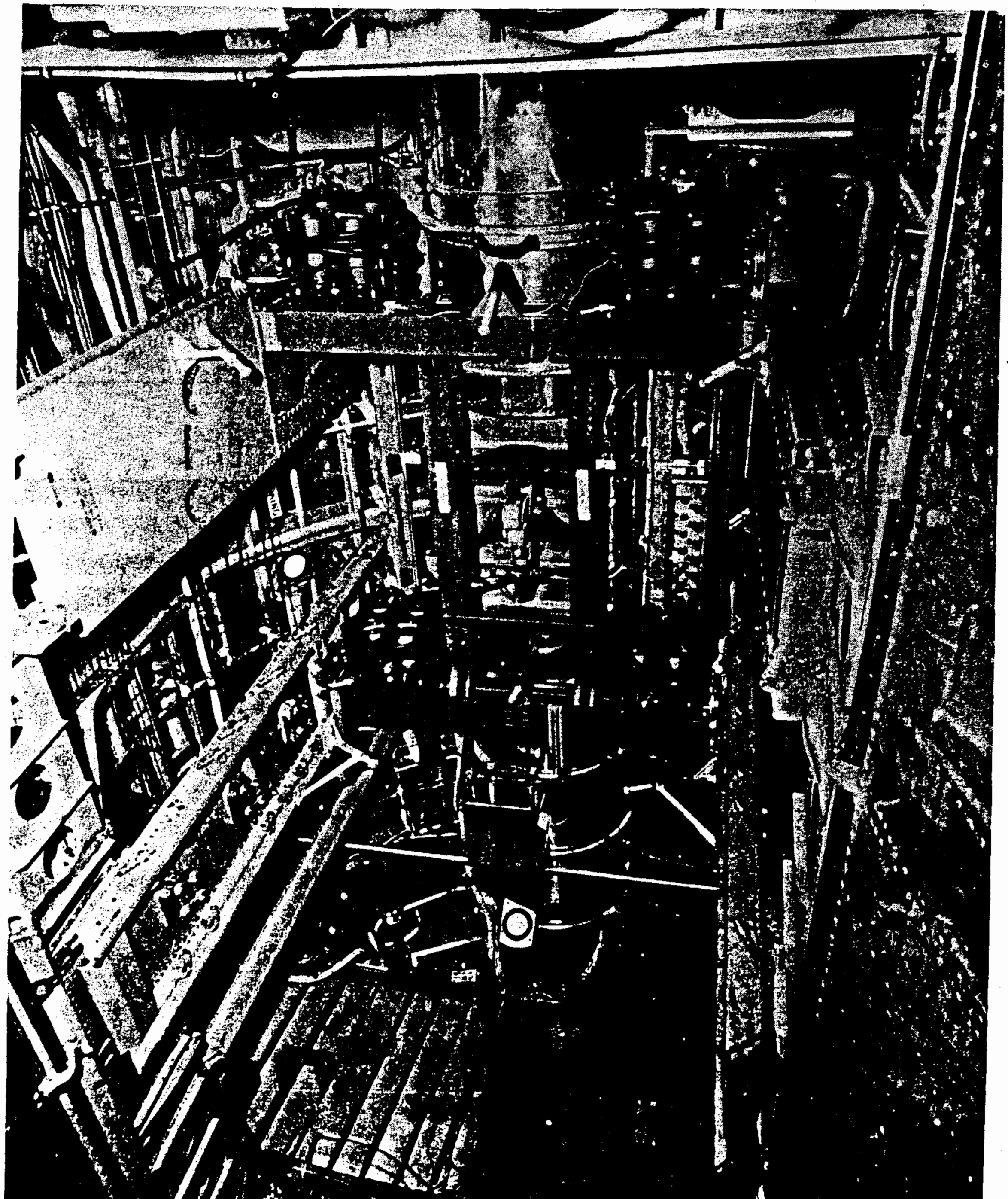

Figure 3

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Figure 3 was for the F. M. bomb shape. For the Little Boy bomb, a different release mount was used. This mount was bolted to the lower side of the longitudinal beams. The Little Boy release mount is shown in position in Figure 4. This carrier frame was statically tested to two thirds of 7g vertically, 3g longitudinally and 2g laterally[1]. In a vertical load to test destruction the carrier failed at 62,000 pounds. Failure occurred in a gusset plate at the junction of the longitudinal and lateral beams. The gusset was redesigned and the destruction test repeated on the revised carrier. Failure occurred in the revised carrier at 85,000 pounds. It should be noted, however, that before this revision became effective, five aircraft were delivered with the weaker carrier; these were 42-65384 thru 387 and 44-27295. (See Glenn L. Martin-Nebraska Company Report E. L. R. Number N-12 for complete stress analysis of carrier and release mount.) (See Glenn L. Martin-Nebraska Company Drawing Numbers A-315 Change C, A-376 Change C, A-407 Change C, A-302 Change B, A-339 Change D and A-421 Change B for further details of carrier and release mounts.)

(2) Rework of Tunnel

In order to realize sufficient clearances, it was necessary to cut out part of the tunnel above the carrier for installation of the release. This rework of the tunnel is shown in Figure 5. A plastic window and two hand holes, fitted with removable plugs were made a part of this rework, and were installed for use in extreme emergency

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[1] Glenn L. Martin-Nebraska Company Report E. L. R. Number N-511.

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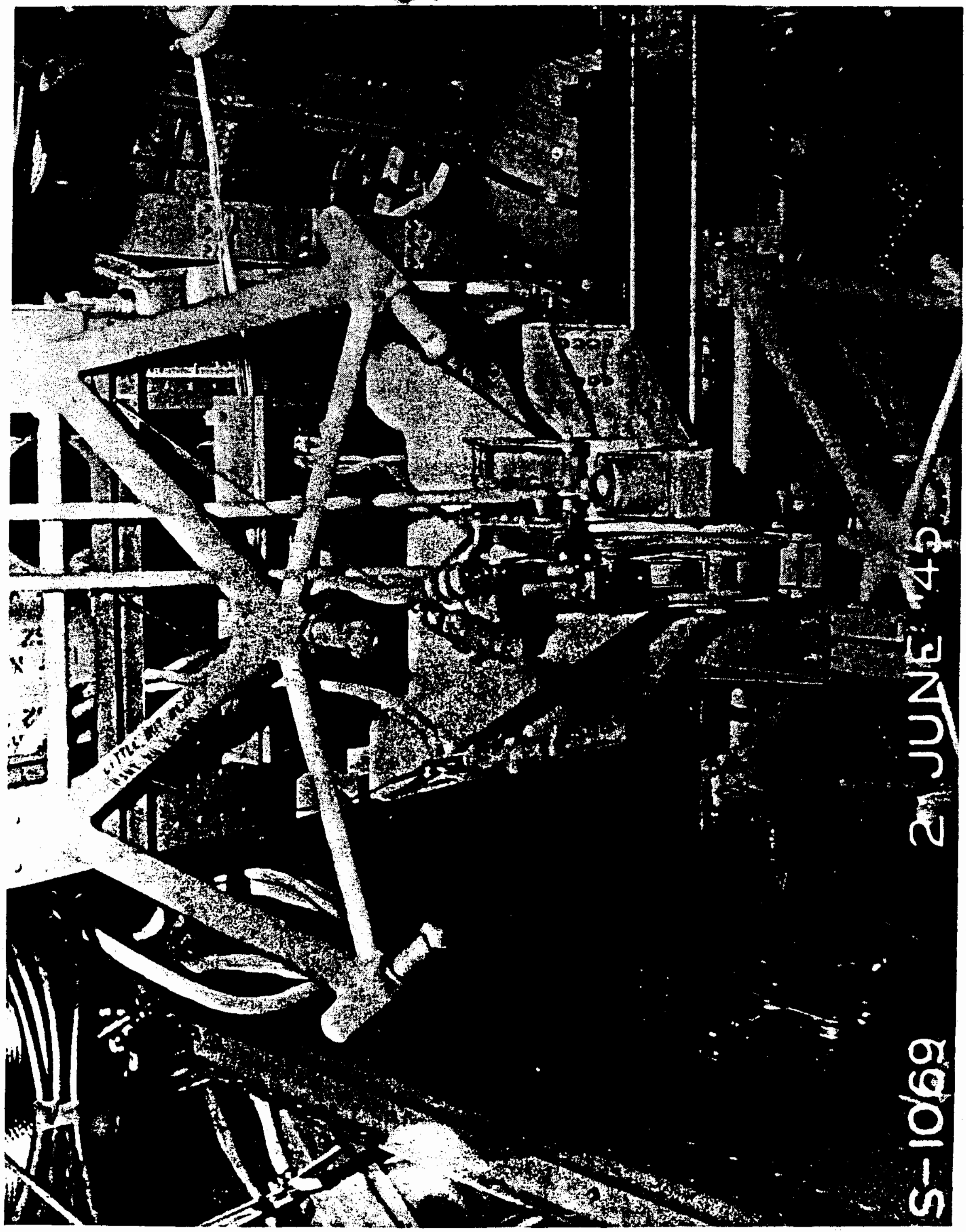

Figure 4

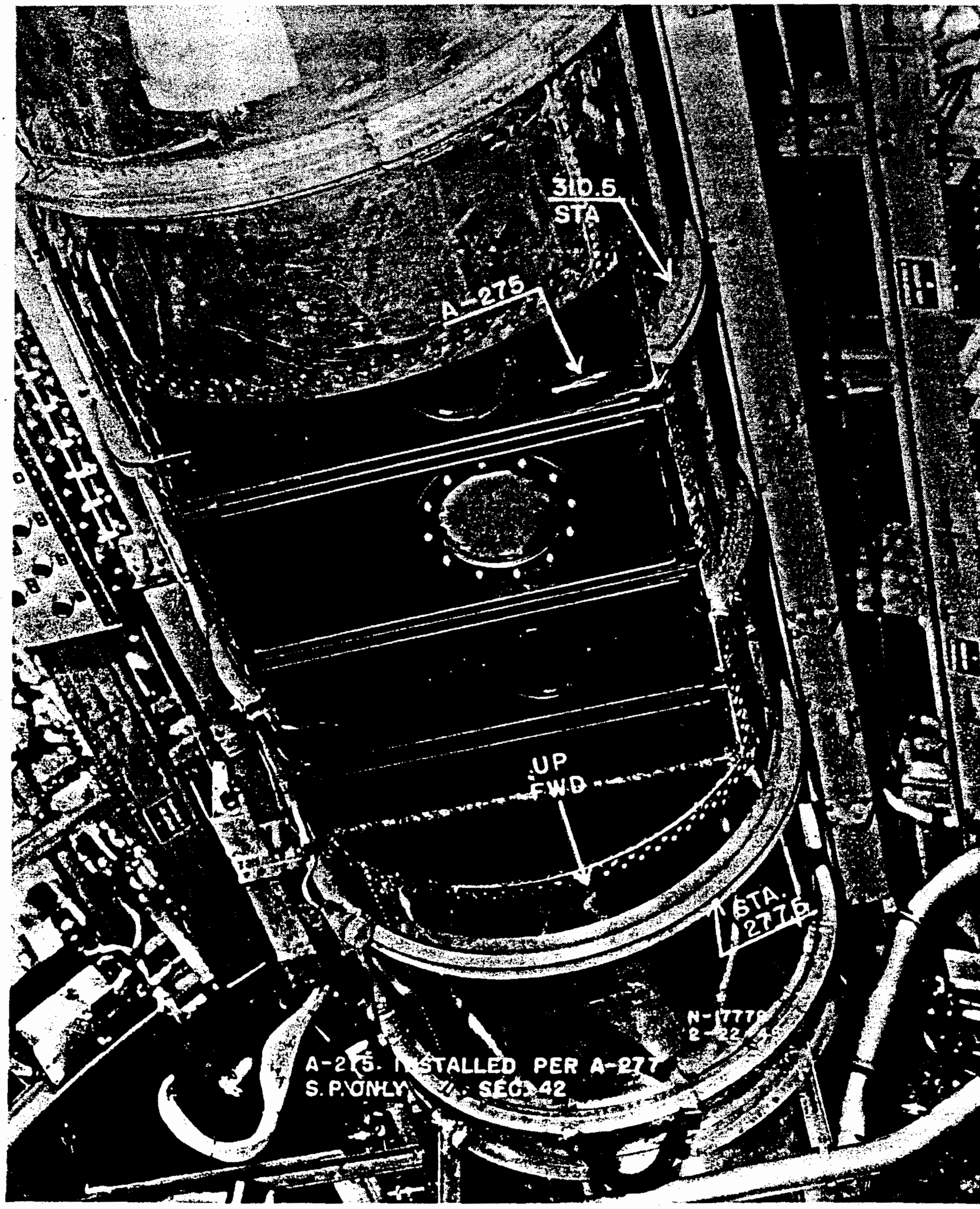

Figure 5

for releasing the bomb in the event both the electrical and mechanical release provisions should fail. (See Drawings A-275 Change A, and A-277 Change A, for further details.)

(3) Special forward rails

Insufficient strength and inadequate fall-out clearance of the standard forward rails indicated the necessity for their replacement with special rails in this position. The special rails fasten to the standard fittings and are shown in Figures 3 and 7.

(4) Sway-Bracing

Since a single point suspension was used on the bomb, it was necessary to brace the bomb against lateral and longitudinal sway. Both bombs were braced at six points. These braces were welded tubular structures fitted with threaded adjustable bearing points. The six sway-braces for the F. M. bomb are clearly shown in Figure 3. Sway-bracing for the Little Boy bomb is shown in Figure 6.

(5) Guide Rails

To prevent possible catching of the F. M. Tail shroud in the bomb bay during fall-out, guide rails were installed. These are shown in Figure 6.

(6) Hoists, cables, equalizer pulleys, and blocks

Figures 3 and 8 show clearly the bomb hoisting provisions installed. Four standard type C-6 bomb hoists were used. A continuous 7/32 aircraft cable was passed through a load equalizer pulley, the through the snatch blocks shown and on to the two hoist drums.

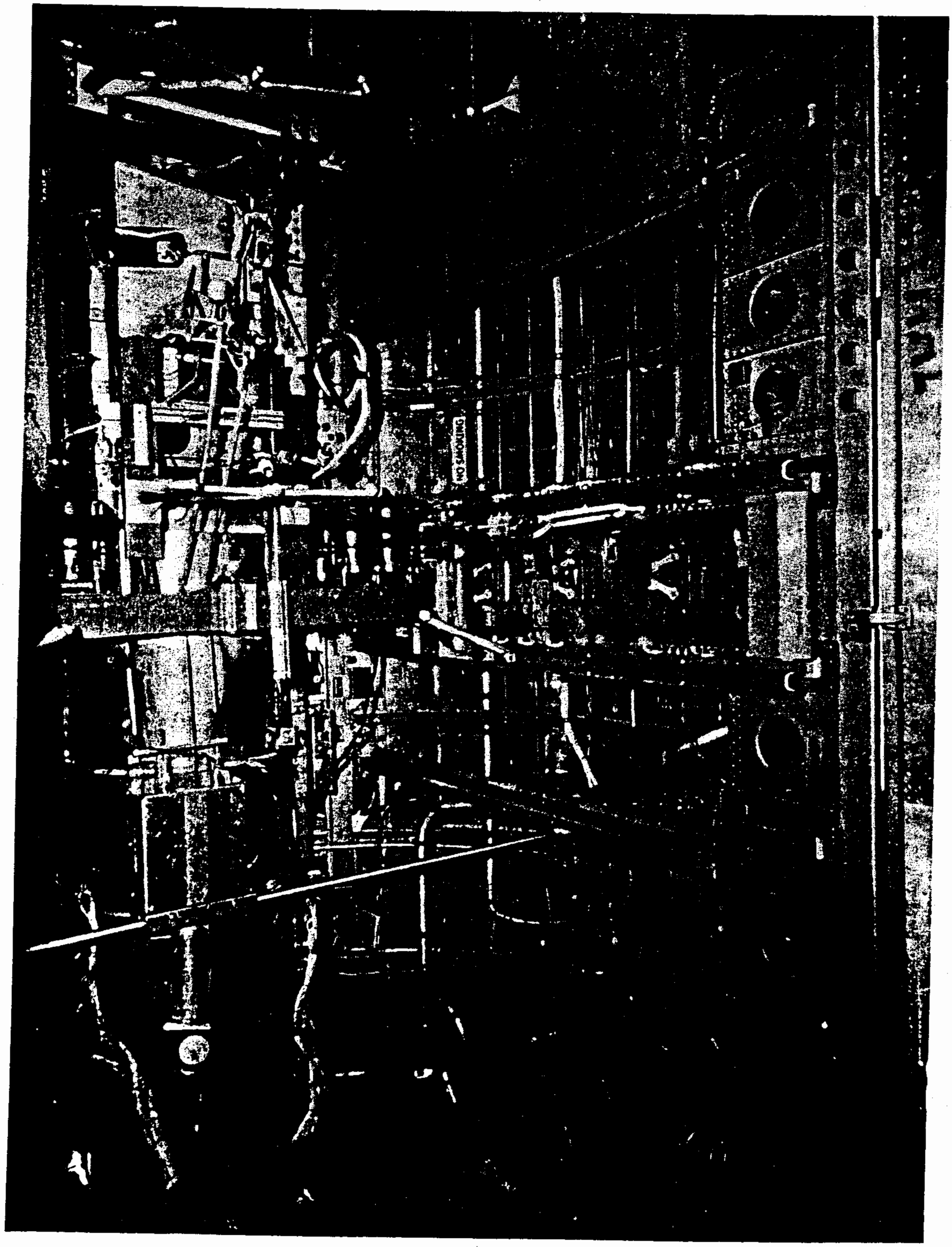

Figure 6

Figure 7

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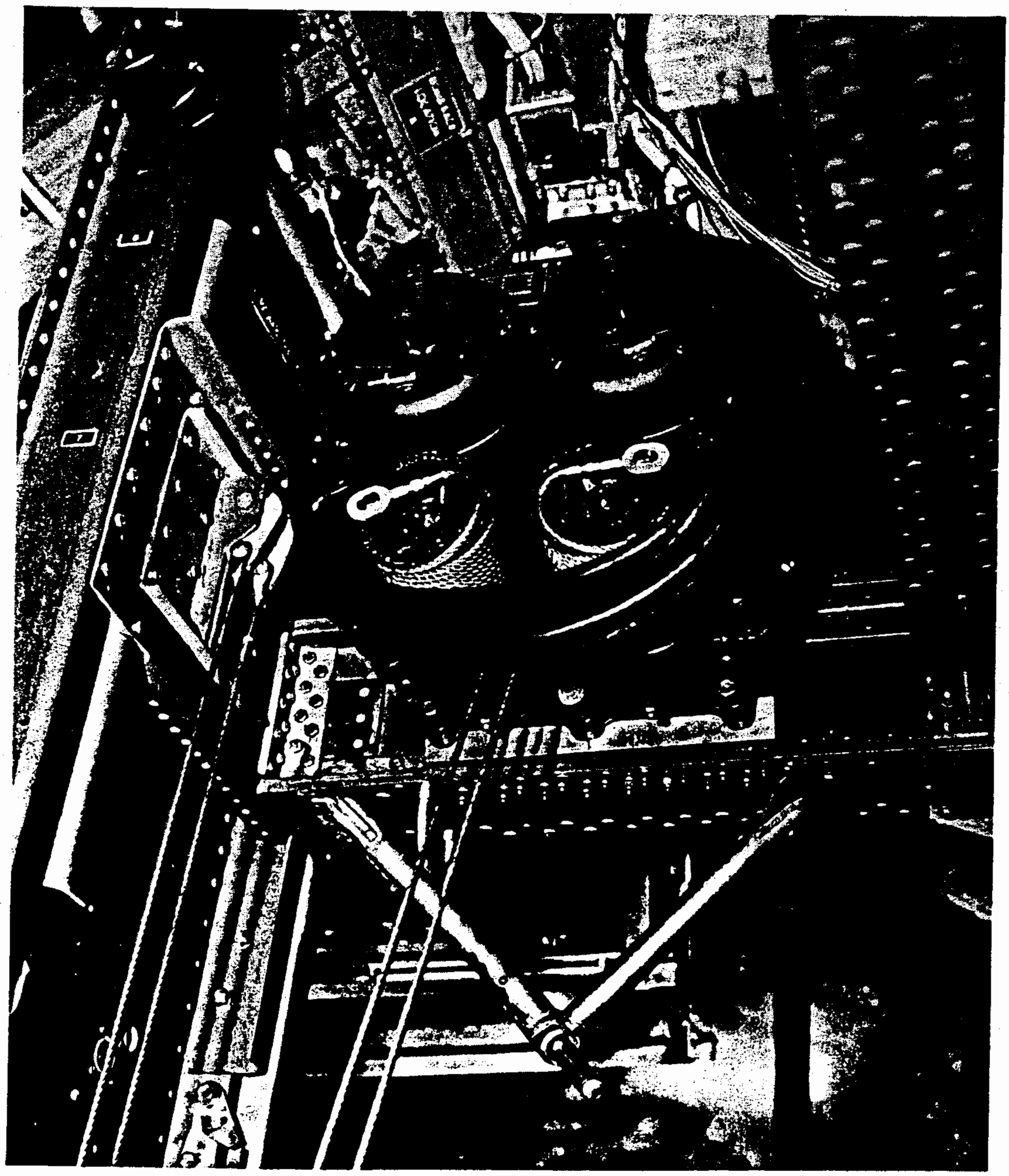

Figure 8

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5.2-2 Special Firing

(1) Fuzing, detonator, and blast gauge control and test circuits

The majority of the special wiring circuits are shown in Drawing A-200, Sheet 2. Drawing Number A-149, Sheet 1A shows the location of the various terminal and junction boxes. More circuits were provided than were actually used. For example, Junction Box Number 4 in the rear bomb bay was never used. The fuzing test and control circuits ran for the most part between Junction Box Number 1 near the Special Observer's position and Junction Box Number 2 in the forward bomb bay. The same was true of the detonator circuits. The inverter at the special observer's feet was used to charge the detonating condensers. The blast gauge control and test circuits ran from Junction Box Number 3 in the radar compartment to Junction Box Number 4 in the forward bomb bay. The blast-gauge group also used the ARR-5 receiver installation and special antenna "A". The photocell installation was not used and was later deleted with the fifteenth aircraft as the effective point.

(2) Keying and release signal wiring

This wiring is shown on Drawing Number A-348 Change B. Two microswitches were installed so that they could be actuated by the release of the bomb itself. One was arranged to key the Collins liaison transmitter; the other keyed the SCR-522 command transmitter. The latter is not provided with tone modulation, hence a small part of the aircraft's 400 cycle supply was used as a tone signal. The amount of modulation voltage from that source was adjusted by the guarded potentiometer on the release signal control panel mounted on the radio operator's table.

5.2-3 Provisions for A special Observer

(1) Table, chair, oxygen outlet, interphone station, etc.

(2) Provisions for test box and controls

The test box mount was provided on the table forward of the radio operator's position. Circuits from this box entered Junction Box Number 1 located on the command transmitter shelf just above the radio operator's table. This junction box is shown in Figure 9.

5.2-4 Bombing Circuit

The bombing circuit is shown in Drawing Number A-279 Change D. Except for the power circuits to the bombsight, the bombing circuit was completely independent of the standard circuits. The controls were on a separate small panel and are shown in Figure 10. Power was fed through a relay, which was closed by the bombsight, through a rack switch, and down opposite sides of the aircraft direct to the release. A safety latch, preventing the release from operating, was released by an arm-safe switch. A pilot light indicated when the latch was disengaged. A salvo switch was provided to apply power directly to the release, by-passing both the bombing relay and the rack switch. A circuit transfer switch merely switched the bombsight from the normal bombing circuits to the bomb release. Means for operating the bombsight on batteries was provided in case of power failure; which provision was never used. A second pilot light indicated that the bomb release solenoid heater was in operation.

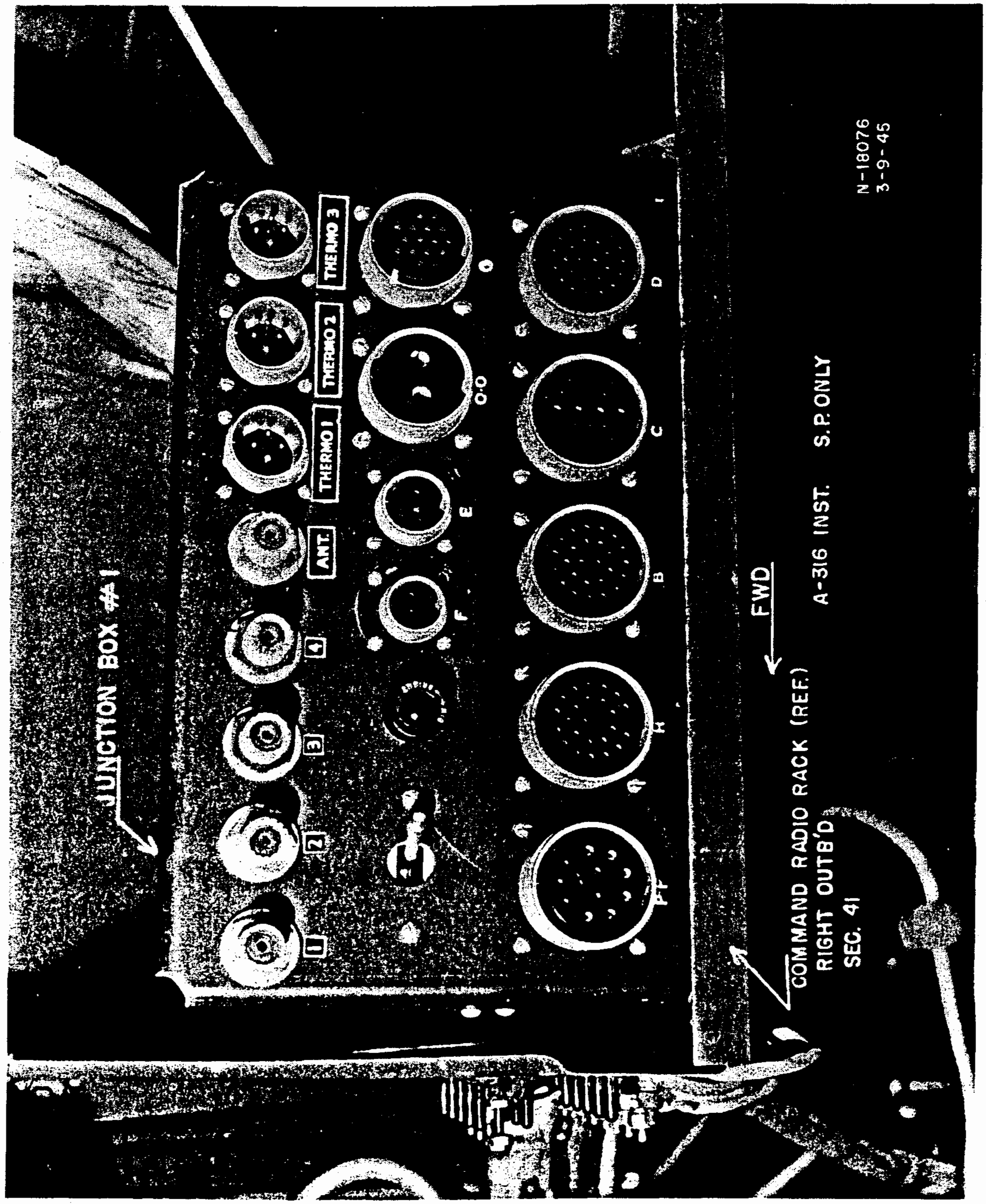
JUNCTION BOX #1
THERMO 1
THERMO 2
THERMO 3
ANT.
1
2
3
4
FWD
COMMAND RADIO RACK (REF.)
RIGHT OUTB'D
SEC. 41
A-316 INST.
S.P. ONLY
N-18076
3-9-45

Figure 9

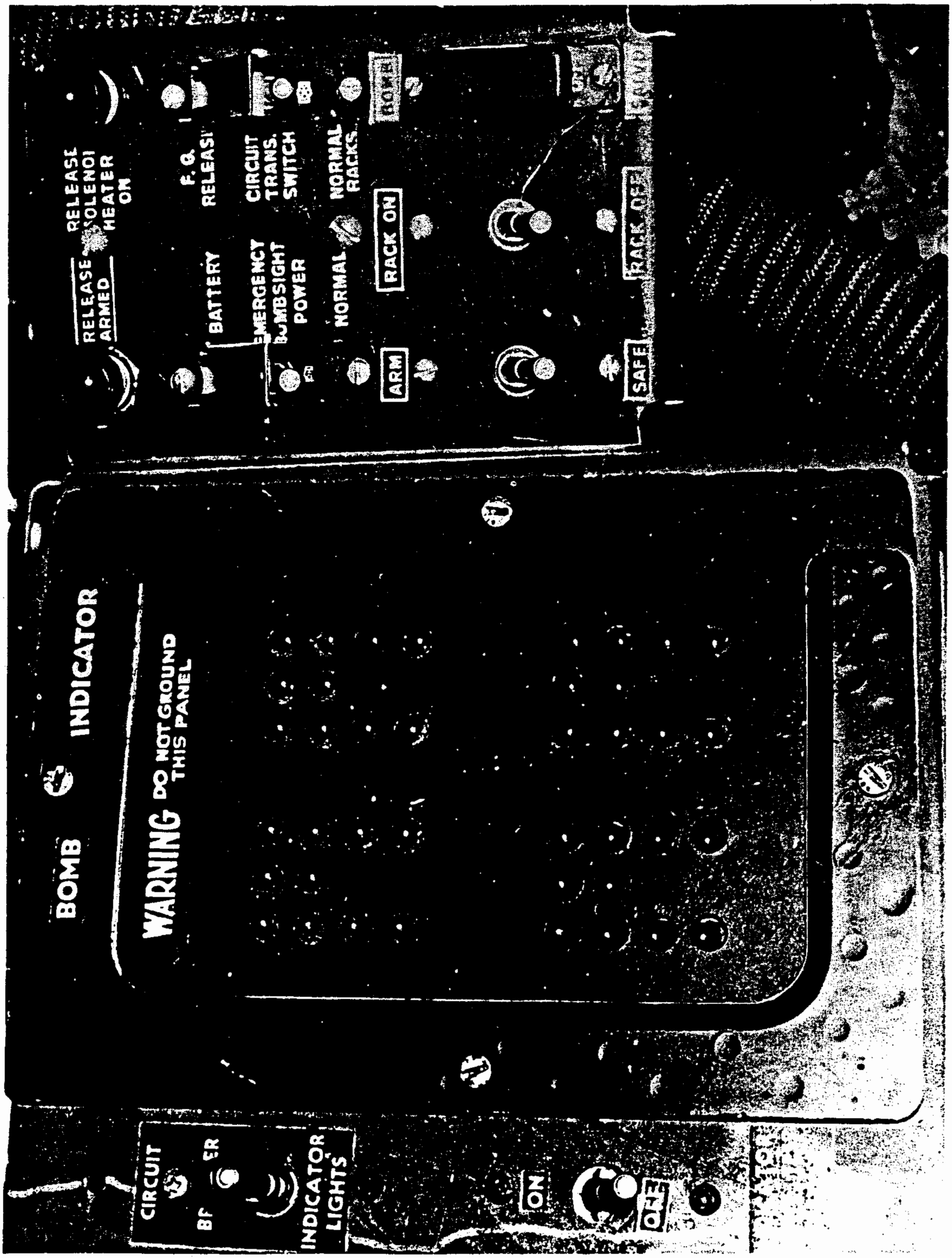
BOMB
INDICATOR
WARNING DO NOT GROUND THIS PANEL
RELEASE ARMED
BATTERY
EMERGENCY BOMBSIGHT POWER
NORMAL
ARM
RACK ON
NORMAL RACKS
CIRCUIT TRANS. SWITCH
SAFE
RACK OFF
CIRCUIT
INDICATOR LIGHTS
ON
OFF

Figure 10

5.2-5 Mechanical Bomb Release Controls

Two levers were provided: One lever disengaged the release safety latch; the other operated the mechanical release lever on the Type F mechanism. Both cables were tube protected and ran down opposite sides of the bomb bay, and were terminated under spring tension in the box shown in Figure 11. Cables with adjustable slack were connected at this point and ran to the release and to the safety latch release sear.

5.2-6 Provision for Special Observational Equipment

(1) Special Antenna

The special antenna was used with the ARR-5 radio receiver installation and consisted of a removable quarter-wave rod. When in place, the antenna rod projected from the underside of the fuselage in the radar compartment; when not in use the antenna was stowed along the roof and a plug was placed in the hole. The installation was pressure tight. (See Drawing Number A-138 Sheet 1A.)

(2) Photocell installation

This consisted of a pressure tight plastic window in the underside of the radar compartment. A photocell was mounted in the plastic window and connected to Junction Box Number 3. This provision was never used and was later deleted.

(3) Equipment rack installation

The equipment rack housed the ARR-5 receiver and other equipment used by the airborne measurements group. An additional shelf was added overseas as a field modification. Junction Box Number 3 was mounted at the forward side of this rack.

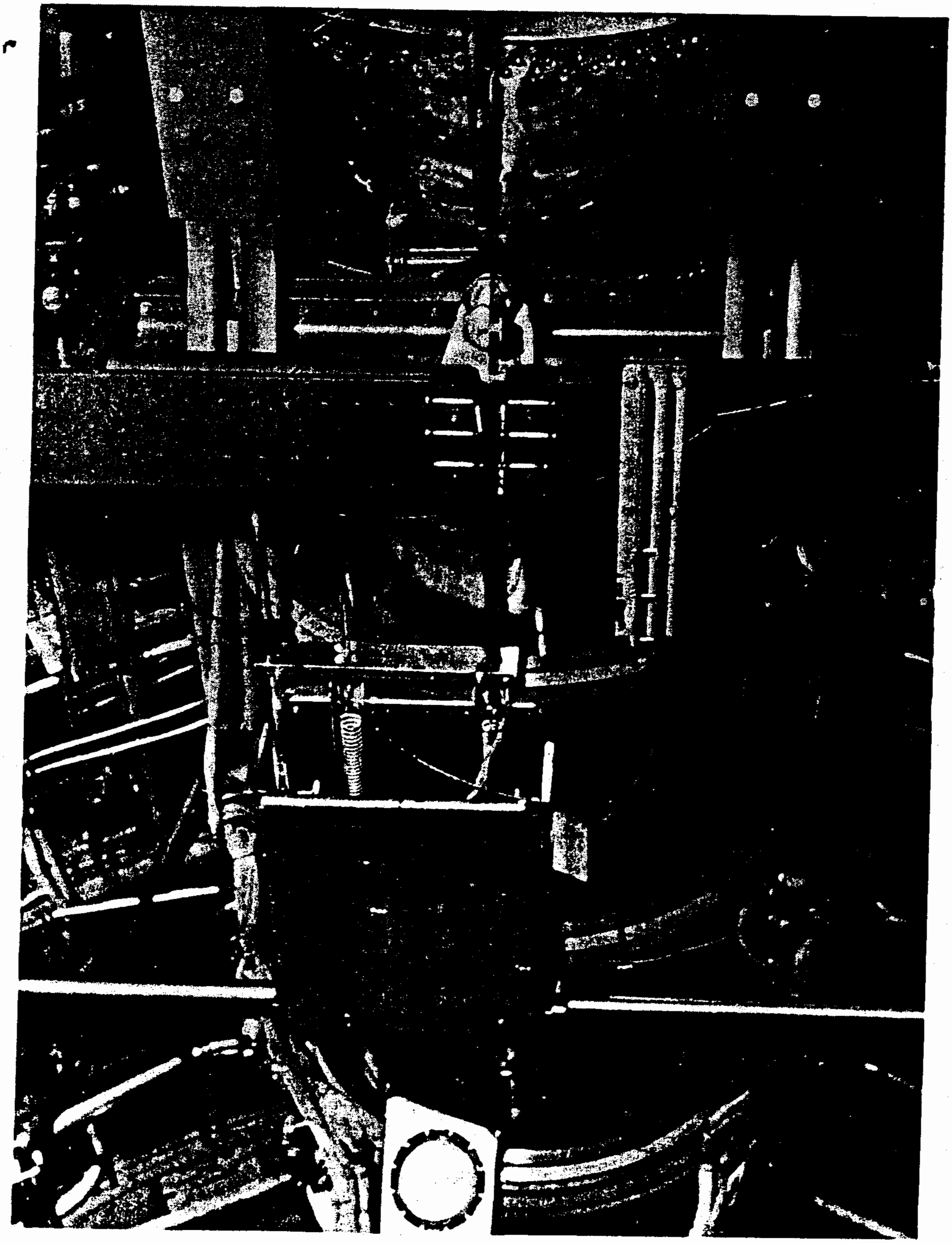

Figure 11

The performance of these special B-29's was exceptional. Flight tests were carried out under the direction of Mr. Warren Dickinson, test engineer for Douglas Aircraft. The basic PIW-VIW curve for these aircraft was obtained and cruise control charts were made for use by the squadron. They were without doubt the finest B-29's in the theater.

CHAPTER 6

HISTORY OF PROJECT A AT TINIAN

by

N. F. Ramsey

6.1 INTRODUCTION

The Project A organization at Tinian consisted of the following:

Officer-in-Charge, Commodore W. S. Parsons USN; Scientific and Technical Deputy to Officer-in-Charge, N. F. Ramsey; Operations Officer and Military Alternate to Officer-in-Charge, Commander F. L. Ashworth, USN; Fat Man Assembly Team headed by Roger S. Warner Jr.; Little Boy Assembly Team headed by Commander Francis A. Birch, USNR; Fuzing Team headed by E. B. Doll; Electrical Detonator Team headed by Lt. Commander E. C. Stevenson, USNR; Pit Team headed by Phillip Morrison and C. P. Baker; Observation Team headed by Luis W. Alvarez and Bernard Waldman; Aircraft Ordnance Team headed by Sheldon H. Dike; and Special Consultants consisting of Robert Serber, W. G. Penney and Captain J. F. Nolan, AUS. The team leaders formed a Project Technical Committee under the chairmanship of Ramsey to coordinate technical matters and to recommend technical actions to Captain Parsons. The following persons were team members:

Agnew, Harold
Anderson, David L., Ensign
Bederson, Ben B., T/5
Bolstad, Milo M.
Brin, Raymond, T/Sgt.
Caleca, Vincent, T/Sgt.
Camac, Morton, T/Sgt.
Carlson, Edward G., T/Sgt.

Collins, Arthur, T/4

Dawson, Robert, T/Sgt.

Fortine, Frank J., T/Sgt.

Goodman, Walter, T/3

Harms, Donald C., T/3

Hopper, J. D., Lt.

Kupferberg, J., T/Sgt. Max

Johnston, Lawrence H.

Langer, Lawrence M.

Larkin, William J., T/Sgt.

Linschitz, Henry

Machen, Arthur B.

Mastick, Donald, Ensign

Matthews, Robert P., T/3

Miller, Victor A., Lt. (j.g.)

Motechko, L. L., T/3

Murphy, William L., T/Sgt.

Nooker, Eugene L., T/Sgt.

Olmstead, T. H.

O'Keefe, ~~G~~ Bernard J., Ensign

Perlman, Ted

Prohs, Wesley R., Ensign

Reynolds, George, Ensign

Russ, Harlow W.

Schreiber, R. E.

Thorton, Gunnar, T/Sgt.

Tucker, J. L., Ensign

Zimmerli, Fred, T/4

Although not strictly members of Project A, the following were closely associated with the work of the Project: Rear Admiral W. R. Purnell, USN, representative of the Atomic Bomb Military Policy Committee; Brig. General T. F. Farrell, representative of Major General L. R. Groves; Colonel E. E. Kirkpatrick, alternate to General Farrell and the Officer in Charge of Construction; Colonel P. W. Tibbets, Commanding Officer of the 509th Composite Group; Lt. Colonel Peer de Silva, Commanding Officer of the First Technical Service Detachment, which served as administrative, security and housing organization for Project A; and Major Charles Begg, Commanding Officer of the First Ordnance Squadron, Special.

Although preliminary construction at Tinian began in April, 1945, intensified technical activities were not started until July. The first half of July was occupied with establishing and installing all of the technical facilities needed for assembly and test work at Tinian. After completion of these technical preparations, a Little Boy unit was assembled and, with the dropping of unit L1 on July 23, the Tinian base became fully operational for Little Boy tests. In the first test, a dummy Little Boy was fired in the air by radar fuze. Here, as in subsequent Tinian tests, excellent results were obtained. The second Little Boy, Unit L2, was dropped on July 24, and a third, Unit L5, on July 25. The only remaining phase of the Little Boy mission, and included as part of the test, was a check of facilities at Iwo Jima for emergency reloading of the bomb into another aircraft. Since the Iwo Jima facilities were not ready until July 29, this test was postponed until then. On July 29 a completely successful test of the Iwo Jima facilities was completed. The plane landed with the L6 Unit at Tinian so that it could be used in the final rehearsal maneuvers. On July 31 the plane with the L6 took off accompanied by two observation planes. The planes flew to Iwo Jima where a rendezvous was made, and then returned to Tinian where the bomb was dropped and observed to function properly. After the release of the bomb all three aircraft rehearsed the turning maneuvers which would be used in combat. With the completion of this test, all tests preliminary to combat delivery of a Little Boy with active material were completed.

The first Fat Man test, unit F13, was made on August 1, 1945. This unit used cast plaster blocks, electronic fuzing, eight electric detonators, Raytheon detonating unit and informers and smoke puffs on the operation of the detonators. The test showed that all essential components of the bomb functioned satisfactorily. A second inert Fat Man, F18, similar to F13, was prepared and loaded into a B-29 for drop on August 3. However, due to lack of information at Tinian of the results of the Wendover tests on the adequacy of the venting in the sealed Fat Man, the unit was unloaded and the barometric switches modified so that this information would be obtained on unit F18. In its modified form the F18 unit was dropped on August 5. All components functioned satisfactorily and the venting was adequate for the internal pressure to close a barometric switch set for 17,000 feet pressure altitude 17 seconds before impact. The only remaining preliminary Fat Man test was unit F33, a replica of the active unit, except for the lack of active material and the use of lower quality high explosive lens castings. The components for the F33 unit arrived at Tinian at 1230 on August 2 and preliminary assembly was begun the same day. Although the F33 unit was fully assembled by August 5, it was not dropped until August 8 due to absence of key crews and aircraft on the final Little Boy mission. A test was then conducted as a final rehearsal for the delivery of the first live Fat Man. Both the rehearsal operation and the detonation of the unit were completely satisfactory.

On July 26, the U^{235} projectile for the Little Boy was delivered by the cruiser INDIANAPOLIS. The U^{235} target insert arrived in three separate parts in three, otherwise empty, Air Transport Command C-54's during the evening of July 28 to 29. All three had arrived by 0200 July 29. Since the earliest date previously discussed for combat delivery of the Fat Man was August 5 (at one time the official date was August 15). Parsons and Ramsey cabled General Groves for permission to drop the first active unit perhaps as early as August 1, with August 2 being more probable since poor weather was forecast for August 1.

Although the active Little Boy unit, No. L11, was completely ready in plenty of time for an August 2 delivery, the weather was unfavorable. The first, second, third, and fourth of August were spent in impatient waiting for good weather. Finally, on the morning of August 5 word was received that the weather should be good on August 6. At 1400 on August 5 General Lemay officially confirmed that the mission would take place on August 6.

The Little Boy was loaded onto its transporting trailer at 1400 on August 5 and, with an accompanying battery of photographers, was taken to the loading pit. The B-29 was backed over the pit at 1500 and the L11 unit loaded shortly thereafter. The aircraft was then taxied to its hard stand where final testing of the unit was completed. By 1800 all was ready. Between then and take-off, the aircraft was under continuous watch both by a military guard and by representatives of the key technical groups.

Final briefing was at 0000 of August 6. Following this, and an early breakfast, the crews assembled at their aircraft. There, amid brilliant floodlights, pictures were taken and retaken by still and motion picture photographers (as though for a Hollywood premiere). For the mission Colonel P. W. Tibbets was pilot of the B-29 (named the Enola Gay) which carried the bomb, Major Thomas Ferebee was bombardier, Captain W. S Parsons was bomb commander, and Lt. Morris Jepson was electronics test officer for the bomb. L. Alvarez,

[redacted] UNCLASSIFIED

Bernard Waldman, Harold Agnew and Larry Johnston rode in the accompanying observation aircraft.

The progress of the mission is best described in the log which Captain Parsons kept during the flight:

Captain Parsons' log:

August 6, 1945

0245	Take off
0300	Started final loading of gun
0315	Finished loading
0605	Headed for Empire from Iwo Jima
0730	Red plugs in (these plugs armed the bomb so it would detonate if released)
0741	Started climb Weather report received that weather over primary and tertiary targets was good but not over secondary target.
0838	Leveled off at 32,700 feet 30,750 IA or 31060' True (Nav Log)
0847	All Archies (electronic fuzes) tested to be O.K.
0904	Course west
0909	Target (Hiroshima) in sight
0915 1/2	Dropped bomb (originally scheduled time was 0915) Flash followed by two slaps on plane. Huge cloud.
1000	Still in sight of cloud which must be over 40,000 high
1003	Fighter reported
1041	Lost sight of cloud 363 miles from Hiroshima with the aircraft being 26,000 feet high. 25,750 IA

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The crews of the strike and observation aircraft reported that 5 minutes after release a low 3 mile diameter dark grey cloud hung over the center of Hiroshima, out of the center of this a white column of smoke rose to a height of 35,000 feet with the top of the cloud being considerably enlarged.

Four hours after the strike, photo-reconnaissance planes found that most of the city of Hiroshima was still obscured by the cloud created by the explosion although fires could be seen around the edges. The following day excellent pictures were obtained showing the tremendous magnitude of the power of a single atomic bomb, which completely destroyed 60 percent of the city of Hiroshima.

The first Fat Man with active material, unit F31, was originally scheduled for dropping on August 11 local time (at one time the schedule called for August 20). However, by August 7 it became apparent that the schedule could be advanced to August 10. When Parsons and Ramsey proposed this change to Tibbets, he expressed regret that the schedule could not be advanced two days instead of only one since good weather was forecast for August 9 and the five succeeding days were expected to be bad. It was finally agreed that Project A would try to be ready for August 9 provided all concerned understood that the advancement of the date by two full days introduced a large measure of uncertainty into the probability of meeting such a drastically revised schedule. However, all went well with the assembly and by 2200 of August 8 the unit was loaded and fully checked.

The strike plane and two observing planes took off at 0347 local time on August 9. Major C. W. Sweeney was pilot of the strike ship, Captain K. K. Beahan was bombardier, Commander F. L. Ashworth was bomb Commander, and Lt. Philip Barnes was electronics test Officer. This mission was as eventful as the Hiroshima mission was operationally routine.

Due to bad weather between Tinian and Iwo Jima, a preliminary rendezvous was not planned for three aircraft at Iwo Jima, and instead, the briefed route to the Japanese Empire was from Tinian direct to Yakoshima or Kyushu. The briefed cruising altitude was 17,000 feet. Commander Ashworth's log for the trip is as follows:

Commander Ashworth's log:

0347	Take off
0400	Changed green plugs to red prior to pressurizing
0500	Charged detonator condensers to test leakage. Satisfactory.
0900	Arrived rendezvous point at Yakoshima and circled awaiting accompanying aircraft.
0920	One B-29 sighted and joined in formation
0950	Departed from Yakoshima proceeding to primary target Kokura having failed to rendezvous with second B-29. The weather reports received by radio indicated good weather at Kokura (3/10 low clouds, no intermediate or high clouds, and forecast of improving conditions). The weather reports for Nagasaki were good but increasing cloudiness was forecast. For this reason the primary target was selected.

1044 Arrived initial point and started run on target. Target was obscured by heavy ground haze and smoke. Two additional runs were made hoping that the target might be picked up after closer observation. However, at no time was the aiming point seen. It was then decided to proceed to Nagasaki; approximately 45 minutes spent in the primary target area.

1150 Arrived in Nagasaki target area. Approach to target was entirely by radar. At 1158 the bomb was dropped after a twenty second visual bombing run. The bomb functioned normally in all respects.

1205 Departed for Okinawa after having circled smoke column. Lack of available gasoline caused by an inoperative bomb tank booster pump forced decision to land at Okinawa before returning to Tinian.

1351 Landed at Yontan Field, Okinawa

1706 Departed Okinawa for Tinian

2245 Landed at Tinian

Due to bad weather, good photo-reconnaissance pictures were not obtained until almost a week after the Nagasaki mission. These showed that the bomb detonated somewhat north of the Mitsubishi Steel and Arm Works. All other factories and buildings on the Urakami River from the Nakajima Gawa River through the Mitsubishi Urakami Ordnance Plant were destroyed. The distance from the northernmost factory that was destroyed to the southern boundary of complete destruction was about three miles and damage might have occurred north of the Urakami Ordnance Plant if any buildings had been there. Although only 44 per cent of the city was destroyed by the official record, this was due to the unfavorable shape of the city and not to the location of the bomb detonation.

On the day following the Nagasaki mission, the Japanese initiated surrender negotations. Consequently, further activity in preparing active units was suspended. However, the entire project was maintained in a state of complete readiness for further assemblies in the event of a failure in the peace negotations. For the first week following the Nagasaki mission the test program at Tinian was continued and three dummy Fat Man units, Nos. F101, F102, and F103, were prepared. These were not dropped, however, since the Japanese had stated their willingness to accept the American terms prior to the date scheduled for the drop. Originally it was planned to return all Project A technical personnel to the United States on August 20, except those assigned to the Farrel mission to investigate the results of the atomic bombing of Japan. However, on August 18, a message was received from General Groves that in view of the then current delays in the surrender procedures all key Project A personnel should remain at Tinian until the success of the occupation of Japan was assured. The scientific and technical personnel finally received authorization for return to the United States on September 5, and departed from Tinian on September 7, 1945. With this departure the activities of Project A were effectively terminated although Colonel Kirkpatrick and Commander Ashworth remained behind at Tinian for final disposition of Project A property.

6.2 CONCLUSION

Project A, after a long period of preparation in the United States, had a very short but highly intense and successful period of activity overseas. As in all urgently expedited development projects for which there are no precedents, many mistakes were made in Project A. With the benefit of the experience accumulated by Project A it would subsequently be possible to replan its activities to accomplish its objectives both with greater economy and with improved designs. However, despite the novelty of the weapon and the lack of precedent for most of its problems, Project A did successfully accomplish all of its major objectives and did so on or ahead of schedule.

The object of Project A was to assure the successful combat use of an atomic bomb at the earliest possible date after a field test of an atomic explosion and after the availability of the necessary nuclear material. This object was very effectively accomplished. The first combat bomb was ready for use against the enemy within seventeen days after the first experimental nuclear explosion at Alamogordo and almost all of the intervening time was spent in accumulating additional active material for making an additional bomb. The first atomic bomb was prepared for combat use against the enemy on August 2 within four days of the time of the delivery of all the active material needed for that bomb. Actual combat use was delayed until August 6 only by bad weather over Japan. The second atomic bomb was used in combat three days after the first, despite its being a completely different model and one much more difficult to assemble. The success of the combat use of the atomic bomb is best summarized by the fact that Japan began surrender negotiations four days after the use of the first atomic bomb.

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UNIVERSITY OF CALIFORNIA

LOS ALAMOS SCIENTIFIC LABORATORY
(CONTRACT W-7405-ENG-36)
P. O. Box 1663
Los Alamos, New Mexico

IN REPLY REFER TO: D-DOC-5099

January 24, 1951

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"When separated from enclosures, handle this document as unclassified (Insert proper classification)"

General Manager
U. S. Atomic Energy Commission
1901 Constitution Avenue, N.W.
Washington 25, D.C.

Attention: Mrs. J. O'Leary

Dear Mrs. O'Leary:

Enclosed herewith are copies 5,6 and 7,8, of report LA-1161 which are being sent to your office for transmittal to the Division of Military Application for their review after accountability has been established by your office.

We feel that this report is not distributable according to Report M-3679, "Standard Distribution Lists", because it contains weapon data.

Very truly yours,
Helen F. Challenger
Helen F. Challenger
Document Room

Enc. 5 docs.
rec. #36268 thru 36271

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

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SESSION XI

ARMING, FIRING, AND INITIATION
- POWER SUPPLIES
- FIRING SETS
- NEUTRON SOURCES

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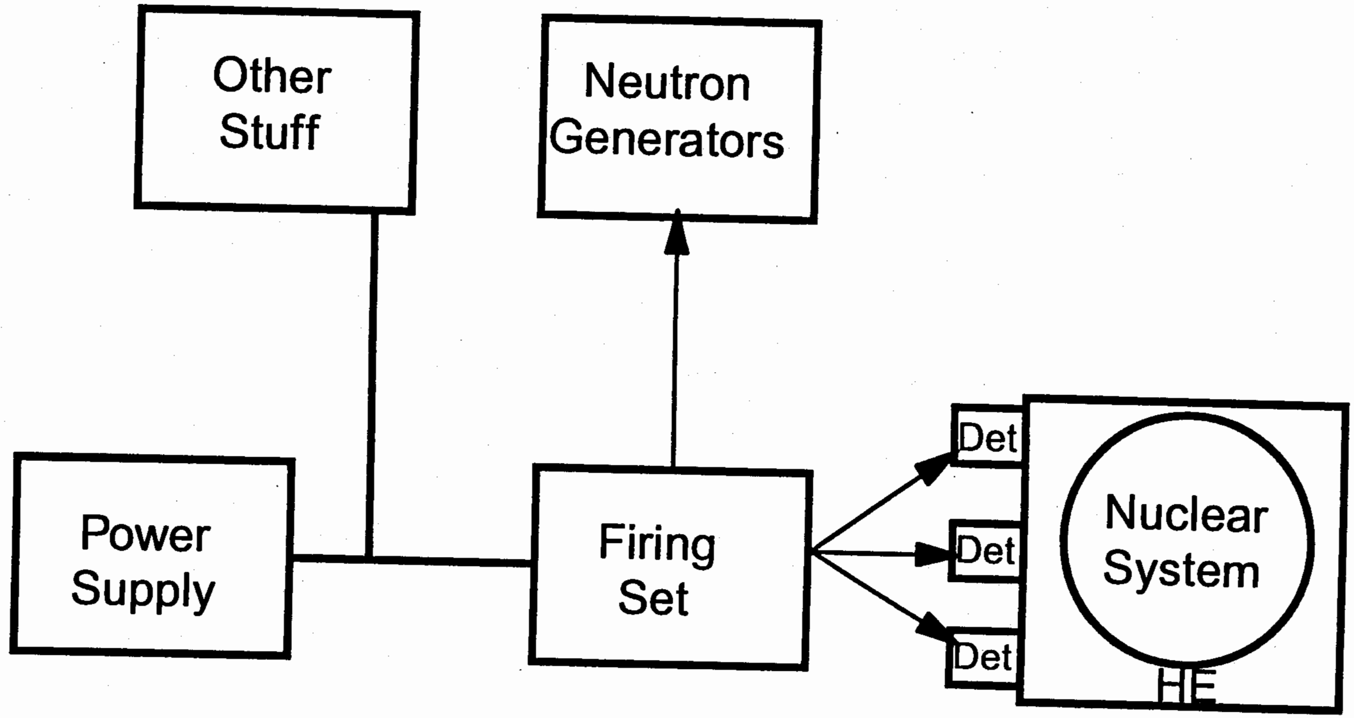

Bomb--Yes
WH--Maybe

Nuclear Weapon

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Assumptions

Understand Basic Concepts For:

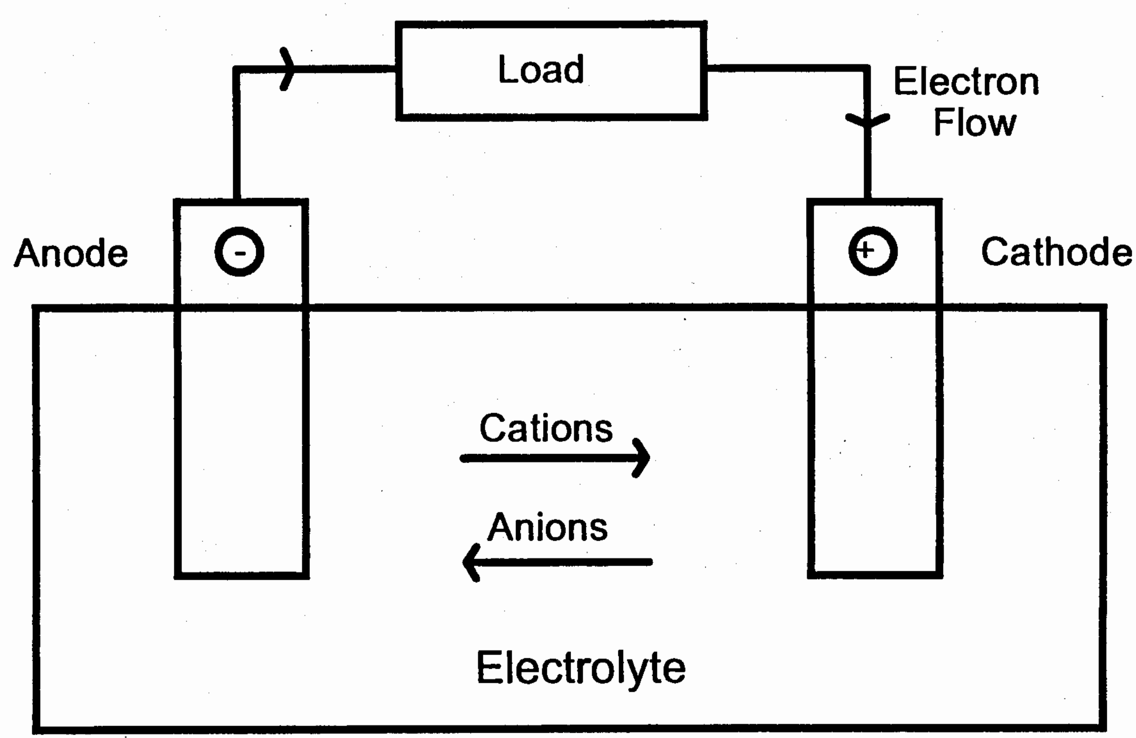
- Detonators
- Initiation Requirements
- Fuzing
- Safety
- Use Control

Implementation of Concepts Will Be Described as Part of This Session

Power Supplies

- Battery Technologies
- Evolution of Battery Development

Battery Cell
(During Discharge)



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Nomenclature

Primary - Life ends upon discharge

Examples: Zinc-Carbon - Flashlight

Alkaline Manganese - Flashlight

Zinc-Silver Oxide - Missile guidance system
- Sandia JTA

Lithium - High energy density applications (such as nuclear weapons)

Secondary - Rechargeable

Examples: Lead-Acid - Automobile

Nickel-Cadmium - Portable appliances
- Sandia PAL Controllers

Iron-Nickel - Electric vehicles

Zinc-Silver Oxide - Portable military equipment

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Nomenclature

Dry Cells - Aqueous electrolyte has been immobilized by use of gelling agents

Solid State Cells - Solid electrolyte has conductance wholly due to ionic motion with solid lattice

Nomenclature

Reserve Battery - Any battery which will not deliver current until activated, e.g., by adding electrolyte or melting electrolyte

Thermal Battery - A reserve battery activated by raising the temperature to melt the electrolyte, which is a salt mixture - used extensively in nuclear weapons

Depolarizer Pad - The active cathode material which is reduced electrochemically during battery discharge

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Nuclear Weapon Batteries

Little Boy	NT—6	Lead Acid	1945
Fat Man	ER—12	Lead Acid	
MK 4, 5, 6, 7	MC193	Nickel—Cadmium	1953
MK 12	MC271	Silver—Zinc	
MK 15	MC473	Thermal Ca—$CaCrO_4$	1955
Multiple	Multiple	Thermal Li—FeS_2	1970's
All New Designs		Thermal Li—FeS_2	Present

NOTE: JTA's, controllers, and support equipment may utilize designs other than thermal batteries

Desirable Ordnance Power Source Characteristics

Reliability

Shelf Life

Ruggedness

Wide Operating Temperature

Cost

Current Density

Pulse Capability

High Cell Voltage

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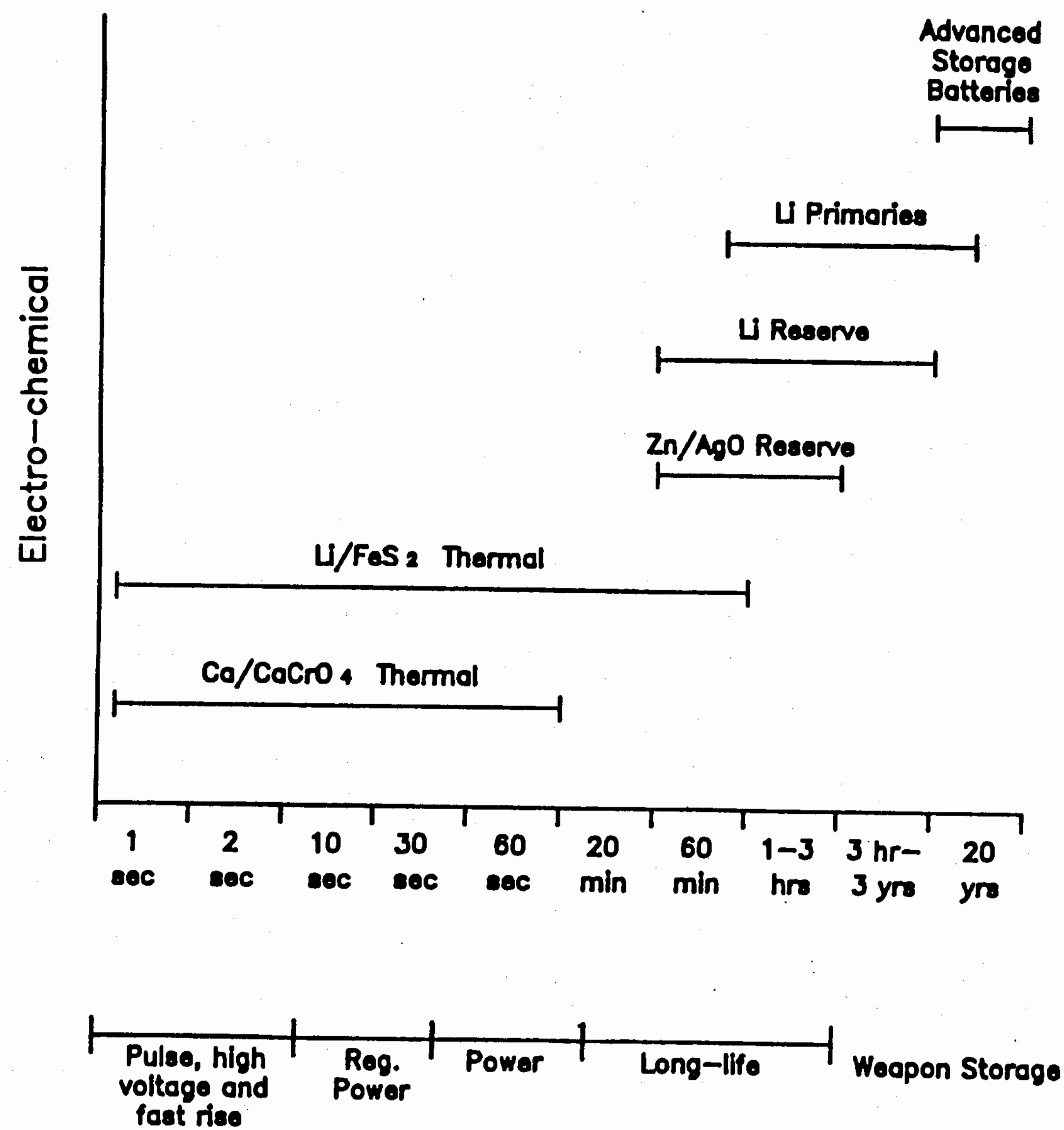
Battery Technologies



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Reactions

$Ca/CaCrO_4$

- **Electrochemical:**

Anode – $Ca \xrightarrow{Li^+} CaLi_2 \rightarrow Ca^{2+}$(double salt)$\downarrow + 2e^-$

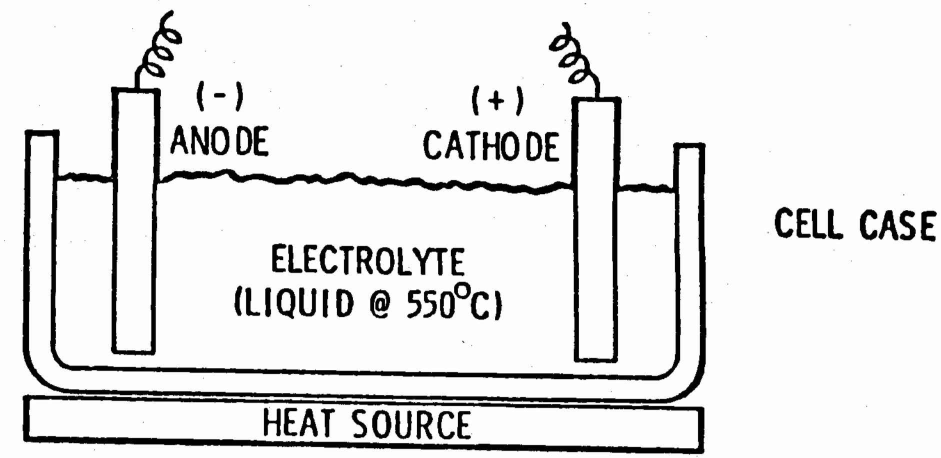
Cathode – $CrO_4^{2-} + 3e^- \rightarrow$ (soluble intermediates) $\xrightarrow{Li^+}$ $Ca_6Cr_4O_xSiCl_2$, $Li_xCa_yCrO_4$, $Li_xCr_yO_z$, CaO

- **Identifiable Side Reactions:**

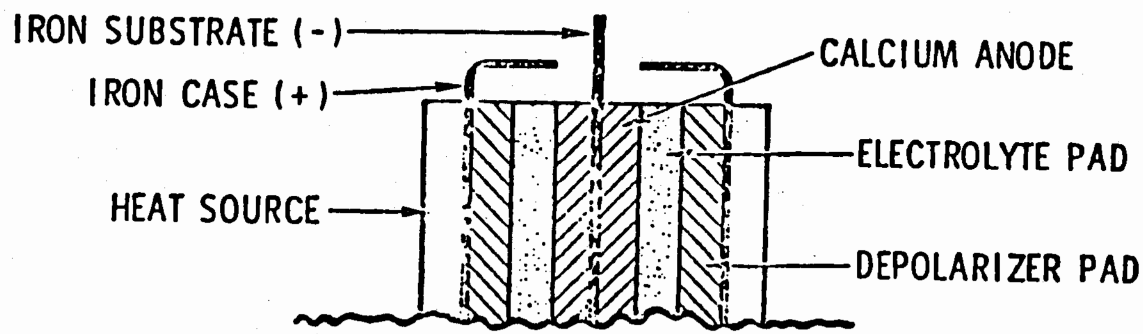
$$4Ca + SiO_2 \rightarrow 2CaO + Ca_2Si + (-660\ cal/g)$$

$$3Ca + 2CaCrO_4 + 2LiCl \rightarrow 2Ca_2CrO_4Cl + CaLi_2 + (-1770\ cal/g)$$

CONVENTIONAL CELL



ANODE - CALCIUM METAL ON IRON SUBSTRATE
CATHODE - CALCIUM CHROMATE (DEPOLARIZER)
ELECTROLYTE - LITHIUM CHLORIDE, POTASSIUM CHLORIDE
HEAT SOURCE - ZIRCONIUM-BARIUM CHROMATE
CELL CASE - IRON



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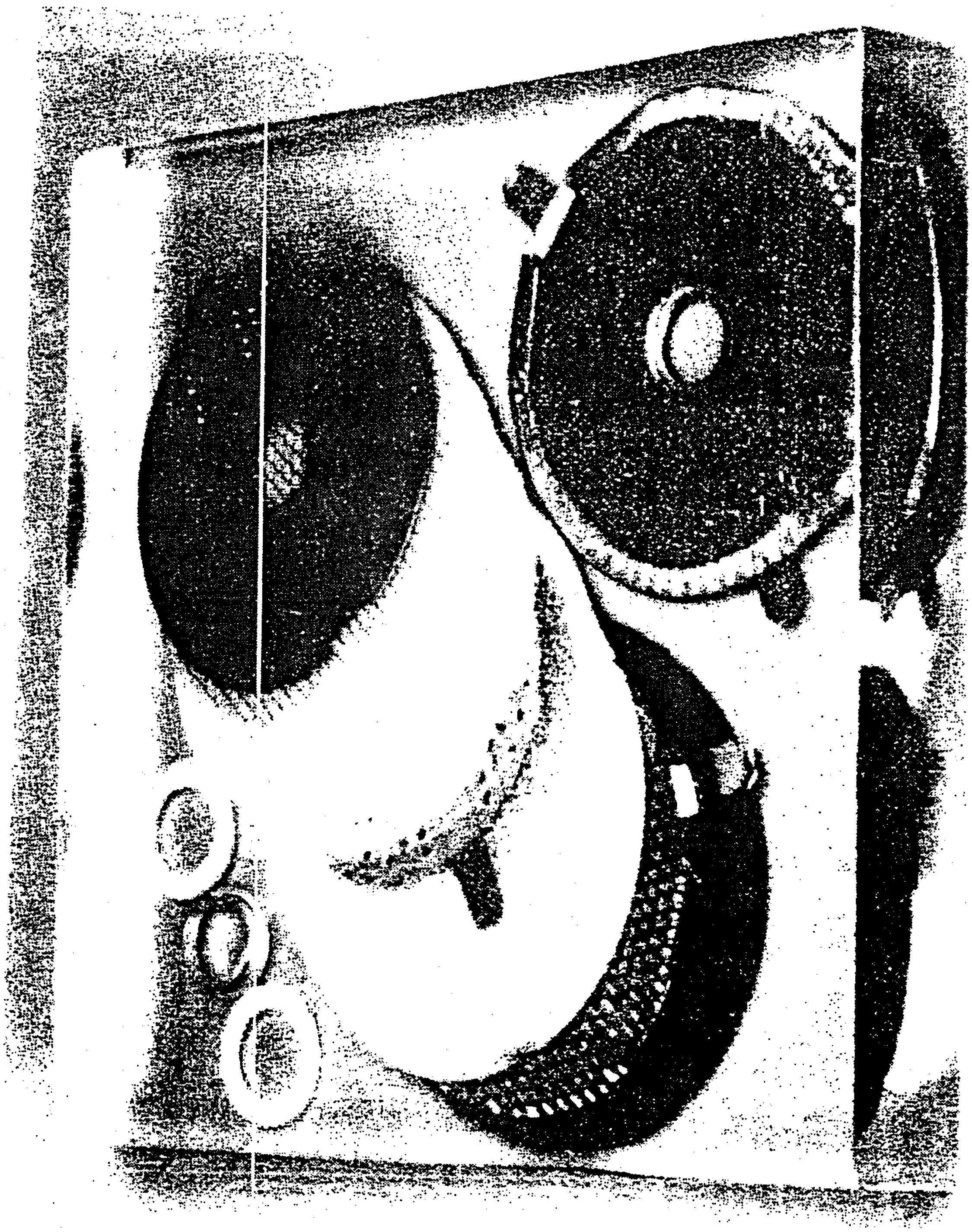
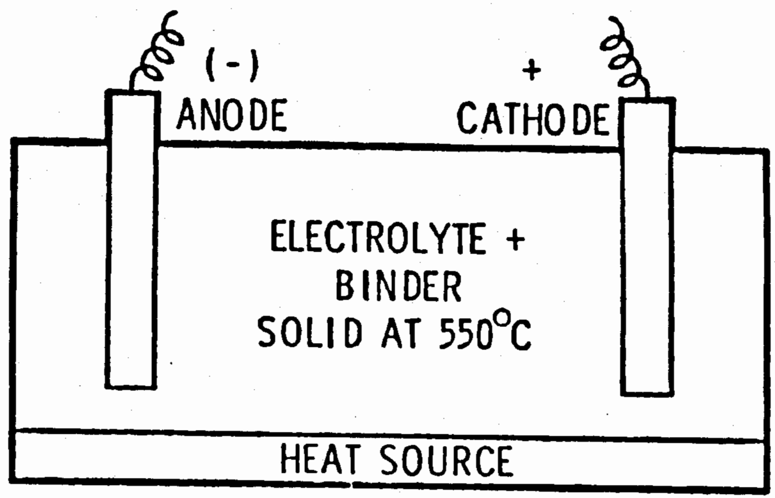
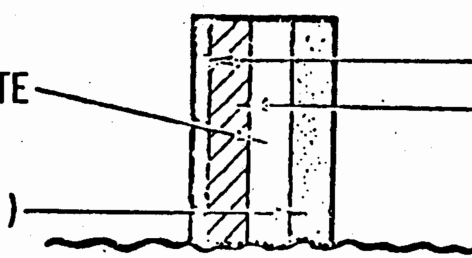


NEW PELLETIZED CELL



ANODE	- CALCIUM ON IRON SUBSTRATE	
CATHODE	- CALCIUM CHROMATE (depolarizer)	DEB
ELECTROLYTE	- LITHIUM CHLORIDE, POTASSIUM CHLORIDE + SiO_2 BINDER	DEB
HEAT SOURCE	- IRON-POTASSIUM PERCHLORATE DISC	
CELL CASE	- NONE	



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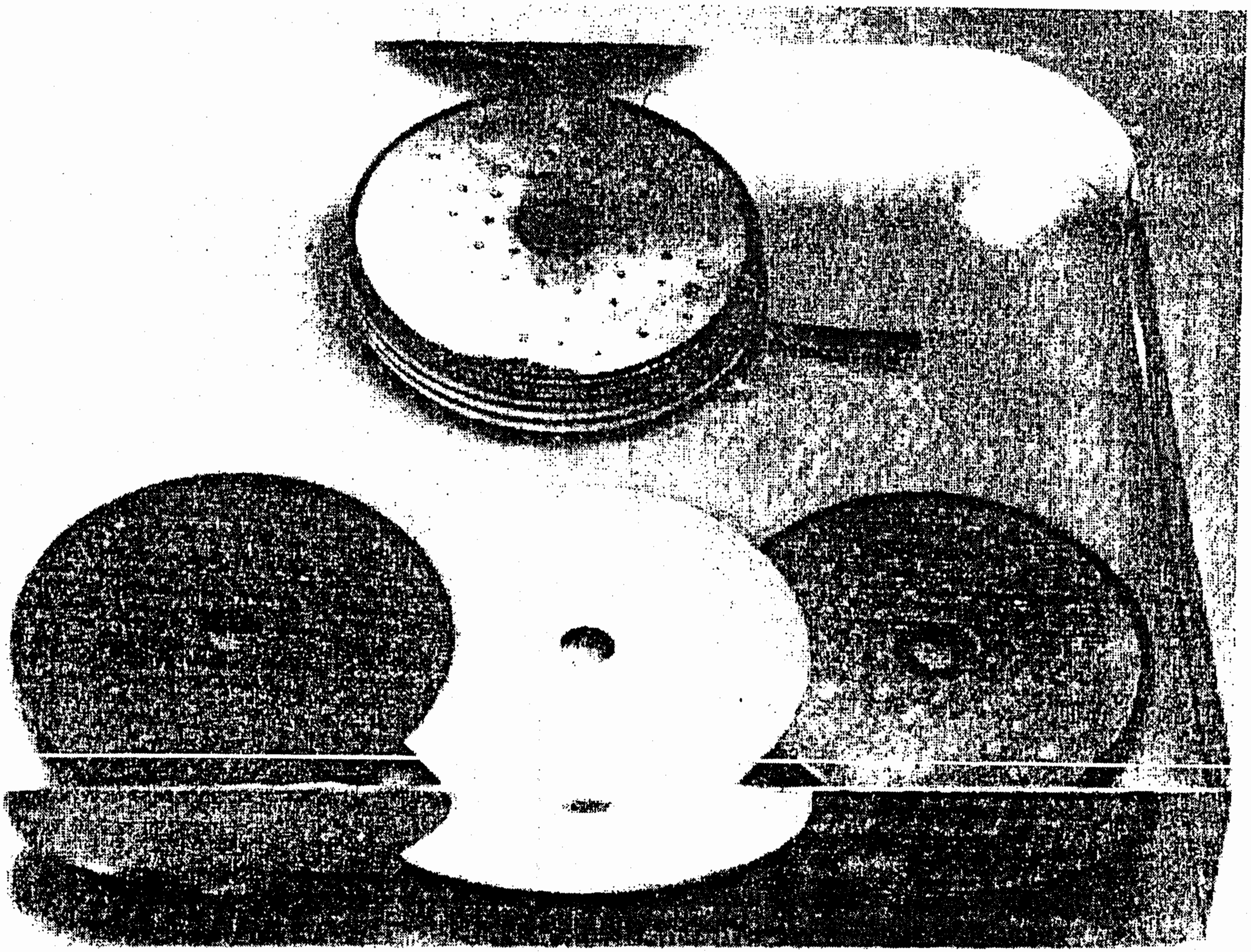

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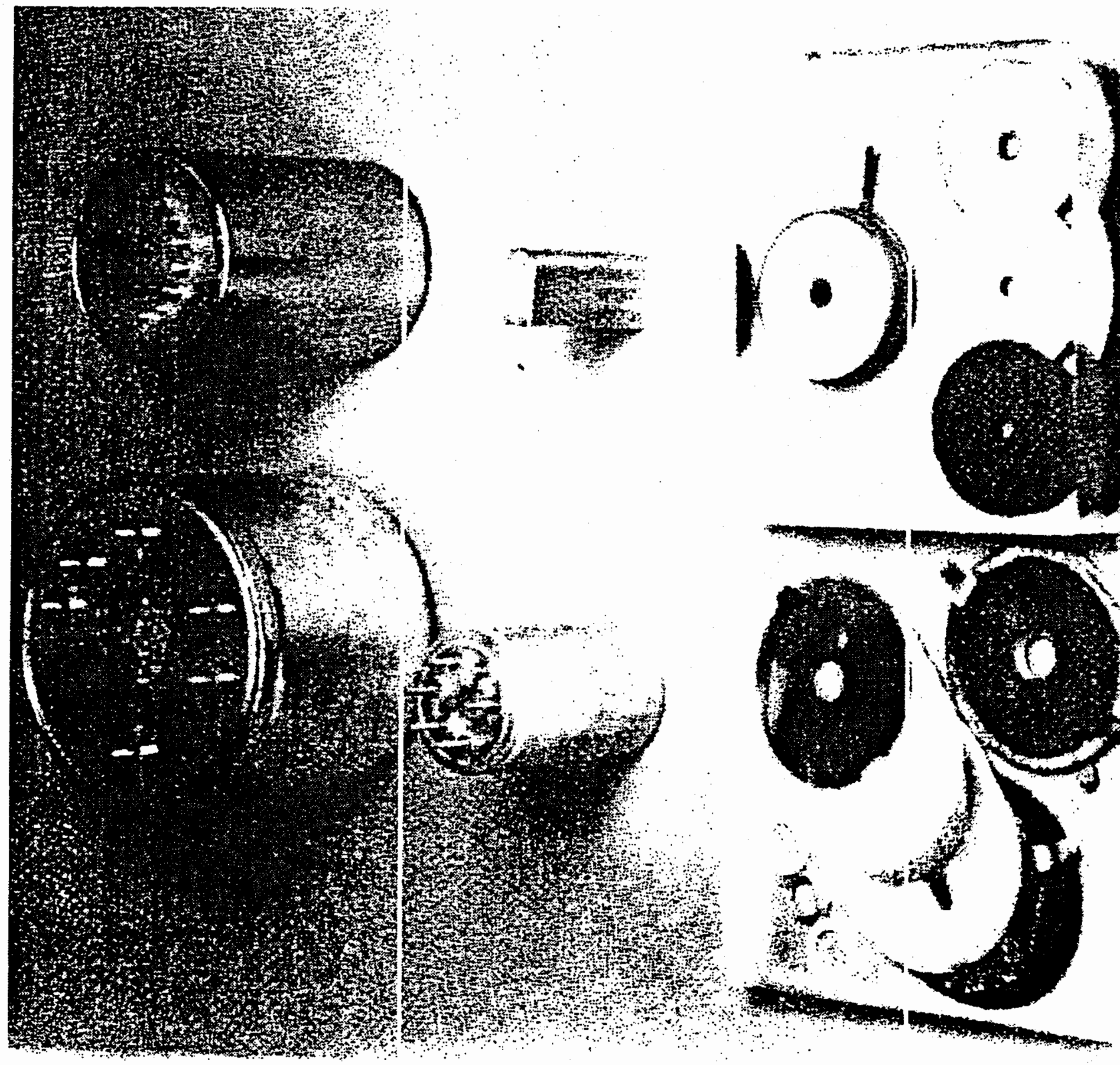

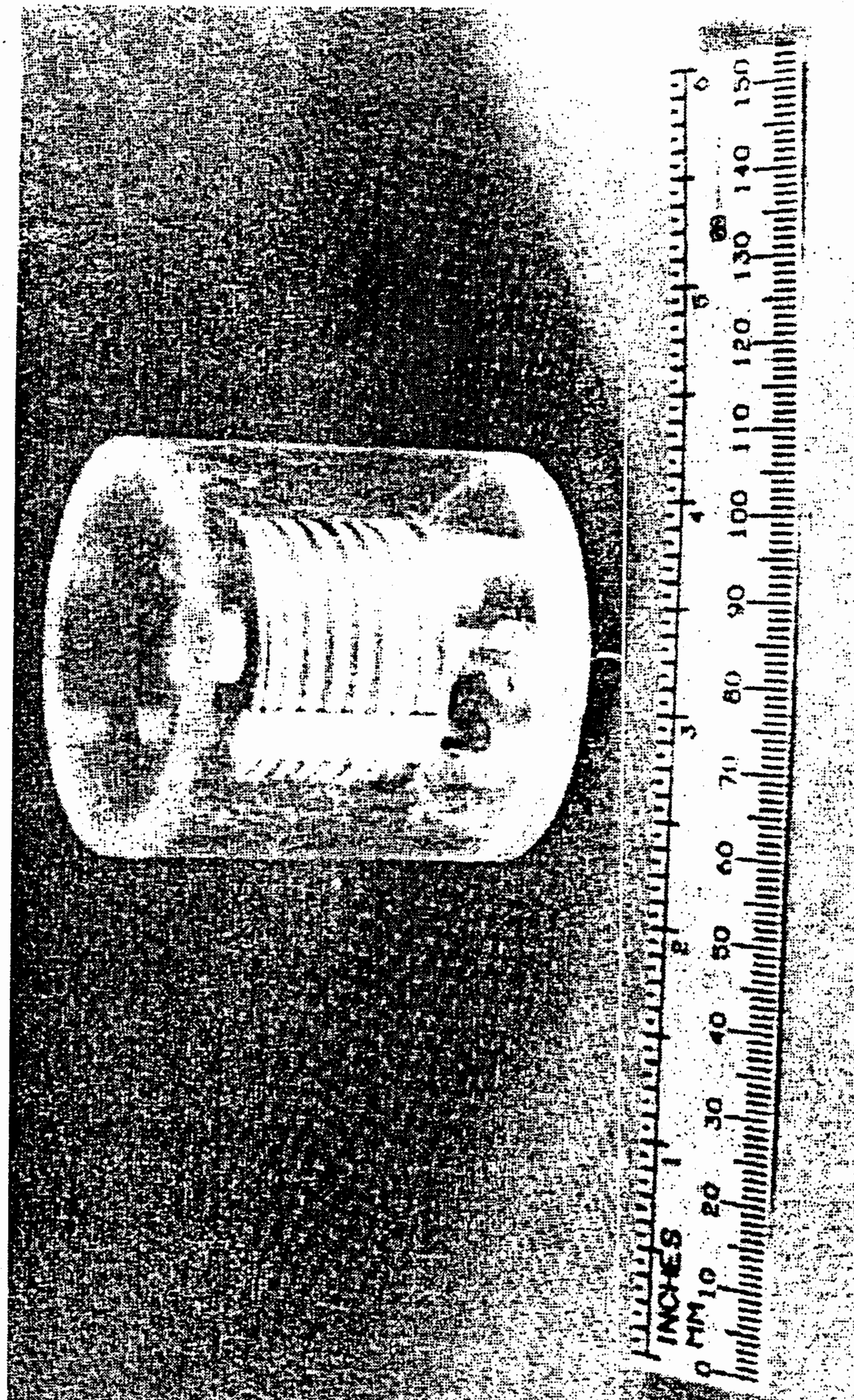
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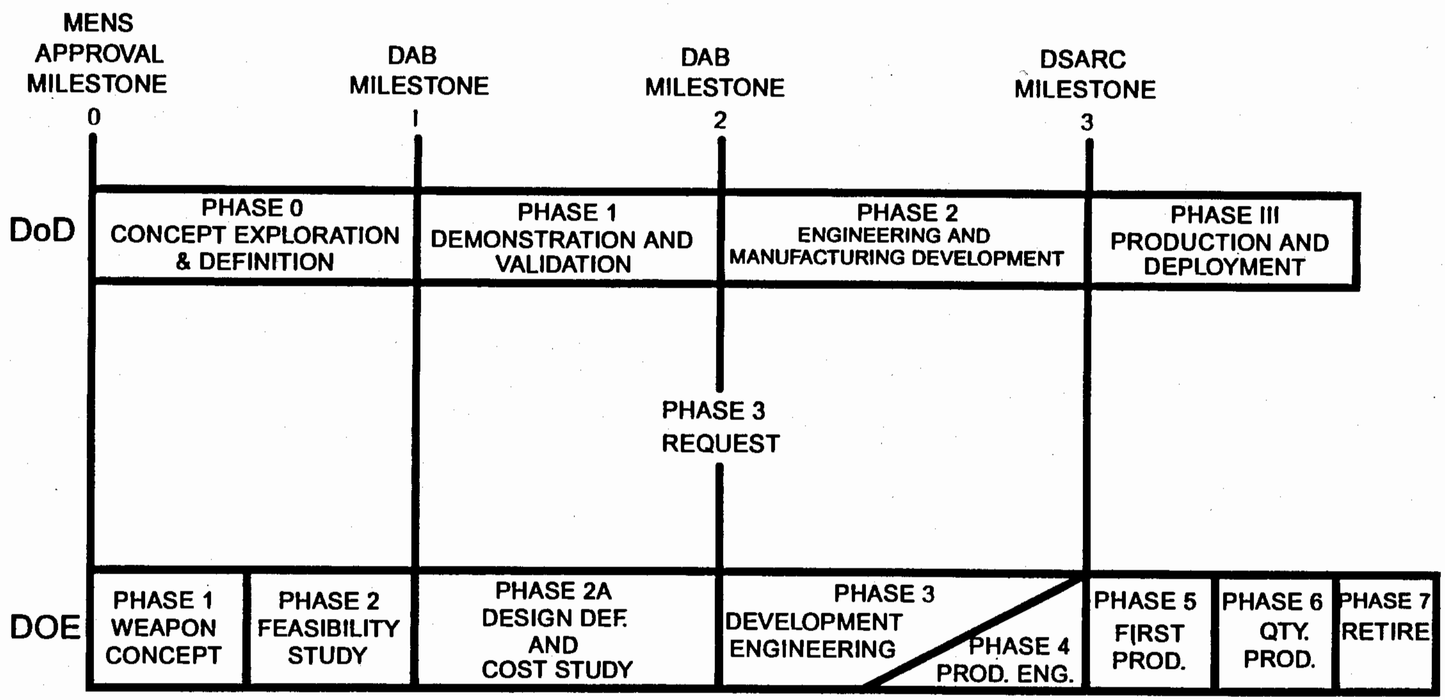


NUCLEAR STOCKPILE

MK NUMBERS__________
AGE RANGE__________
RELIABILITY__________

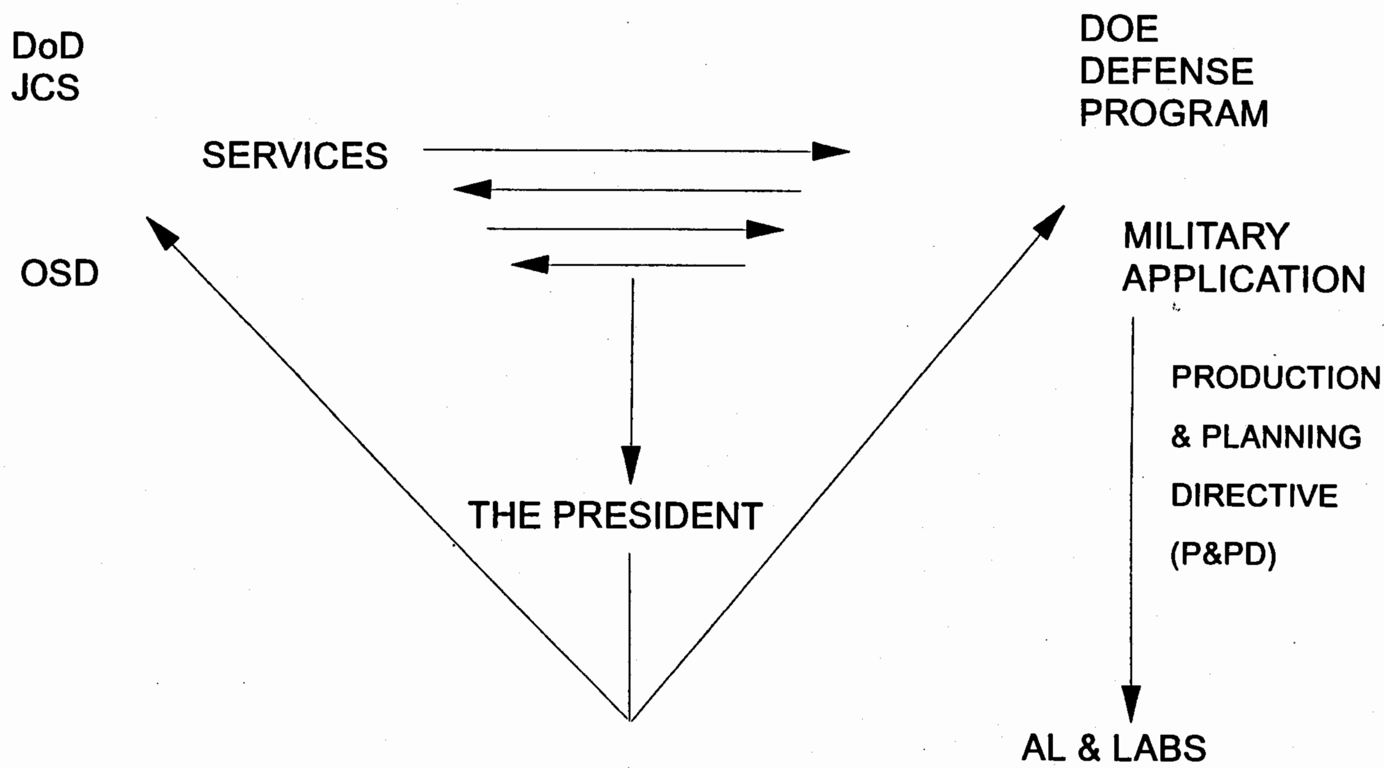
NEW MATERIAL
- LABORATORY TESTS } 1900
- FLIGHT TESTS } 1900

STOCKPILE
- LABORATORY TESTS } 6800
- FLIGHT TESTS } 6800

AUTHORITY AND RESPONSIBILITY HAVE BEEN PLACED WHERE APPROPRIATE INSIGHTS LIE

- OVERALL GUIDANCE AND DIRECTION ARE PROVIDED BY A DOE HEADQUARTERS GROUP - THE DIVISION OF MILITARY APPLICATION
- RESPONSIBILITY FOR WEAPON PRODUCTION IS DELEGATED TO THE ALBUQUERQUE OPERATIONS OFFICE
- THE RESPONSIBILITY FOR ALLOCATION OF RESOURCES AT THE THREE LABORATORIES IS THE PREROGATIVE OF THE DIRECTORS OF THE LABORATORIES SINCE THIS IS WHERE TECHNICAL COMPETENCE EXISTS

ANNUAL STOCKPILE PAPER



LOOKS 11 YEARS AHEAD FOR PLANNING
AUTHORIZED 5 YEARS OF PRODUCTION
AND LONG LEAD PROCUREMENT
DoD & DOE MAY ADJUST UP TO 10%

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PLANT MISSION POLICY, PART II ALO RS3172-3/08333.

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GLOSSARY

ABM	Anti Ballistic Missile
ACDA	Arms Control and Disarmament Agency
ADM	Atomic Demolition Munition
AEC	Atomic Energy Commission (then ERDA, now DOE)
AF&F	Arming, Fuzing and Firing
AFAP	Artillery Fired Atomic Projectile
AK	Adaption Kit
α	Alpha (Neutron Multiplication Rate)
AFWL	Air Force Weapons Laboratory (now Phillips Laboratory)
ALCM	Air Launched Cruise Missile
AL	Albuquerque Operations Office
AMAC	Aircraft Monitor and Control
ASDP	Assistant Secretary (DOE) for Defense Programs
ATSD (AE)	Assistant to the Secretary of Defense for Atomic Energy
AWLPG	AL Workload Planning Guidance
Barn	Unit of cross section; 10^{-24} cm^2
Boosting	The use of Deuterium/Tritium to increase primary yield
Burnt Orange	The colors of a well-known outstanding university
CAT (A,B,D,E, or F) PAL	Permissive Action Link - Code controlled open switch in the weapon's arming circuit. Characteristics as defined in the "General Characteristics of PAL" definition
CD	Command Disable (locally initiated disablement of a nuclear weapon). Not, certificate of deposit, but can be command destruct
NVD	Non Violent Disablement (component removal)
CDU	Capacitor Discharge Unit
CEP	Circular Error Probable; circle within which 50% of the weapons are expected to hit
Channel	The space around the secondary and between the primary and secondary but inside the radiation case
CINC	Commander-in-Chief

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CNWDI	Critical Nuclear Weapon Design Information; a DoD category of Secret RD information or higherpertaining to sensitive weapon design information (not, Caught Naked While Driving Intoxicated)
Critical Mass	The minimum amount of fissionable material capable of supporting a chain reaction under precisely specified conditions
CTB	Comprehensive Test Ban
Natural Uranium	Contains about .7% U235
DAB	Defense Acquisition Board
DASMA	Deputy Assistant Secretary for Military Applications
Depleted Uranium	Uranium which has had much of the isotope U235 removed. Essentially U238
Destruct	Normally refers to the intentional destruction of a weapon by the high order detonation of the weapon's HE at a single point
Disablement	Usually nonviolent. Actions taken on weapon hardware to prevent normal use. (Disablement &Destruct normally differ in degree)
DNA	Defense Nuclear Agency
DOD	Department of Defense
DRAAG	Design Review and Acceptance Group
EBW	Exploding BridgeWire (Detonator)
EMP	Electromagnetic Pulse
EMR, EMI	Electromagnetic Radiation, Electromagnetic Interference
ENDS	Enhanced Nuclear Detonation Safety
Enhanced Electrical Safety	Embodiment of the exclusion region; strong-link; weak-link; unique signal concept (ENDS)
EOD	Explosive Ordnance Disposal
EP	Earth Penetrator
ER	Enhanced Radiation (usually neutron enhancement)
ERDA	Energy Research Development Administration (nee AEC, now DOE)
ESD	Environmental Sensing Device
FEBA	Forward Edge of Battle Area - FLOT
FLOT	Forward line of troops
FPU	First Production Unit
FRP	Fine Resistant Pit
Fuze	Component or subsystem that triggers the firing set. Use of fuse will likely bring abuse on you from old fuzing heads
FY	Fiscal Year
FRD	Restricted Data. Same as RD for foreign nationals
GLCM	Ground Launched Cruise Missile
HE	High Explosive
HOB	Height of Burst; vertical distance from the earth's surface to the point of burst

ICBM	Intercontinental Ballistic Missile
IHE	Insensitive High Explosive. Some form of TATB
INC	Insertable Nuclear Capsule
Interstage Area	The space between the primary and secondary
INF	Intermediate Range Nuclear Forces
Intrinsic Radiation	Naturally occuring neutron and gamma radiation present at the surface of a weapon
IOC	Initial Operational Capability
JAIEG	Joint Atomic Information Exchange Group
JCAE	Joint Atomic Information Exchange Group
JCS	Joint Chiefs of Staff
JTA	Joint Test Assembly
kT	Kiloton equivalent of TNT hydrodynamic yield
LANL	Los Alamos National Laboratory
Lay-down	A form of weapon delivery and/or fuzing. Parachute delivered bomb from very low altitudes with delayed ground burst using a timer fuze
LLC	Limited Life Component; component which must be periodically replaced due to aging
Limited Stockpile Item	A stockpiled weapon which has not been accepted as a "standard" item and for which the DoD has requested additional development
LLNL	Lawrence Livermore National Laboratory
LPO	Lead Project Officer
LRNTF	Long Range Theater Nuclear Forces
MA	Military Application; (DOE) - usually refers to the DASMA office or staff
MAR	Major Assembly Release; SNL prepared, AL approved statement that war reserve weapon material is satisfactory for release on a designated date to the DoD for specified use qualified by exceptions and limitations
MIR	Major Impact Report
MIRV	Multiple Independent Reentry Vehicle
Mk#	Mark Number. The system of numbering nuclear weapons <u>and</u> RV/RB's, cars and other assorted goods (like TV programs!) For nuclear weapons, now replaced by W for Warhead and B for bomb or other
MLC	Military Liaison Committee
MRV	Multiple Reentry Vehicle
MT	Megaton, million tons equiva lent TNT. Also metric tons—1000 kilograms

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National Command Authority	Normally means the President; may sometimes also include those in designated chain authorized to release nuclear weapons
New Material Tests	Tests of a product from the production line before it goes into the stockpile
NEST	Nuclear Explosive Search Team
NPT	Non Proliferation Treaty
NSAM	Nation Security Action Memo
NSC	National Security Council
NTS	Nevada Test Site
NWDG	Nuclear Weapons Development Guidance
NWEF	Naval Weapons Evaluation Facility
OMA	Office of Military Application (DOE)
OMB	Office of Management and Budget
One point	The detonation of the weapon HE at a single point
Oy	Oralloy (Oak Ridge Alloy). Uranium enriched in the isotope U235 to 93.5%
OSD	Office of the Secretary of Defense
PL	Phillips Laboratory (formerly Air Force Weapons Lab)
PAL	Permissive Action Link (coded use control feature)
PA&E	Program Analysis and Evaluation, OSD, (not program annihilation and elimination)
P&PD	Production & Planning Directive
P&S	Production & Surveillance
PM-NUC	Program Manager - Nuclear Munitions (Army program office for nuclear)
POC	Programs of Cooperation
POG	Project Officers Group
POM	Meeting of the POG
Primary	The "fission" device
Pu	Plutonium, a reactor produced fissionable material obtained by bombarding U238 with neutrons
QA	Quality Assurance (DoD uses QART - Quality Assurance, Reliability Testing)
QRA	Quick Reaction Alert; weapon system deployed in a state that would allow its employment in a stated minimum specified time
RB	Reentry Body (Navy term for RV)
RD	Restricted Data; all data concerning design, manufacture, or utilization of nuclear weapons and the production of special nuclear material which has not been removed by the Atomic Energy Act of 1954
Rolomite	A Sandia Designed ESD
RRR	Reduced Residual Radiation (reduced fission devices - formerly MRR, minimum residual radiation)
RTG	Radioisotopic Thermoelectric Generator
RV	Reentry Vehicle (Army, Air Force - Navy calls them RB's); definitely not a recreational vehicle

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SAC	Strategic Air Command
Secondary	The "thermonuclear" device
Sec Def	Secretary of Defense
Shake	10^{-8} seconds
SLBM	Submarine Launched Ballistic Missile
SLCM	Sea Launched Cruise Missile
SNL	Sandia National Laboratories
SNM	Special Nuclear Material - Pu, Oy
SP	Strategic Programs - Navy SLBM office
Specified Command	Combat command with a broad and continuing mission - usually a single Service such as the Strategic Air Command
SRAM	Short Range Attack Missile
SS Material	Source Strength Material - DOE audits one kilogram quantities.
SSPO	Strategic Systems Program Office (now SP)
Standard Stockpile Item	A nuclear weapon which meets the approved military characteristics to DoD's satisfaction
Stockpile Tests	QA test of a system withdrawn from the stockpile; that rare instance that a stockpiled weapon is tested downhole at NTS - a stockpile "confidence test"
STS	Stockpile-to-Target Sequence
TATB	Triamino-Trinitro-Benzene (See IHE)
TTR	Tonopah Test Range, Sandia's testing range at Tonopah, Nevada
TREE	Transient radiation effects on electronics
Tritium	Third isotope of hydrogen, radioactive gas used to boost weapons
TTBT	Threshold Test Ban Treaty
Tu	Tuballoy. Natural Uranium; sometimes also includes depleted uranium, i.e., essentially U238
γ	Map - A contour depicting permissable velocity, reentry angle combinations for a missile RV/RB
Unified Command	A combat command with a broad and continuing mission composed of forces of two or more services under a single commander
USANCA	U.S. Army Nuclear and Chemical Agency
USDR&E	Under Secretary of Defense for Research and Engineering
WR	War Reserve(nuclear weapons material (in DOE or DoD custody) intended for employment in the event of war
Weapons Grade Pu	Plutonium which has 6% or less Pu240 content. Pu239 is the "good" stuff
WDCR	Weapon Design & Cost Report
WES	Warhead Electrical System
WSV	Weapons Safety Vault (Weapons Security Vault)
X-unit	A device used to provide energy to initiate the nuclear system detonators

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WEAPONS/WEAPON APPLICATIONS

WEAPON*	APPLICATION	SERVICE
FATMAN	BOMB	AF
LITTLEBOY	BOMB	AF
Mk III	BOMB	AF
Mk 4	BOMB	AF
T-4	ADM	A
Mk 5	BOMB	AF,N
Mk 5	MATADOR	AF
Mk 5	REGULUS I	N
Mk 6	BOMB	AF
Mk 7	BOMB	AF,N
Mk 7	HONEST JOHN	A
Mk 7	CORPORAL	A
Mk 7	BOAR	N
Mk 7	BETTY	N
Mk 7	ADM	A
Mk 7	NIKE HERCULES	A
Mk 8	BOMB	N
Mk 9	280-mm AFAP	A
Mk 11	BOMB	N

*Absence of entry indicates system not fielded

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WEAPON	APPLICATION	SERVICE
Mk 12	BOMB	AF,N
Mk 14	BOMB	AF
Mk 15	BOMB	AF,N
Mk 17	BOMB	AF
Mk 18	BOMB	AF,N
Mk19	280-mm AFAP	A
Mk21	BOMB	AF
Mk23	16" AFAP	N
B24	BOMB	AF
W25	GENIE	AF
B27	BOMB	N
W27	REGULUS I	N
B28	BOMB	AF,N
W28	HOUNDDOG	AF
W28	MACE	AF
W30	TALOS	N
W30	ADM	A
W31	HONEST JOHN	A
W31	NIKE HERCULES	A
W31	ADM	A
W33	8" PROJECTILE	A,N

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WEAPON	APPLICATION	SERVICE
W34	LULU	N
W34	ASTOR	N
B34	HOTPOINT	N
B36	BOMB	AF
W38	ATLAS	AF
W38	TITAN I	AF
B39	BOMB	AF,N
W39	B-58 pod	AF
W39	REDSTONE	A
W39	SNARK	AF
W40	BOMARC	AF
W40	LACROSSE	A
B41	BOMB	AF
B43	BOMB	N,AF
W44	ASROC	N
W45	BULLPUP	N
W45	TERRIER	N
W45	LITTLE JOHN	A
W45	MADM	A
W47	POLARIS	N
W48	155-mm AFAP	A,N

WEAPON	APPLICATION	SERVICE
W49	ATLAS	AF
W49	THOR	AF
W49	JUPITER	A,AF
W49	TITAN I	AF
W50	PERSHING	A
W50	NIKE ZEUS	A
W52	SERGEANT	A
W53	BOMB	AF
W53	TITAN II	AF
W54	FALCON	AF
W54	DAVY CROCKETT	A
W54	SADM	A,N
W55	SUBROC	N
W56	MINUTEMAN	AF
B57	BOMB/DEPTH BOMB	AF,N
W58	POLARIS A3	N
W59	MINUTEMAN I	AF
B61	BOMB	AF,N
W62	MINUTEMAN II	AF
W66	SPRINT	A
W68	POSEIDON C3	N
W69	SRAM	AF

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WEAPON	APPLICATION	SERVICE
W70	LANCE	A
W71	SPARTAN	A
W72	WALLEYE	AF
W76	TRIDENT I	N
W78	MINUTEMAN III	AF
W79	8" AFAP	A,N
W80	SLCM	N
W80	ALCM	AF
B83	BOMB	AF
W84	GLCM	AF
W85	PERSHING II	A
W87	PEACEKEEPER ICBM	AF
W88	TRIDENT II	N

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION II

- REVIEW OF WEAPONS PHYSICS
- THEORY OF NUCLEAR EXPLOSIONS

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Weapons Physics and Nuclear Material

- Several basic nuclear physics concepts and the properties of the nuclear fissile material are very important to the understanding of weaponization
  - The physics of fission
  - Nuclear properties
  - Availability of material
  - How the fissile material is obtained
  - Energy available and energy trades

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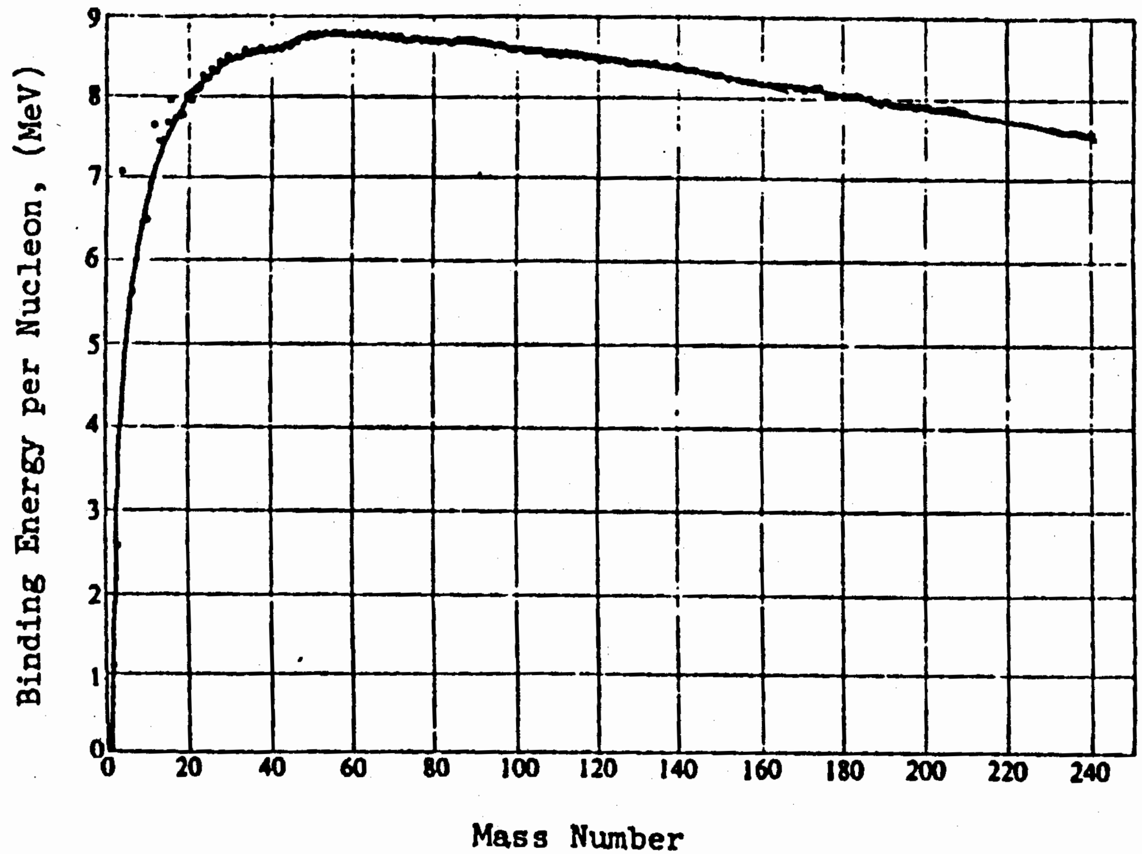
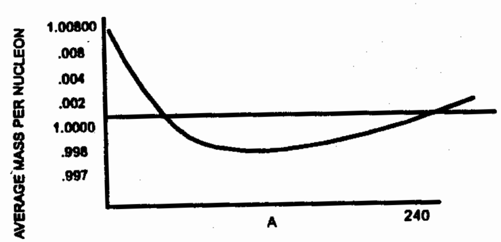
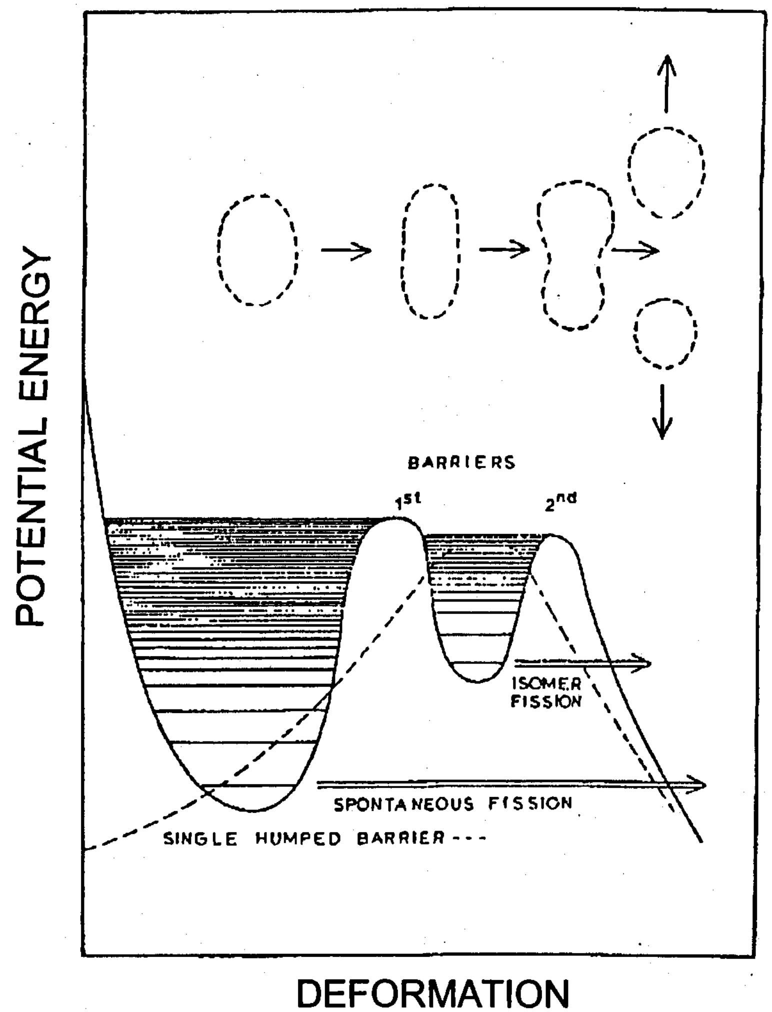
NUCLEAR BINDING ENERGY

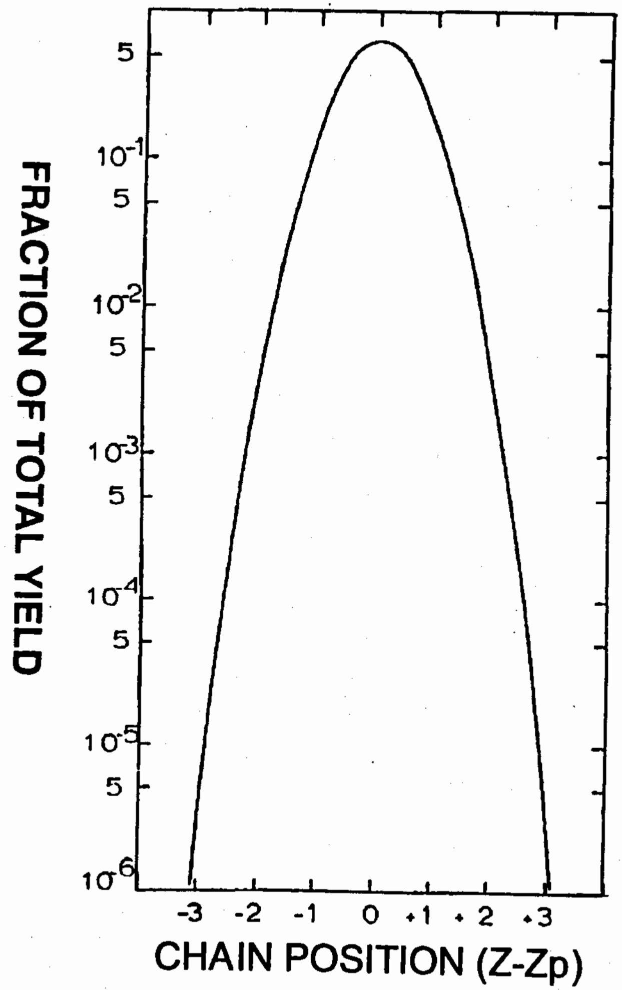




LIQUID DROP MODEL APPLIED TO POTENTIAL BARRIERS



CHARGE DISTRIBUTION CURVE



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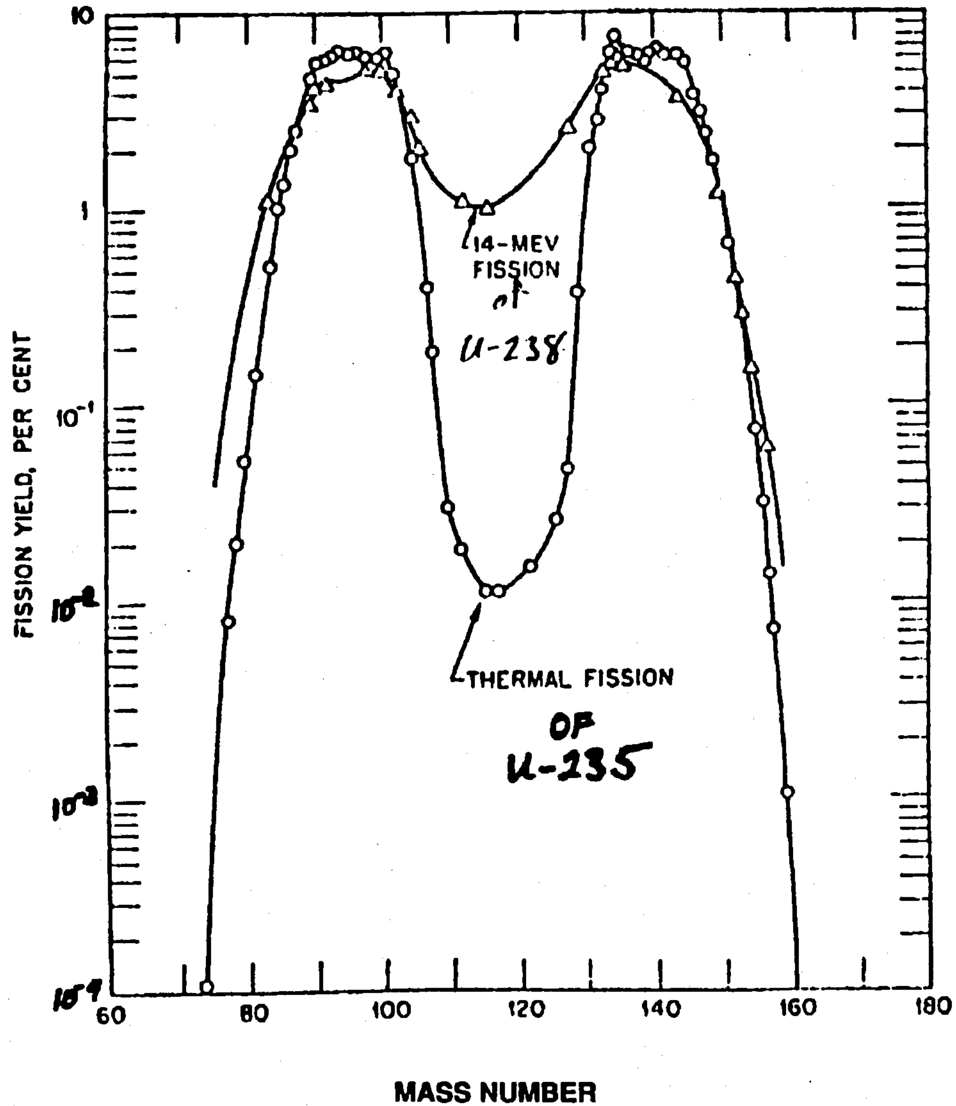

LIKELIHOOD FOR FISSION FRAGMENT

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Terminology

Asymmetric fission	-	division of excited nucleus into two unequal fragments with masses about 100 & 140 ama.
Binary	-	division at scission point into two parts.
Cross-Section	-	probability that a certain reaction between a nucleus and an incident particle or photon will occur, as in a neutron and U-235 (measured in "barns")
Fission Fragment	-	fragment after scission but before prompt neutron emission
Fission Product	-	fragment after prompt neutron emission

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The Gang of Four

$^{238}U_{92}$ % in nature - 99.27 When the $^{238}U_{92}$ is extracted, it is called depleted ^{238}U or TUBALLOY or D38 (from UK WWII effort - TUBE ALLOY). Will fission but not fissile Physically separated	^{239}Pu % in nature - essentially zero (mine in South Africa) Made in Reactor: $N + ^{238}U = ^{239}Pu$
^{235}U % in nature - 00.73 Concentrated to 93.5%. Called ORALLOY for Oak Ridge Alloy	^{240}Pu % in nature - essentially zero Made by reactor. If you leave the ^{239}Pu in "too long," it will absorb a $N \rightarrow ^{240}Pu$. Spontaneously fissions (originally a problem for pre-ignition).

CALCULATION OF ENERGY RELEASE

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{42}Mo^{95} + {}_{57}La^{139} \quad 7\,{}_{-1}e^{0} + 2\,{}_{0}n^{1}$$

235.0439	94.905837
1.0087	138.906400
	.003850
	2.017340
236.0526 amu ⟶	235.8334 amu

MASS DEFECT OF .219 amu

n = 1.00867 amu
p = 1.00728 amu
e = .00055 amu

$$(.219\ \text{amu})\ \left(931.4\ \frac{\text{MeV}}{\text{amu}}\right) \simeq 204\ \text{MeV}$$

THE EXAMPLE STARTED WITH

$$_{54}Xe^{139} \xrightarrow{3\beta} {}_{57}La^{139} \quad \text{AND} \quad {}_{38}SR^{95} \xrightarrow{4\beta} {}_{42}Mo^{95}$$

FISSION CHAIN

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THEORETICAL FISSION ENERGY

- THERE ARE $\frac{6.025X10^{23}}{235.0439}$ ATOMS PER GRAM OF $_{92}U^{235}$
- THEREFORE, 1 kg OF $_{92}U^{235}$ HAS $2.5634X10^{24}$ ATOMS
- HENCE, @ 180 MeV PER FISSION 1 kg OF $_{92}U^{235}$ WOULD PRODUCE
- $4.6141x10^{26}$ MeV IF EACH ATOM WERE FISSIONED.
- CONVERTING TO KILOTONS
- $(4.6141X10^{26}$ MeV$)$ $(3.824X10^{-26}$ $\frac{kT}{MeV}$ $)=$ 18 kT
  T

FACTORS AFFECTING CRITICAL MASS

- GEOMETRY
- AMOUNT OF MATERIAL
- TYPE OF MATERIAL
- PURITY OF MATERIAL
- SURROUNDING MATERIAL
- DENSITY

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WEAPONS MATERIALS

Plutonium 239 = Pu^{239} = P^{239}_{94} = Pu

Made by placing natural uranium as the target in a reactor. Weapons grade Pu = having less than 6% Pu^{240}.

Oralloy = Oy = Uranium that has been enriched to 93 .X% U^{235}_{92}

Tuballoy -- Tu -- natural uranium but also includes depleted uranium (i.e. U^{238})

Tritium = H^3_1 = T^3 = T

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CRITICAL MASS (kg)

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Property / Alloy Metal	γ- Pu	δ -Pu
Alloy Material	Alloy	1 ±0.2 wt % Ga
Maximum Stable Temp (°C)	117	525
Density (g/cm^3)	19.6	15.8
Working Character-istic Similar to	Brittle, Cast Iron	Annealed Copper
Tensile Strength (GPa)3	0.62	0.1
Weldability	Not	Easily
Coefficient of Linear Expansion @ 25°C (10^{-6} cm/cm- °C)	54	6

DOE b(3)

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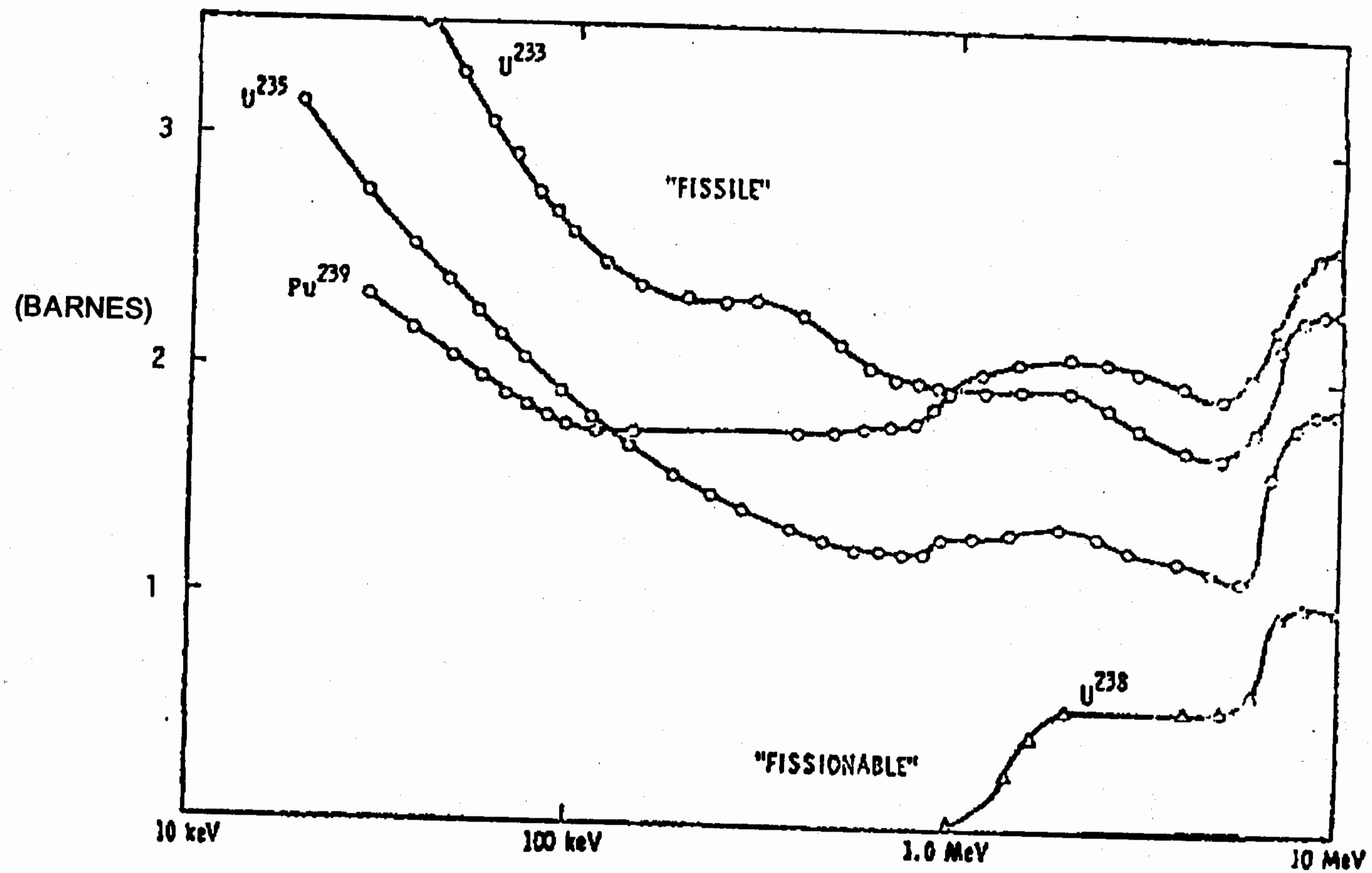
FISSION CROSS SECTIONS



INCIDENT NEUTRON ENERGY

NOTE: The thermal neutron energy is not on the chart

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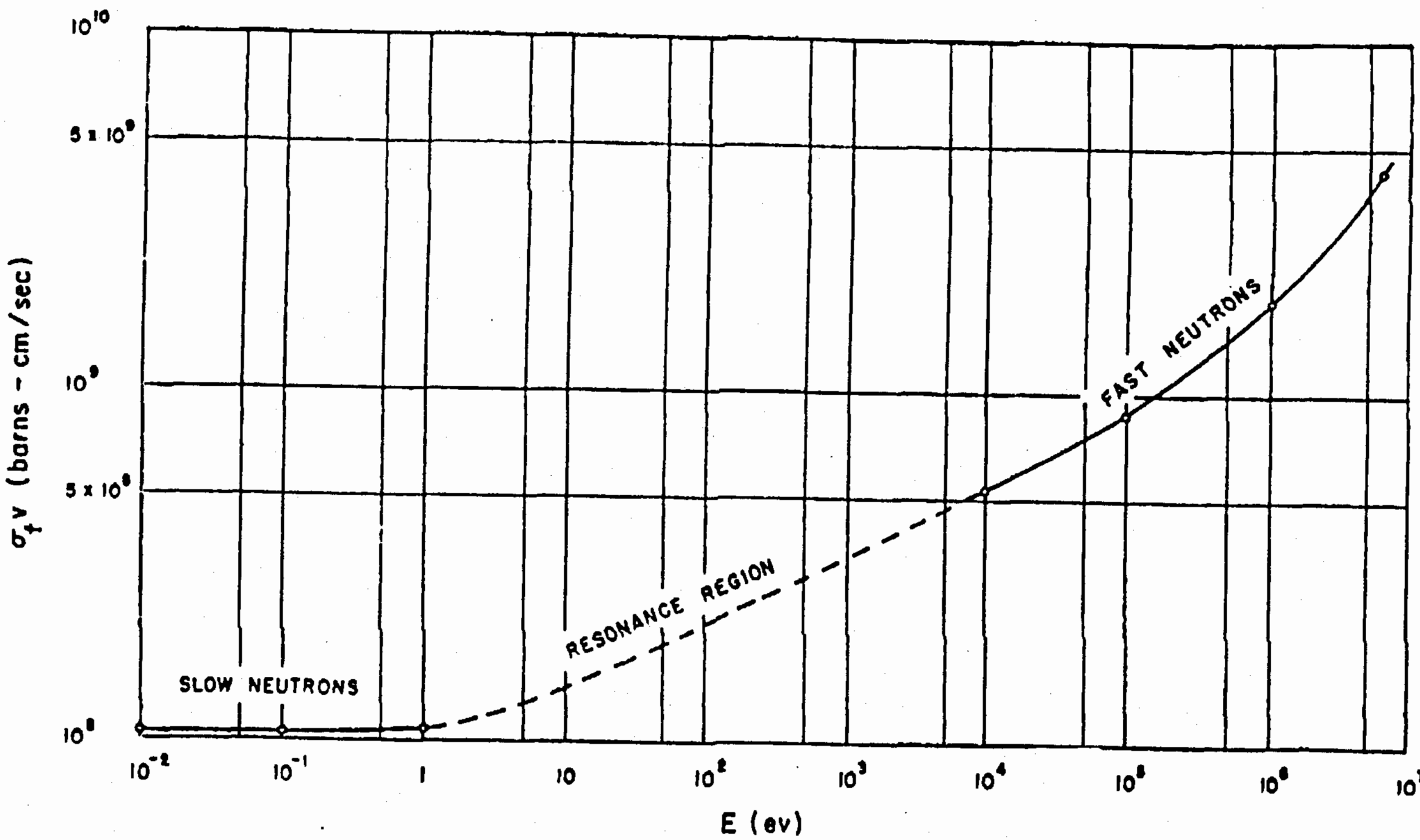
Variation of Cross Section x Velocity for 235U

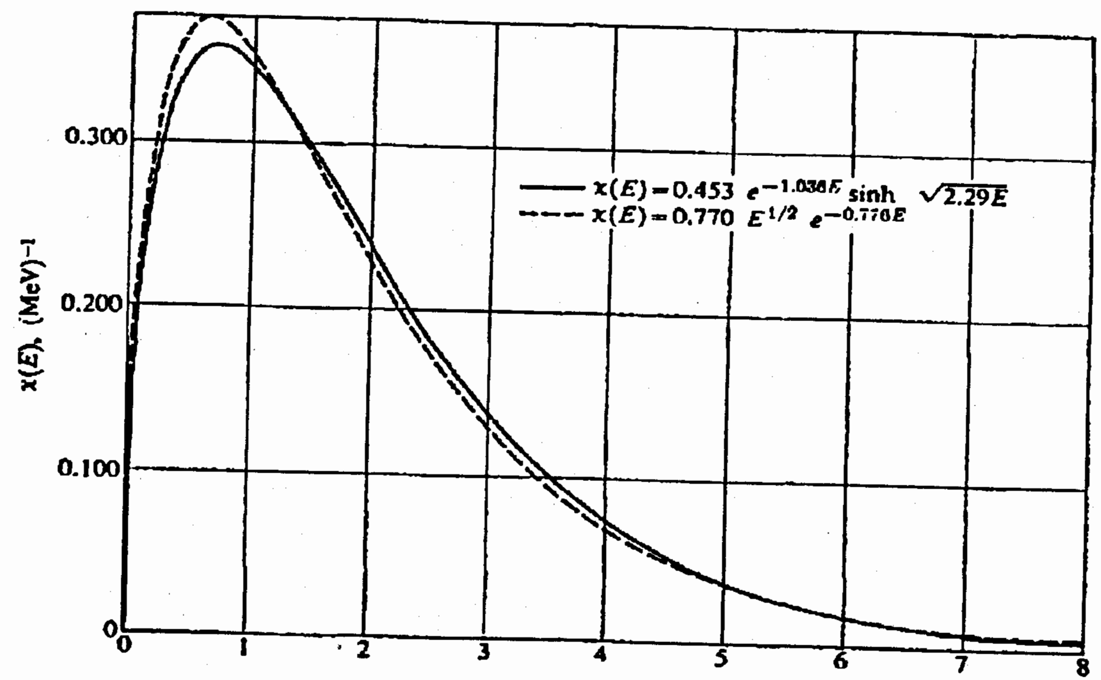


Neutron Energy

Fission is more effective at higher energies N

Smallest fission generation time at high energies ($T = 1/N\sigma_f \cdot v$)

Neutron Energy (MeV)
U_{235} Fission Neutron Energy Spectrum



(Reference, Lamarsh, 1966)

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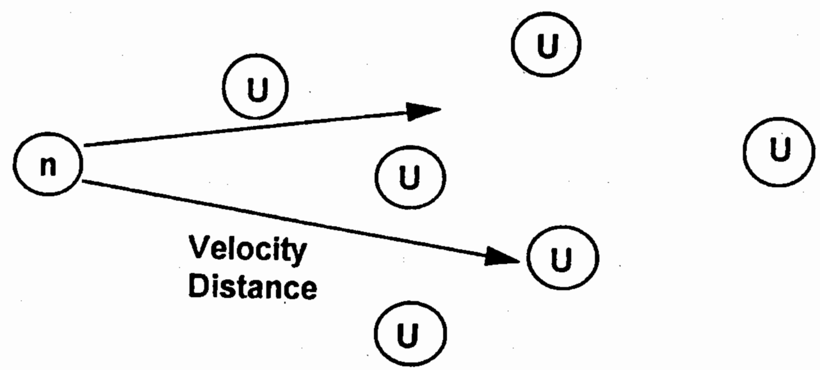
Shake was Invented Before Rock and Roll



- Fission mean free path - how long before it clobbers an atom like URANIUM
- Average velocity - how fast it is going

- $$\tau = \frac{\textit{fission mean free path}}{\textit{average velocity of neutron}}$$

These values are derived experimentally and are related to the fission cross section and velocity of the neutron.

- $\tau = 10^{-8}$ Seconds or 1 shake
  (real fast like the shake of a lamb's tail)

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We Care About Neutrons

- An efficient way to fission U235 or Pu239 is with neutrons.
- The fission of one atom of U235 or Pu239 releases approximately 200 MeV.
- To create an explosion by fission, a bunch of neutrons are required.
- The more neutrons--the more fission, i.e., We Care About Neutrons!
- Remember that each fission gives off integral numbers of neutrons--about 2-4, but over a bunch of fissions, we measure an average (i.e., 2.54 etc.) and this varies with input neutron energy.

  υ = ave. number of neutrons
- The whole idea or sustaining the fission process is to get these fission neutrons to go fission more U235 or Pu239.
  - If all the neutrons escape without fissioning anything, then the reaction fizzles! (The population becomes extent.)
  - If at least one of the 2 to 4 neutrons fissions something every generation, then we have a steady state condition--a reactor.
  - If most of the neutrons fissions another atom etc., etc., we have a run-away condition--a nuclear explosion.

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We Care About the Neutrons that Escape

- We call the escapees "lost neutrons," and the abbreviation is l (the letter after k).
- So the number of neutrons available for population growth is the average number per fission (υ), i.e., 2.54 minus the lost ones.
- Someone called this k. (I suppose because it is in the alphabet before l.)
- Therefore: $k = \upsilon - l$
  - for every neutron causing fission in one generation k will cause it in the next generation.

    (just remember the old graffito "Kilroy was here" and as everyone knows Kilroy helped cause the population explosion.)

We Care About the Multiplication

- Now let's look at a bunch of fissions and bunch of neutrons.
- If we start with some number of neutrons (one or more), let that number equal n.

  n = number of neutrons at beginning of a generation

- Remember, k= number of neutrons available for Round 2...
- And k times n (k · n) equals number of neutrons at the next generation.
- Don't forget we've used up the original neutrons (n) in the first fission process..
- The gain of neutrons is thus:

$$n \bullet k - n$$

(number of neutrons we started with)•(average number in a fission of Round 2 (etc.)) minus the ones we used up in the previous round.

Your Bank Interest Rates do not Grow as Fast as a Bomb Rate

– We still care about neutrons, but we really care about the rate (speed) that they are produced.

- The rate is the $\dfrac{\text{change in the number of neutrons}}{\text{change in time}}$
- Mathematically this is represented

$$\frac{\Delta n}{\Delta t} \Rightarrow \frac{dn}{dt}$$

- To get the rate change, we divide the actual gain in neutrons by time (τ)

$$\frac{nk - n}{\tau}$$

- Therefore $\dfrac{dn}{dt} = \dfrac{nk - n}{\tau}$

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Apply Basic Calculus

- $\frac{dn}{dt} = \frac{nk - n}{\tau} = \frac{n(k-1)}{\tau}$
- *Let* α *"alpha"* $= \frac{k-1}{\tau}$ *substitution gives*
- $\frac{dn}{dt} = n\alpha$; *Rearrange (cross multiply and divide)*
- $\frac{dn}{n} = \alpha\, dt$ *Integrate from zero neutrons* (N_o) *to N neutrons.*
- $N = N_o\, e^{\alpha t}$

  If α *is known, one can calculate the number of neutrons at any time* (t).

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THE ENERGY RELEASED IS PROPORTIONAL TO THE NUMBER OF FISSIONS

$$\alpha \approx \frac{\nu - \ell - 1}{\tau} \approx \frac{3-1-1}{\tau} \approx \frac{1}{\tau} \approx \text{of/order } 10^{8} \text{ gen/sec}$$

(1 gen/shake) for 1 MeV Neutron

$$n = n_o e^{\alpha t} \cong n_o e^{\frac{t}{\tau}} \cong e^{g}, \quad g \cong \text{ number of generations}$$

THE ENERGY RELEASED IS PROPORTIONAL TO THE NUMBER OF FISSIONS.

THE NUMBER OF FISSIONS IS PROPORTIONAL TO THE NUMBER OF NEUTRONS.

1 fission $\cong 7 \times 10^{-21}$ tons of TNT

At $g = 48$ WE WOULD HAVE $\approx$ 9800 lbs.

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ENERGY RELEASE

DOE
b(3)

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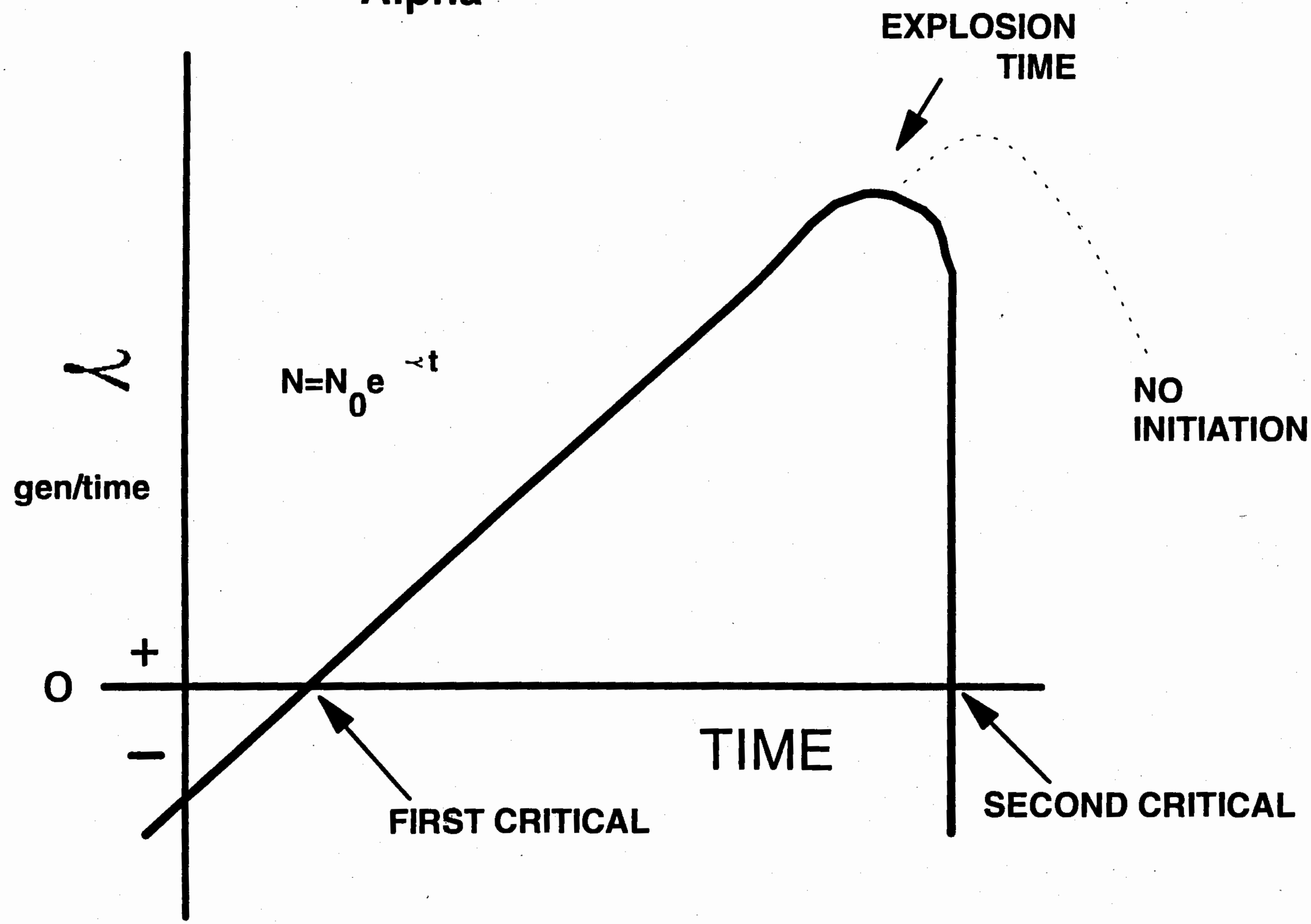
γ - Curve

Alpha



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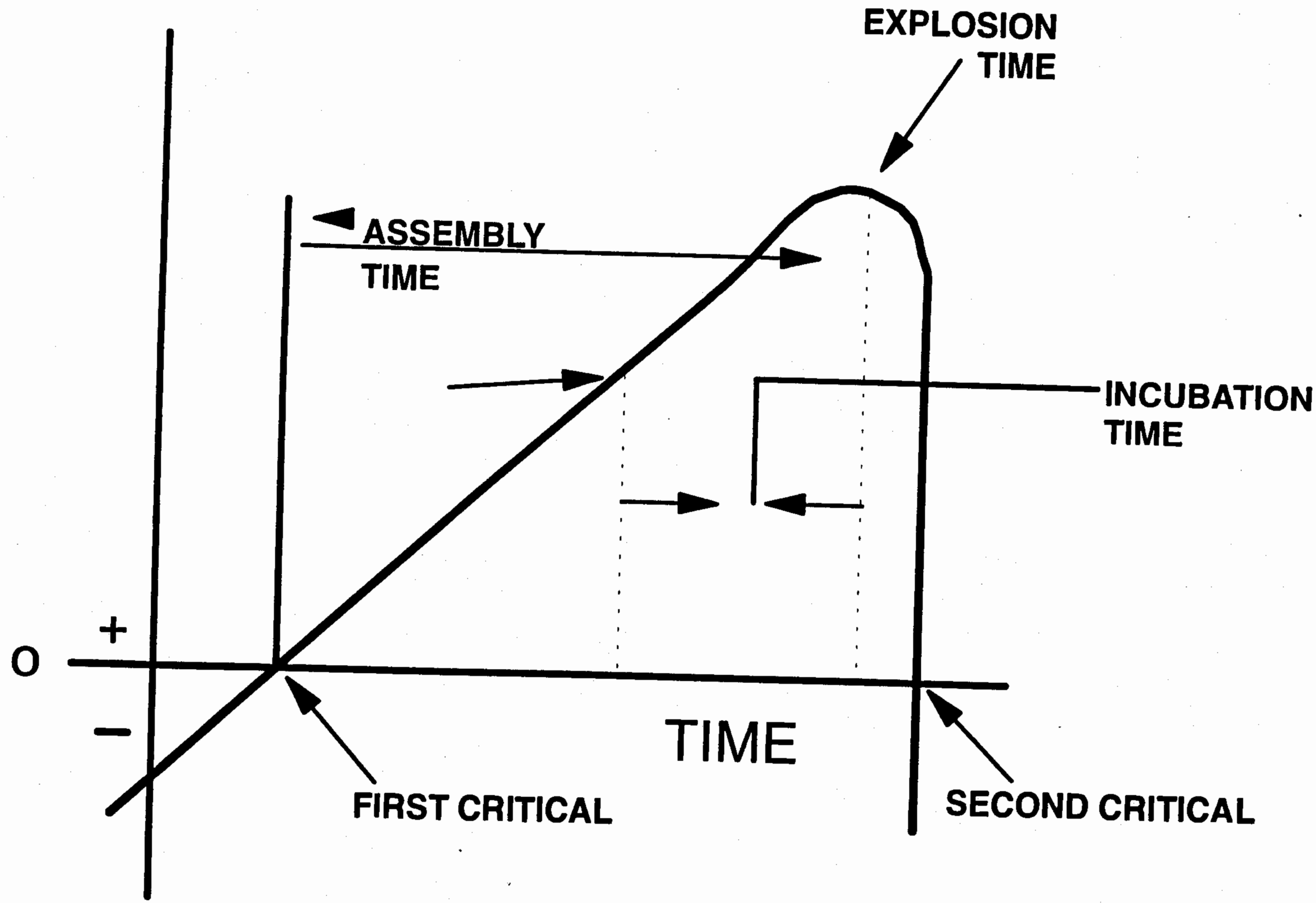
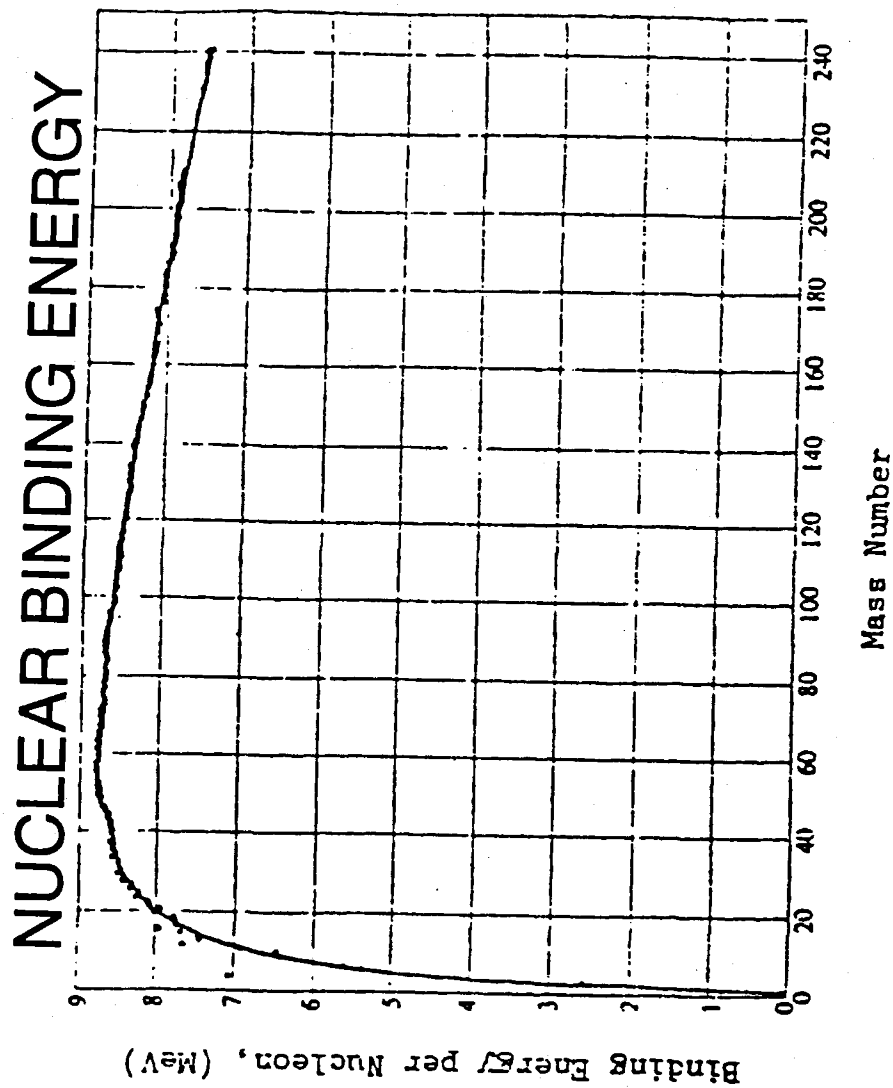
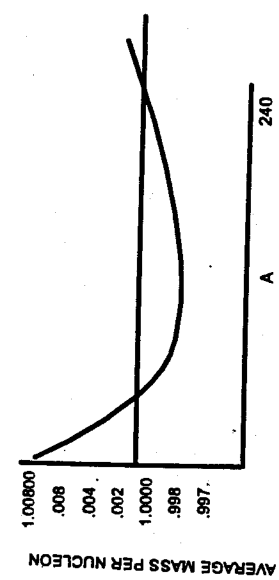
γ - Curve


EXPLOSION TIME
ASSEMBLY TIME
INCUBATION TIME
+
O
−
TIME
FIRST CRITICAL
SECOND CRITICAL

γ - Curve

DOE b(3)


NUCLEAR BINDING ENERGY
Binding Energy per Nucleon, (MeV)
Mass Number
0
1
2
3
4
5
6
7
8
9
20
40
60
80
100
120
140
160
180
200
220
240


AVERAGE MASS PER NUCLEON
1.00800
.008
.004
.002
1.0000
.998
.997
A
240

Potential Fusion Reaction

$$_1D^2 + {}_1D^2 \rightarrow {}_2He^3 + {}_on^1 + 3.27\ \text{MeV}$$

$$_1D^2 + {}_1D^2 \rightarrow {}_1T^3 + {}_1H^1 + 4.03\ \text{MeV}$$

$$_1D^2 + {}_1T^3 \rightarrow {}_2He^4 + {}_on^1 + 17.6\ \text{MeV}$$

$$_1D^2 + {}_2He^3 \rightarrow {}_2He^4 + {}_1H^1 + 18.3\ \text{MeV}$$

$$_1T^3 + {}_1T^3 \rightarrow {}_2He^4 + 2\,{}_on^1 + 11.3\ \text{MeV}$$

$$_3Li^6 + n \rightarrow {}_2He^4 + {}_1T^3 + 4.6\ \text{MeV}$$

THEORETICAL FUSION ENERGY IN EQUAL ATOM MIXTURE OF $L_i^6 D$

$$1 \text{ Kg of } L_i^6 \text{ has } \frac{6.025 \times 10^{26}}{6.0151} = 1.00165 \times 10^{26} \text{ Atoms}$$

$$1 \text{ Kg of D has } \frac{6.025 \times 10^{26}}{2.0141} = 2.99141 \times 10^{26} \text{ Atoms}$$

HENCE,

$$.25084 \text{ Kg of D has } \left(\frac{2.01410}{6.01512 + 2.0141}\right)\left(2.99141 \times 10^{26}\right) \cong .750384 \times 10^{26} \text{ Atoms}$$

$$.74915 \text{ Kg of } L_i^6 \text{ has } \left(\frac{6.01512}{6.01512 + 2.0141}\right)\left(1.00165 \times 10^{26}\right) \cong .750390 \times 10^{26} \text{ Atoms}$$

$$L_i^6 + {}_0n^1 \Longrightarrow (.75039 \times 10^{26})\ (4.6 \text{ MeV}) \cong 13.2 \text{ Kt}$$

$$D + T \Longrightarrow (.75039 \times 10^{26})\ (17.6 \text{ MeV}) = 50.5 \text{ Kt}$$

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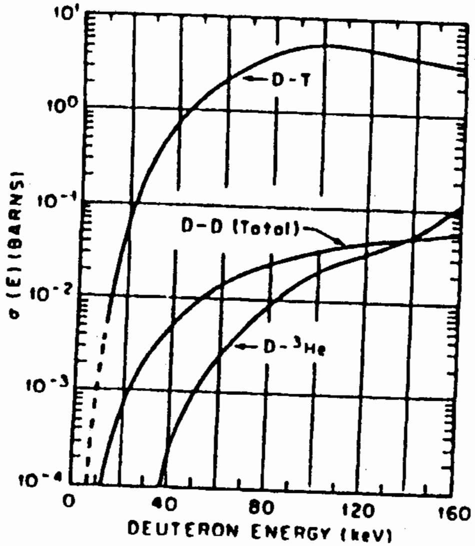
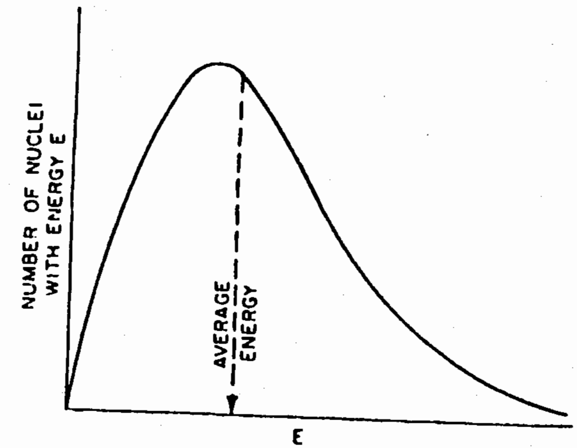
TEMPERATURE EXPRESSED IN kT (ENERGY)

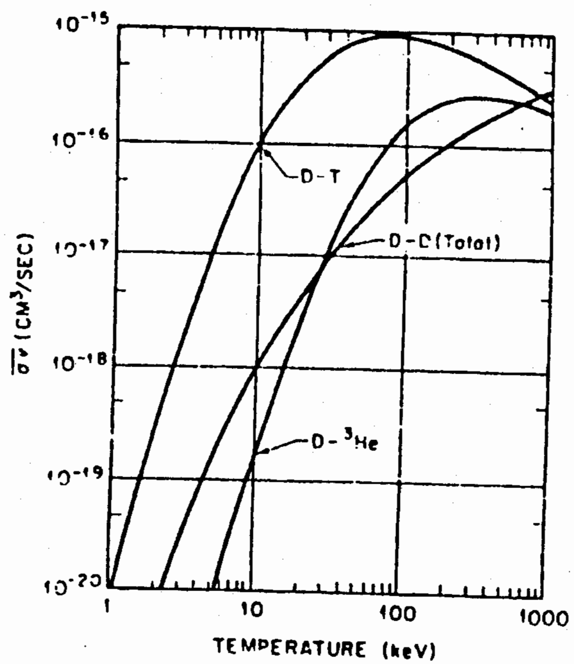
where K is Boltzmann Constant $\begin{cases} 1.38\text{X}10^{-16} \text{ erg/ }^{\circ}\text{K} \\ 8.62\text{X}10^{-8} \text{ keV/ }^{\circ}\text{K} \end{cases}$

T (in keV) = $8.62\text{X}10^{-8}$ T (in °Kelvin)

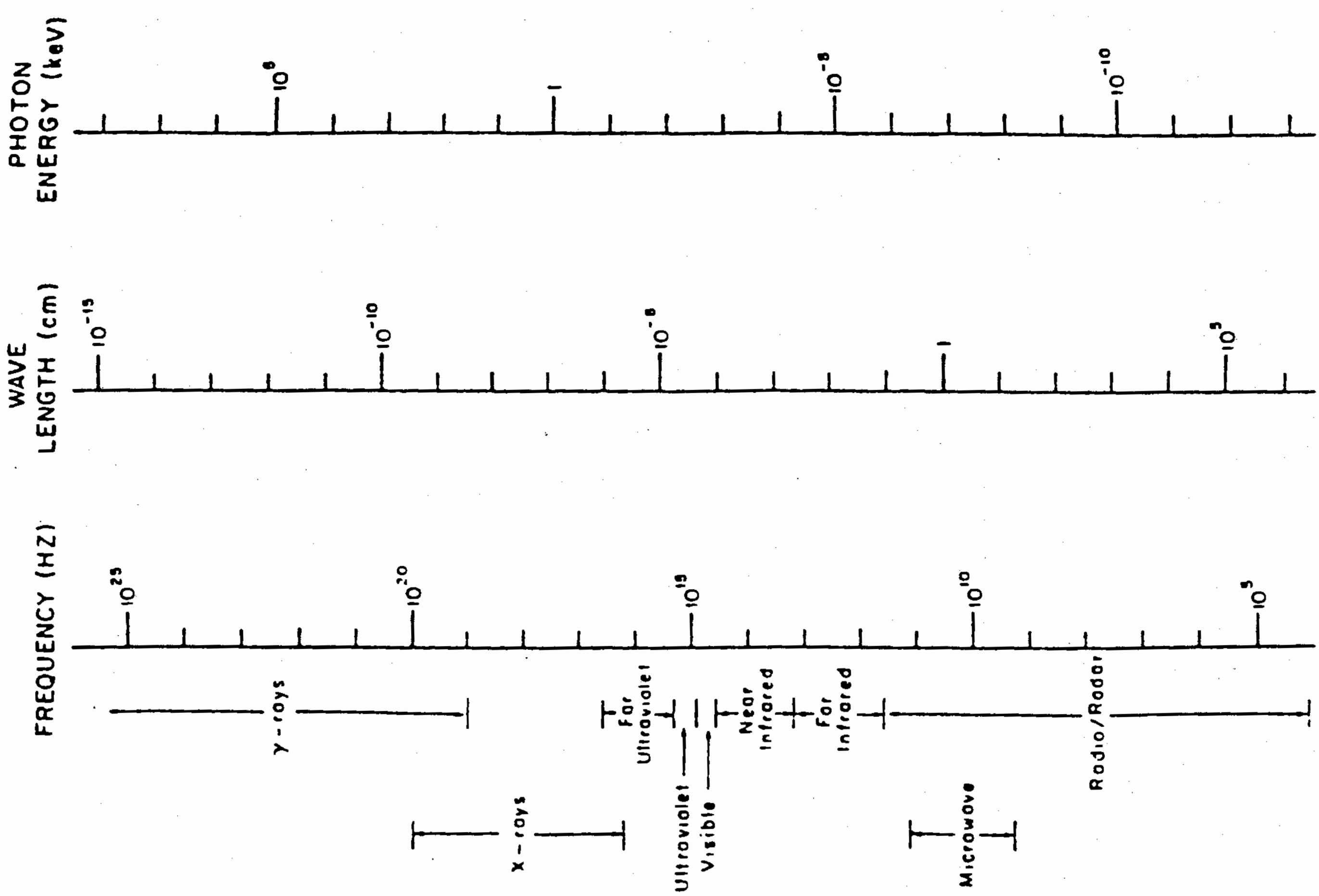
Temperature of 1 keV = $1.16\text{x}10^{7}$ degrees Kelvin


σ (E) (BARNS)
10¹
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
D-T
D-D (Total)
D-³He
0
40
80
120
160
DEUTERON ENERGY (keV)


NUMBER OF NUCLEI
WITH ENERGY E
AVERAGE
ENERGY
E


σv (CM³/SEC)
10⁻¹⁵
10⁻¹⁶
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10⁻²⁰
D-T
D-D (Total)
D-³He
1
10
100
1000
TEMPERATURE (keV)

~~SECRET~~ UNCLASSIFIED



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Thermal Nuclear (TN)

TN BURN - REACTION IN ONE VOLUME RAISES TEMPERATURE IN AN IMMEDIATELY ADJACENT VOLUME.

FUSION REACTION RATE R_{12} :

$$R_{12} = N_1 N_2 \quad \sigma v$$

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Thermal Nuclear Plasma

AT FUSION TEMPERATURES, WE HAVE A PLASMA OF IONS (NUCLEI AND ELECTRONS).

$$\text{ENERGY} = aT_{(ion)} + bT_{(electron)} + cT^4_{(radiation)}$$

IF PLASMA IS IN THERMODYNAMIC EQUILIBRIUM THE THREE TEMPERATURES ARE EQUAL ➡ AT HIGH TEMPERATURES, RADIATION WILL DOMINATE.

D-D ENERGY REPRODUCTION TIME

TEMP (keV)	COMPRESSION 10	20	50	100
3	22	7.6	2.2	1.0
5	19	5.4	1.4	.4

TIME IN SHAKES

DOE b(3)

DOE b(3)

REFERENCES

AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED; SRD (N) SIGMA 1 *etc.*; GLASSTONE AND REDMAN.

SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE; UNC 3rd EDITION

BASIC NUCLEAR PHYSICS; INTERSERVICE NUCLEAR WEAPONS SCHOOL

DNA PUBLICATIONS — TECHNOLOGY ANALYSIS REPORT

SANDIA, LLL, LANL TECHNOLOGY REPORTS

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION III

- NUCLEAR EFFECTS

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CONVENTIONAL EXPLOSIVE

RELEASE OF ENERGY ARISES FROM THE BREAKING OF CHEMICAL BONDS (ELECTRON BONDS) IN THE HIGH EXPLOSIVE MATERIAL

NUCLEAR EXPLOSIVE

RELEASE OF ENERGY ARISES FROM THE BREAKING OR MAKING OF NUCLEAR BONDS (HADRON-HADRON)

FISSION AND FUSION YIELDS ENERGY RELEASE + PARTICLES

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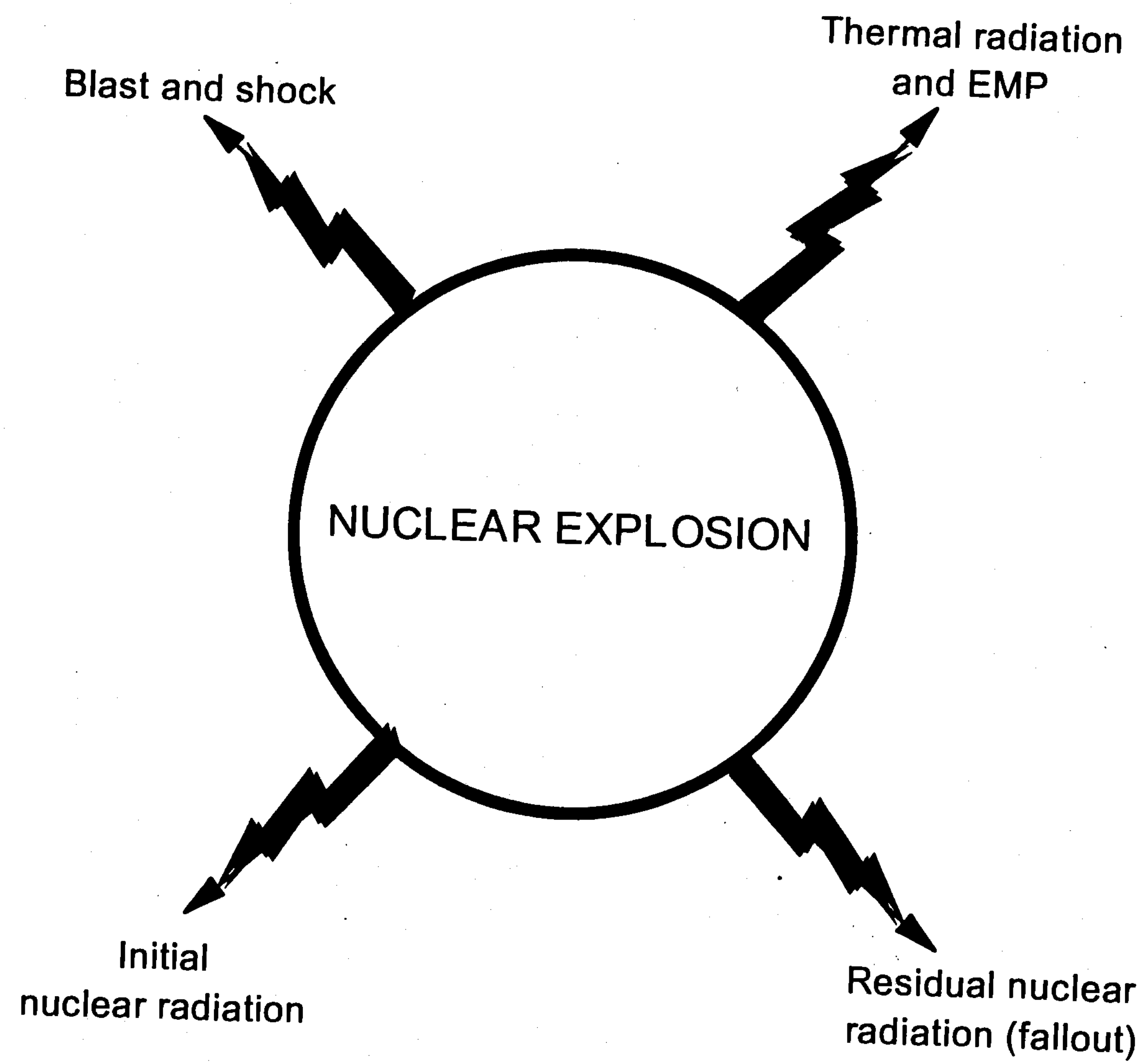
Effects of a Nuclear Explosion



Nuclear Effects Generalities

Subject Generally Divided into 3 areas

- Phenomenology
  - Physics at the weapons source
- Interaction of the nuclear energy with environment and hardware
- Military effects
  - Smashing (over pressure)
  - Turning over (dynamic - winds)
  - Fires (Thermal pulse)
  - Radiation
  - Craters

What are Nuclear Effects Calculations Used For?

- Determining how "hard" (radiation, blast, etc.) to make the weapon system (major cost implication)
- Determine the proper yield/accuracy combination
- Placement of weapon system on the battlefield
- Targeting
- Number of nuclear weapons required to achieve an objective
- Safety zones
- Etc.

What Are Nuclear Effects Calculations Used For? (Continued)

- Historically, this is an area that has caused much discussion and argument. However, over the years, DNA has developed tools to standardize the methodology and has contributed greatly to the understanding of this area.
  - Textbooks
  - Nomograms/Slide Rules
  - TI59 - Programs
  - HP 41 CX - Programs
  - Personal Computer Software

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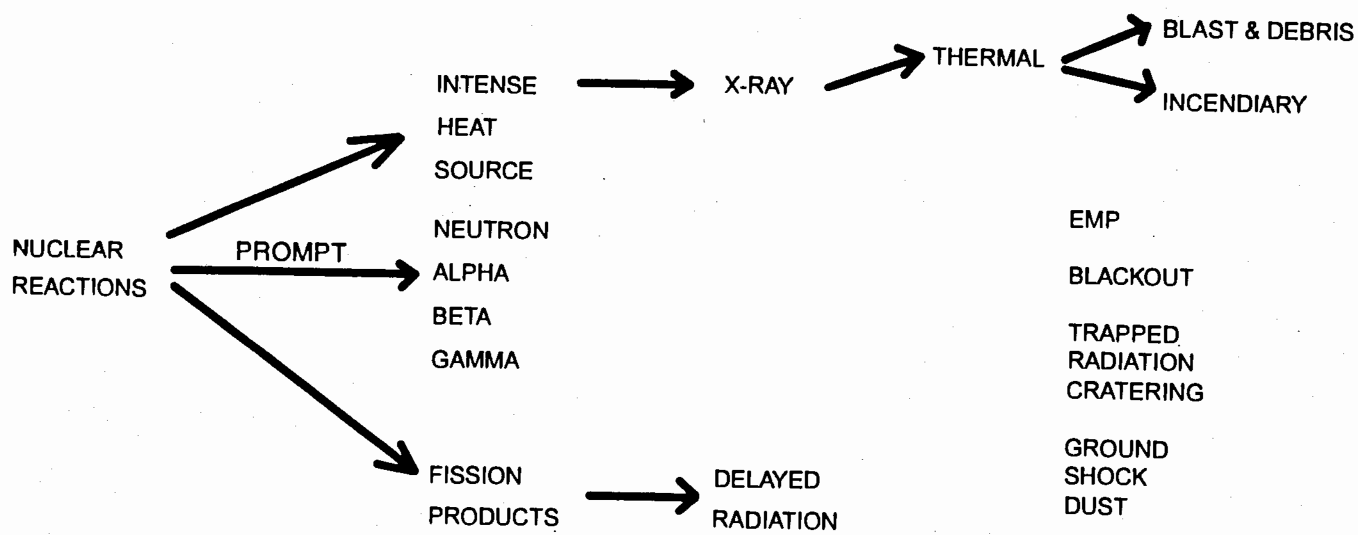
CONVENTIONAL WEAPON

NUCLEAR WEAPON



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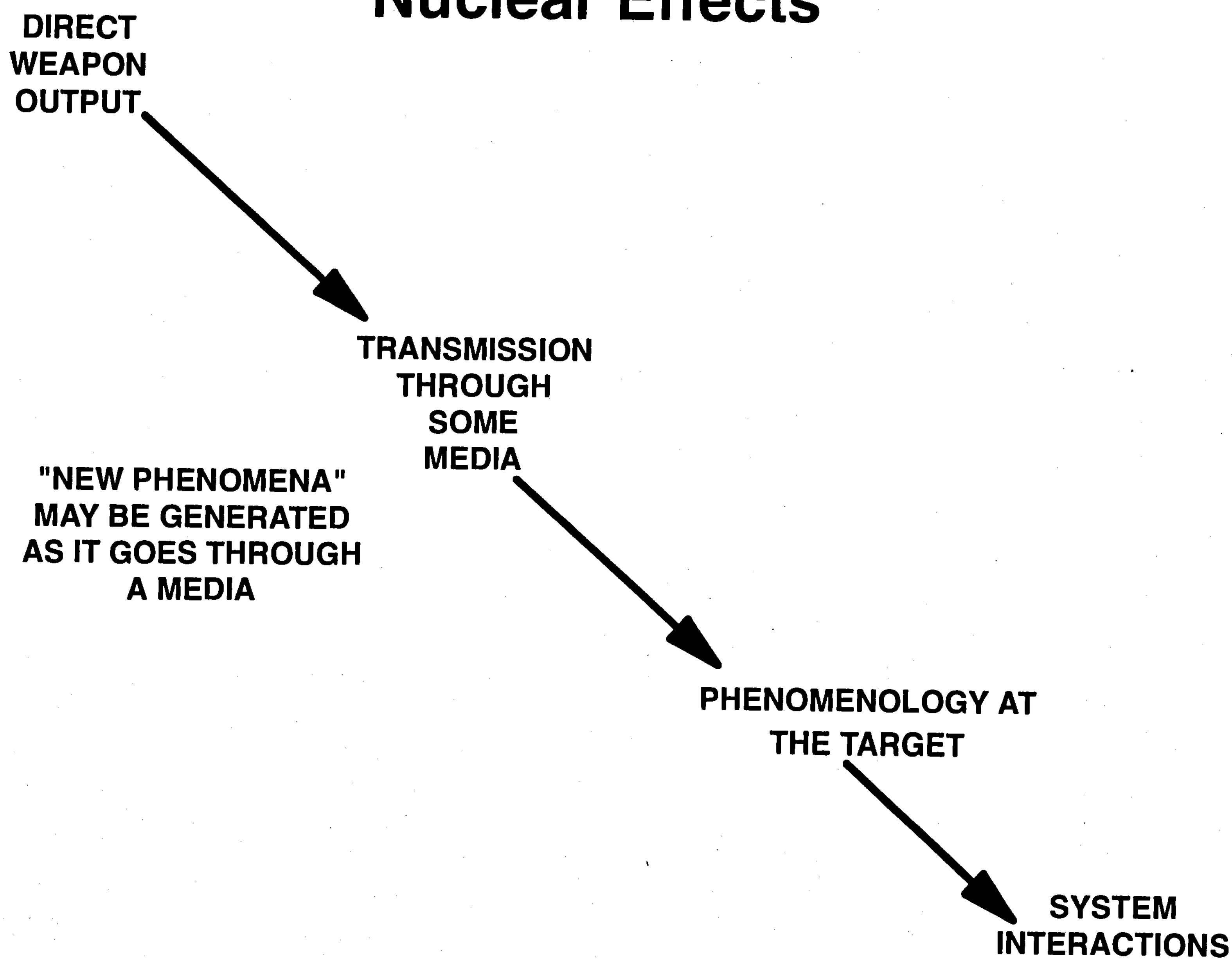
Nuclear Effects



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THE NUCLEAR PHENOMENOLOGY EXPERIENCED BY A SYSTEM DEPENDS ON:

- YIELD OF WEAPON
- DESIGN OF WEAPON
- WHERE WEAPON WAS DETONATED
- WHERE SYSTEM IS
- FOR SOME EFFECTS, WHAT SYSTEM IS DOING

NEUTRONS COME DIRECTLY FROM

FISSION

N + FISSIONABLE MATERIAL $\rightarrow$ TWO OR MORE FISSION FRAGMENTS + NEUTRONS + ENERGY

AND

FUSION

$D + T \rightarrow H_e^4$ + NEUTRON + ENERGY

$T + T \rightarrow H_e^4$ + 2 NEUTRONS + ENERGY

$D + D \rightarrow H_e^3$ + NEUTRON + ENERGY

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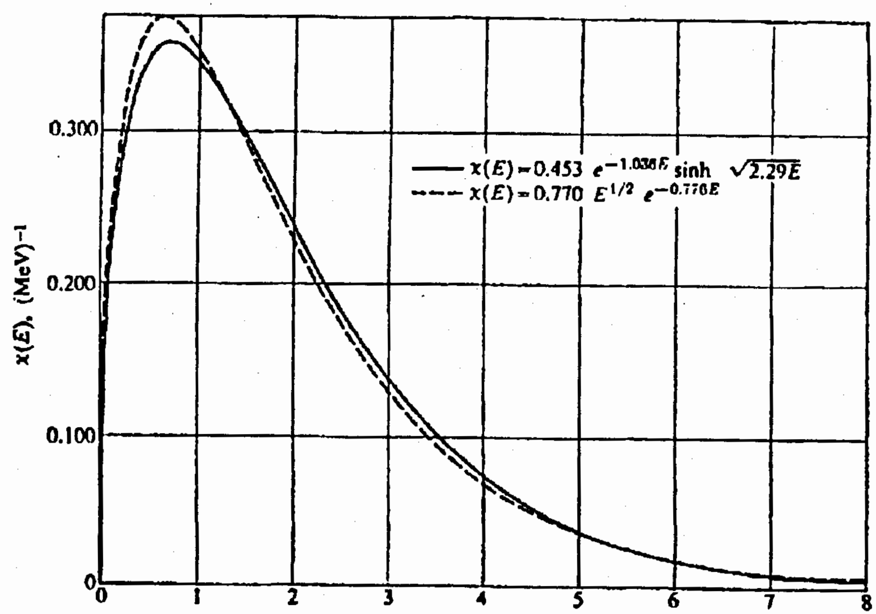
Fission Neutron Energy Spectrum



Neutron Energy (MeV)

Reference: Lamarsh, 1966

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X - RAYS

- ELECTROMAGNETIC RADIATION
- SOURCE - T^4 RADIATION FROM THE DEVICE
- USUALLY 70 TO 80% OF PROMPT ENERGY

DoE b(3)

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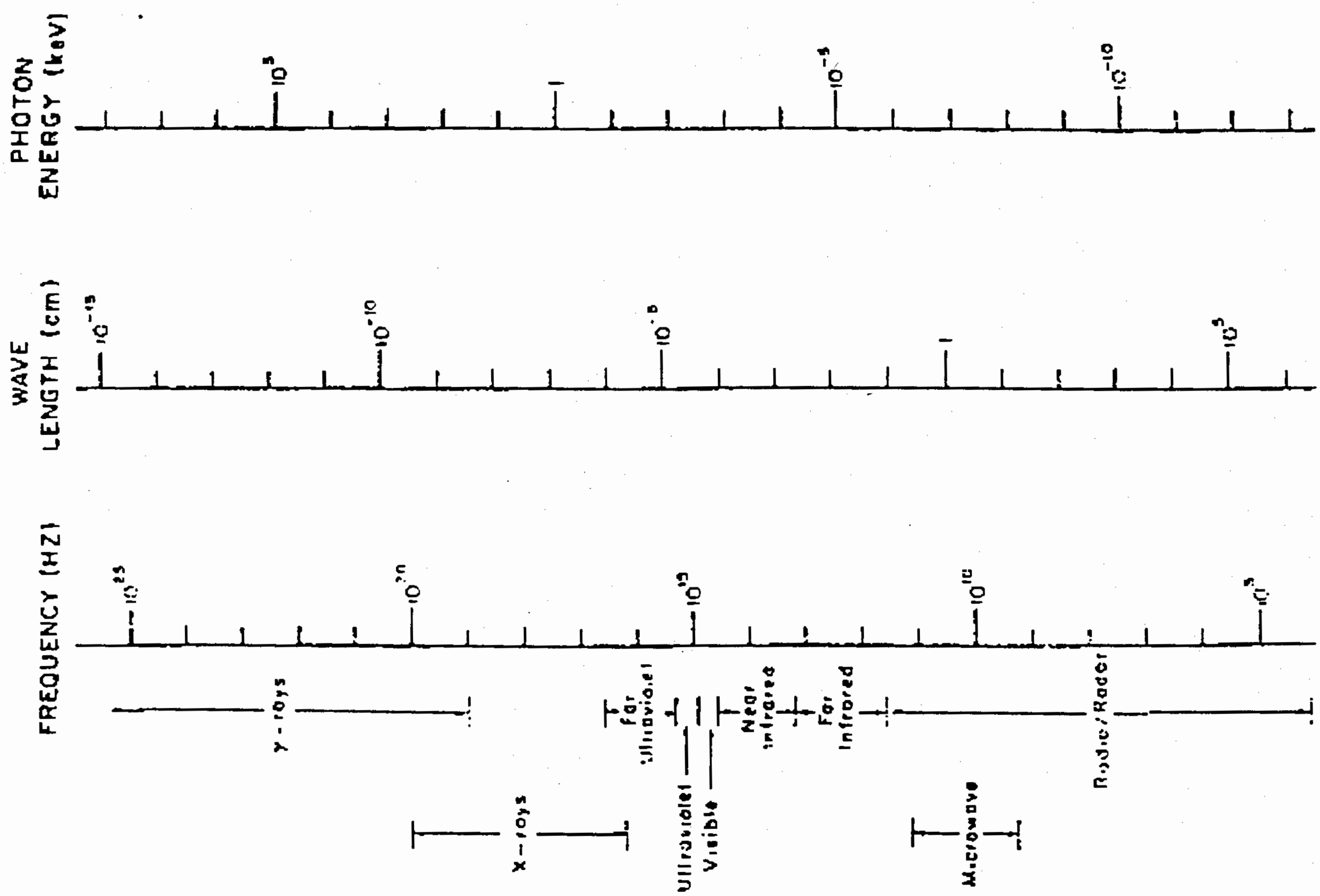

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Blackbody

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DOE b(3)

GAMMA RAYS

ELECTROMAGNETIC RADIATION

SOURCE:

- DETONATION FISSIONS

EARLY

- NEUTRON INELASTIC SCATTER IN WEAPON DEBRIS

- NEUTRON INELASTIC SCATTER IN THE AIR AND GROUND

LATER - CAPTURE OF SLOW NEUTRONS BY NITROGEN

- FISSION PRODUCT DECAY

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DOE b(3)

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BLAST AMD THERMAL

IT'S HOT, HOT,----
SO IT RADIATES HEAT

THERE'S HIGH, HIGH, HIGH PRESSURE----
SO IT TRANSMITS A PRESSURE PULSE

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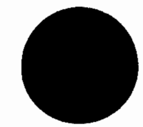
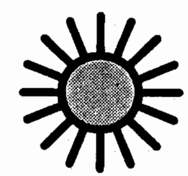
SEQUENCE OF EVENTS AFTER A NUCLEAR DETONATION IN THE ATMOSPHERE

1. ONCE UPON A TIME THERE WAS A NUCLEAR WEAPON--NOW THERE'S THIS 10 MILLION PLUS DEGREE BLOB OF VAPORIZED MATERIAL OCCUPYING ROUGHLY THE SAME VOLUME (78% OF ENERGY IS IN X-RAY).



2. THIS VOLUME RADIATES ELECTROMAGNETIC ENERGY IN THE X-RAY SPECTRUM.



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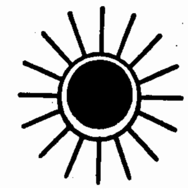
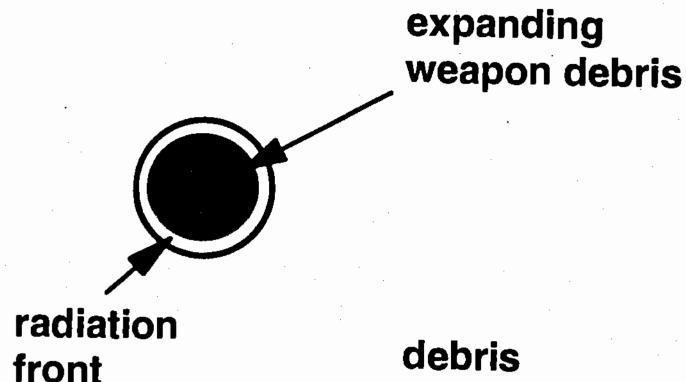
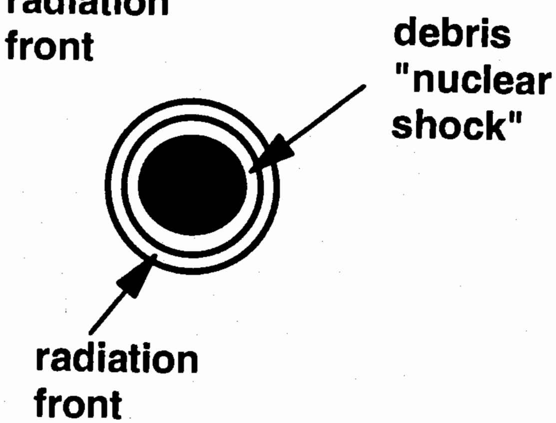
3. THE MEAN FREEPATH OF "X-RAYS" IS .3 cm AT SEALEVEL. THE SURROUNDING LAYER OF AIR IS SUPERHEATED. INITIAL X-RAY FIREBALL



4. THIS ABSORPTION AND RERADIATING PROCESS RESULTS IN A RAPIDLY EXPANDING RADIATION FIREBALL. RADIATION GROWTH PHASE.



5. THE WEAPON DEBRIS SNOWPLOWS AIR AND A "NUCLEAR SHOCK" IS FORMED. RADIATION FIREBALL CONTINUES TO GROW, BUT GROWTH SLOWS BECAUSE COOLING REDUCES MFP.



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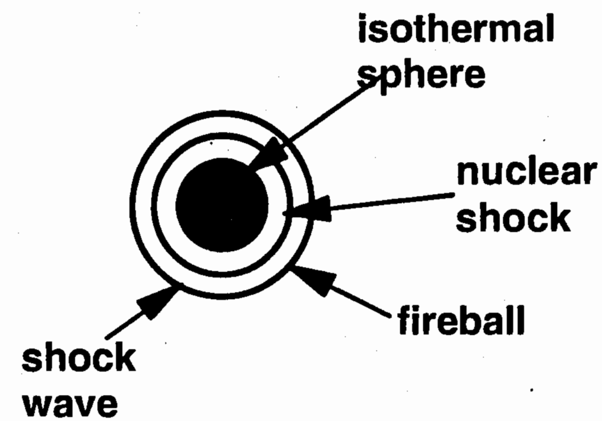
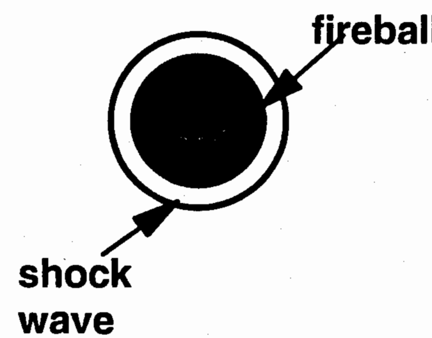
6.

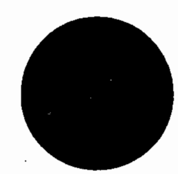
SHOCKWAVE ASSOCIATED WITH THE FRONT BECOMES DOMINANT. NUCLEAR SHOCK STARTS TO "CATCH-UP." <u>HYDRODYNAMIC SEPARATION</u>



7. NUCLEAR SHOCK CATCHES UP, BUT REINFORCED SHOCKWAVE COOLS TO 3,000 DEGREES CELCIUS AND STARTS TO BECOME TRANSPARENT. <u>SHOCK BREAKAWAY.</u>



8. NO FURTHER INTERACTION BETWEEN EXPANDING SHOCKWAVE AND FIREBALL.



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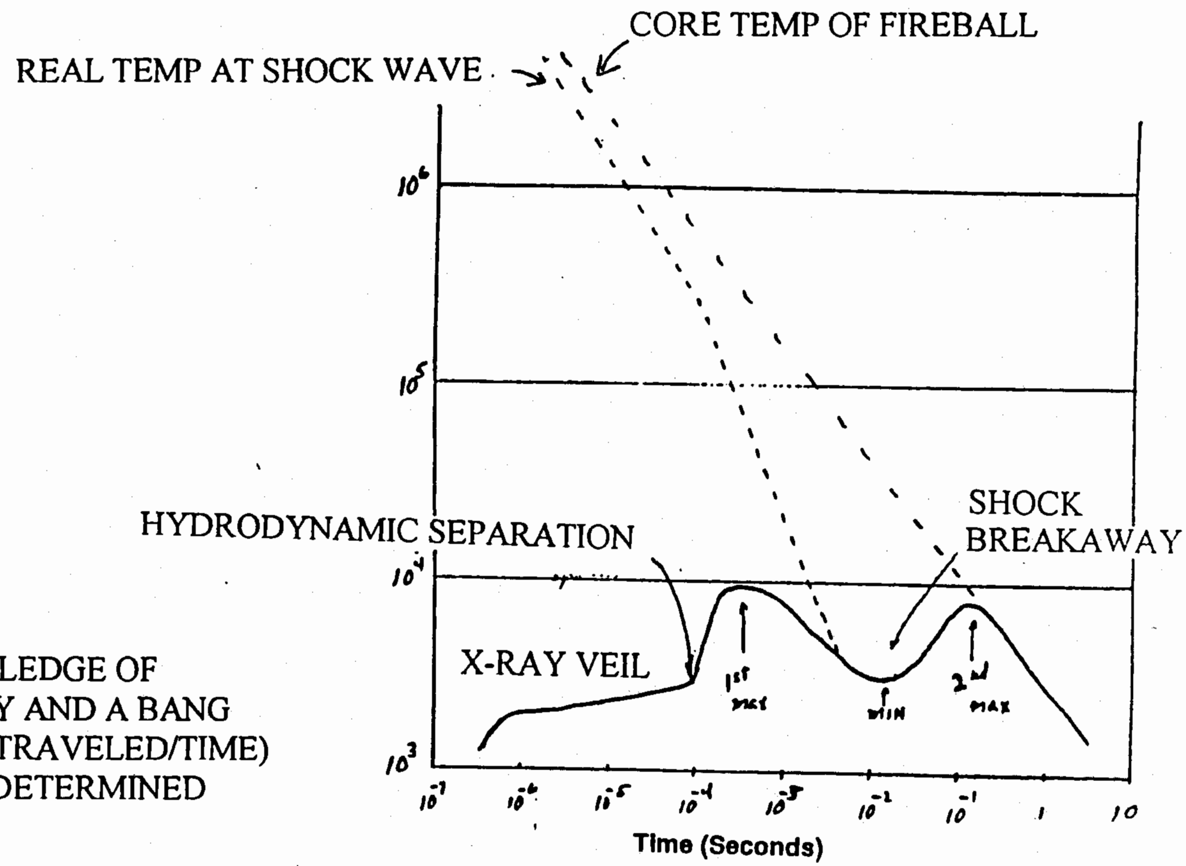
THERMAL Observed Thermal Pulse



USE: FROM A KNOWLEDGE OF SHOCK BREAKAWAY AND A BANG METER (DISTANCE TRAVELED/TIME) THE YIELD CAN BE DETERMINED

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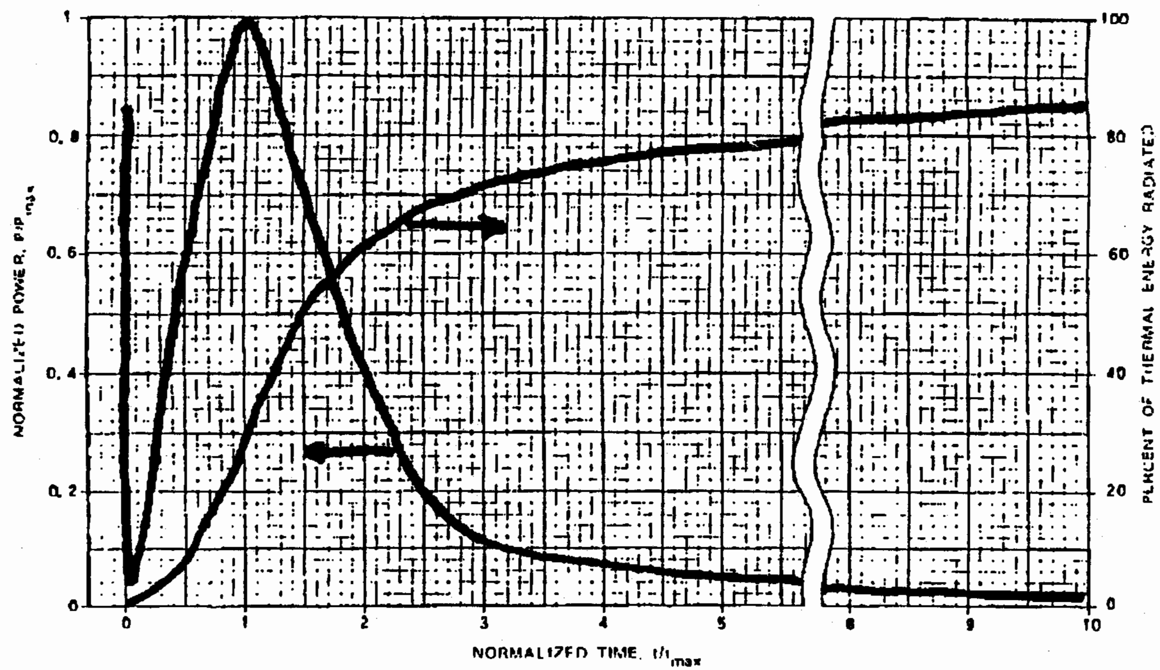
Power-Time and Energy-Time Curves for a 200 Kiloton Burst at 5000 ft



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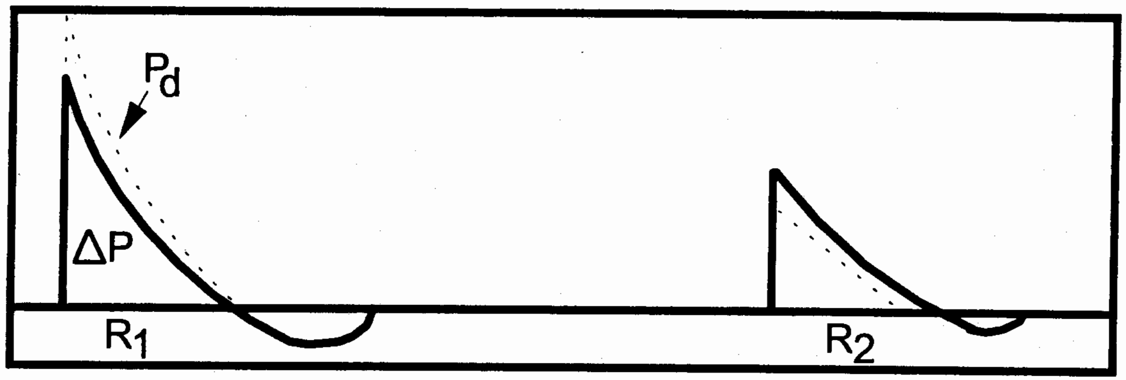
BLAST



$R_2 > R_1$

OVERPRESSURE $\Delta P = P - P_o$

DYNAMIC (GUST) $P_d = 1/2\ MV^2$

TIME DEPENDENCE

$P_d > \Delta P$ ($\Delta P > 100$ PSI)

$P_d < \Delta P$ ($\Delta P < 100$ PSI)

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AWAY FROM SOURCE AIRBLAST

SCALABLE PHENOMENA — SACH'S SCALING $\left[\frac{D_1}{D_0}\right] = \left[\frac{W_1}{W_0}\right]^{1/3}$

BASIS IS COMPLETE DATA FOR 1 CASE EX: 1 KT STANDARD

FOR ALTITUDES OTHER THAN SEA LEVEL $\left[\frac{D_1}{D_0}\right] = \left[\frac{W_1}{W_0}\right]^{1/3} \left[\frac{P_0}{P}\right]^{1/3}$

OTHER IMPORTANT ASPECTS:

- MACHSTEM AND TRIPLE POINT PATH
- OPTIMAL HOB FOR MAXIMIZING OVERPRESSURE
- PRECURSOR

WILL BE COVERED LATER AND IN THE EFFECTS MOVIE

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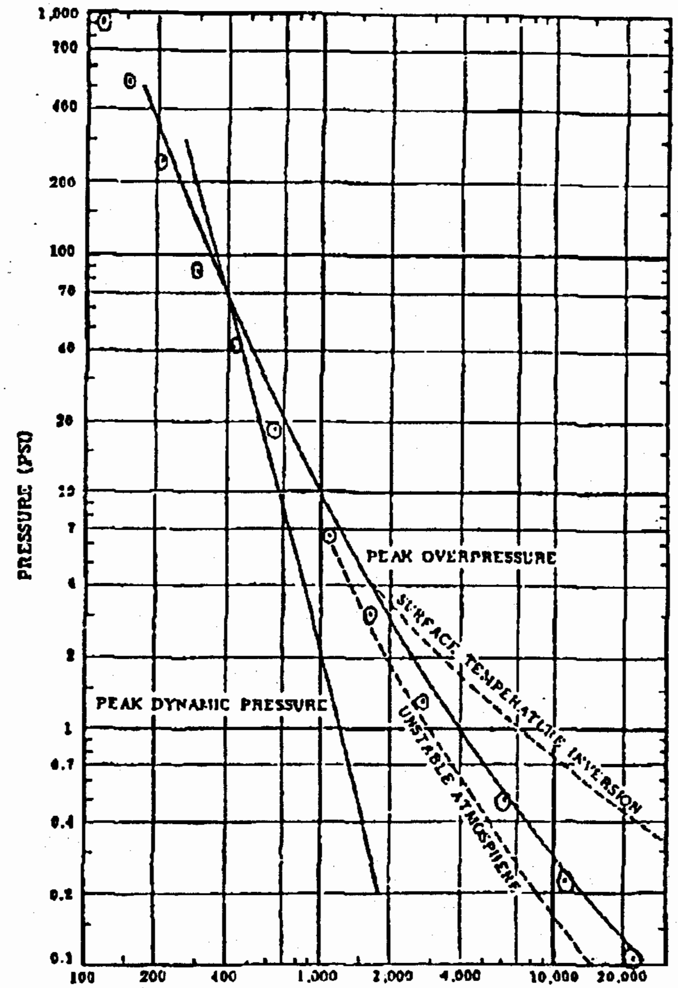
⊙ = Data from AFWL - TR 73-75



Distance from Ground Zero (feet)
1 Kiloton Standard (from Glasstone)

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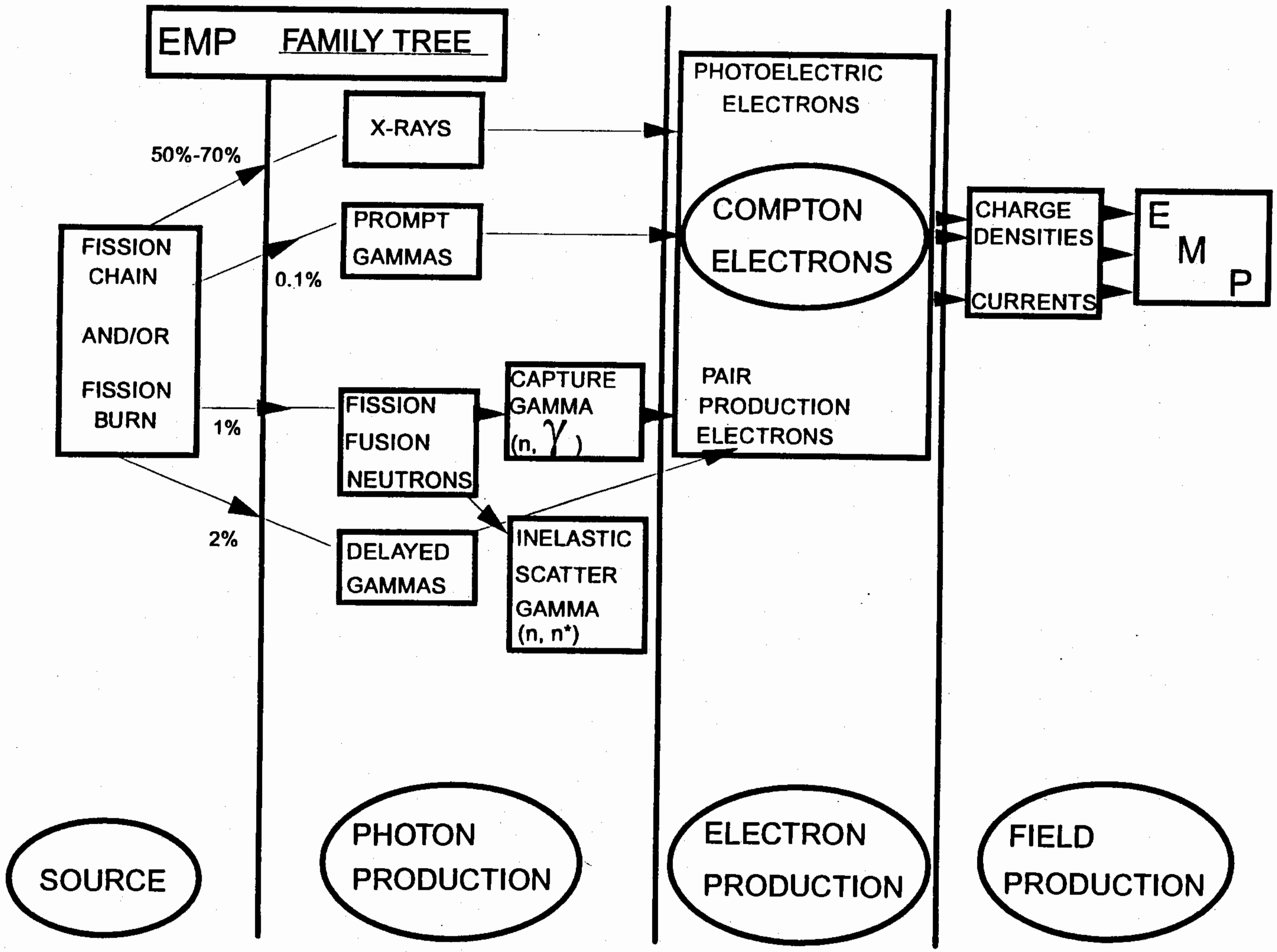

Bottom Line: electron moves in assymetric field

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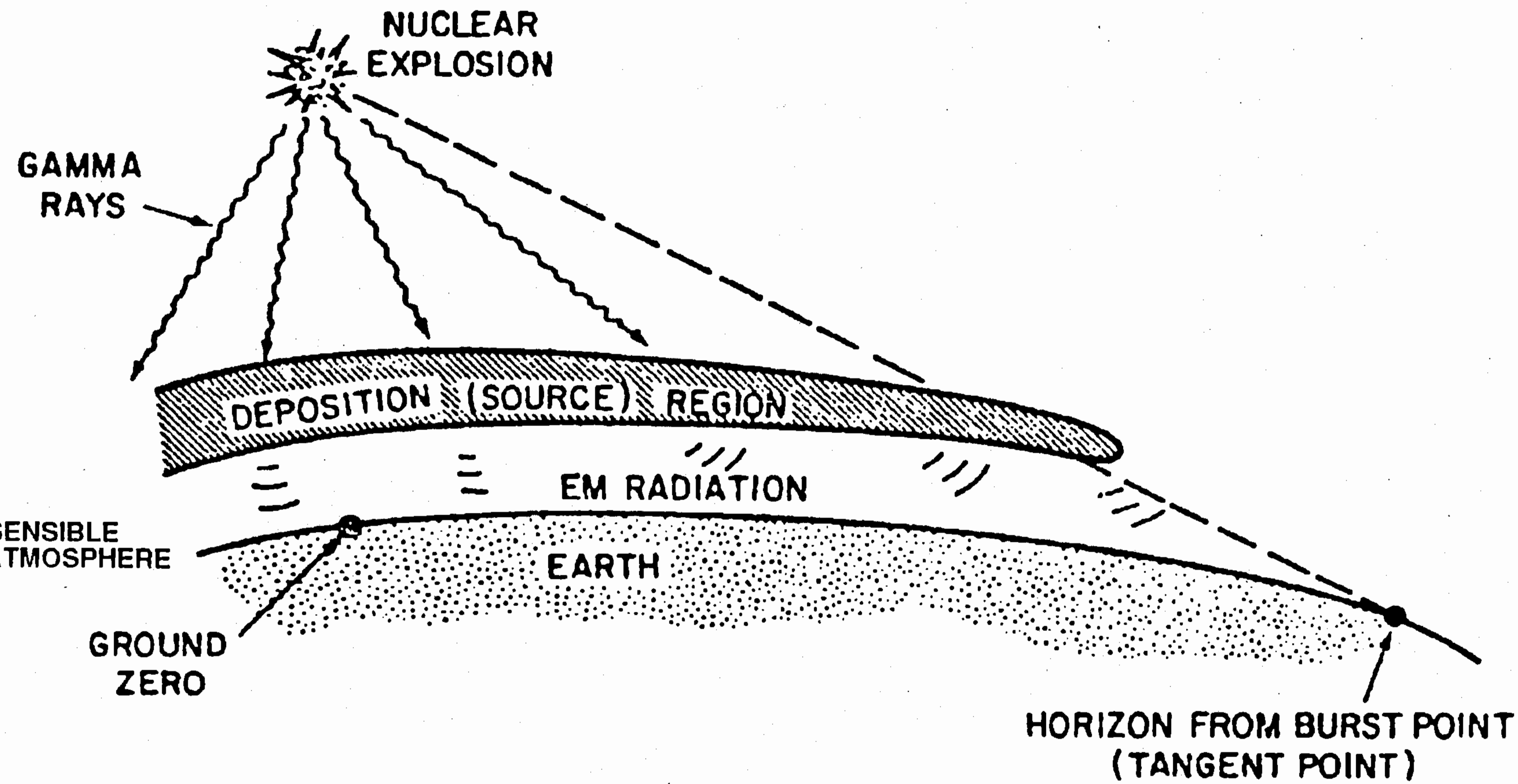
[redacted] UNCLASSIFIED

High Altitude EMP



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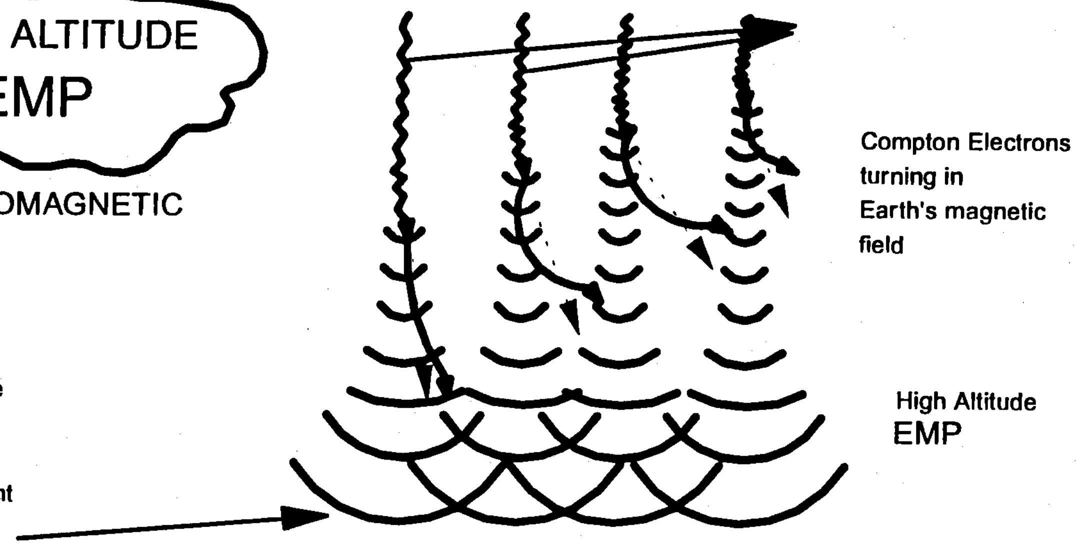
HIGH ALTITUDE EMP

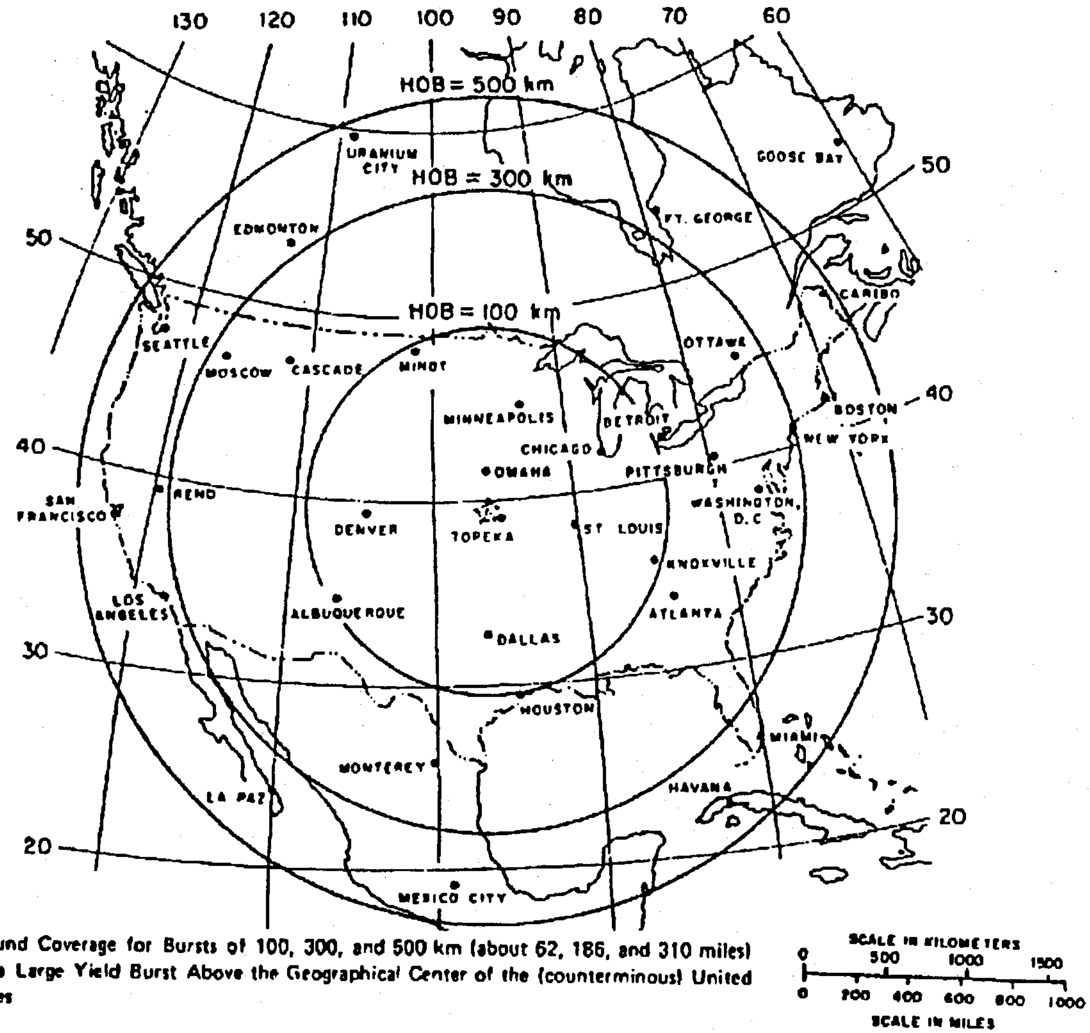
ELECTROMAGNETIC PULSE



KEY Points

1. Each γ gives a downward traveling compton electron.
2. The electrons are turned by the earth's magnetic field.
3. The realistic electrons radiate energy downward.
4. The γ's and EMP radiation travel at the same speed.
   This leads to constructive interference of radiation from all electrons.

EMP PULSE



Ground Coverage for Bursts of 100, 300, and 500 km (about 62, 186, and 310 miles) for a Large Yield Burst Above the Geographical Center of the (counterminous) United States

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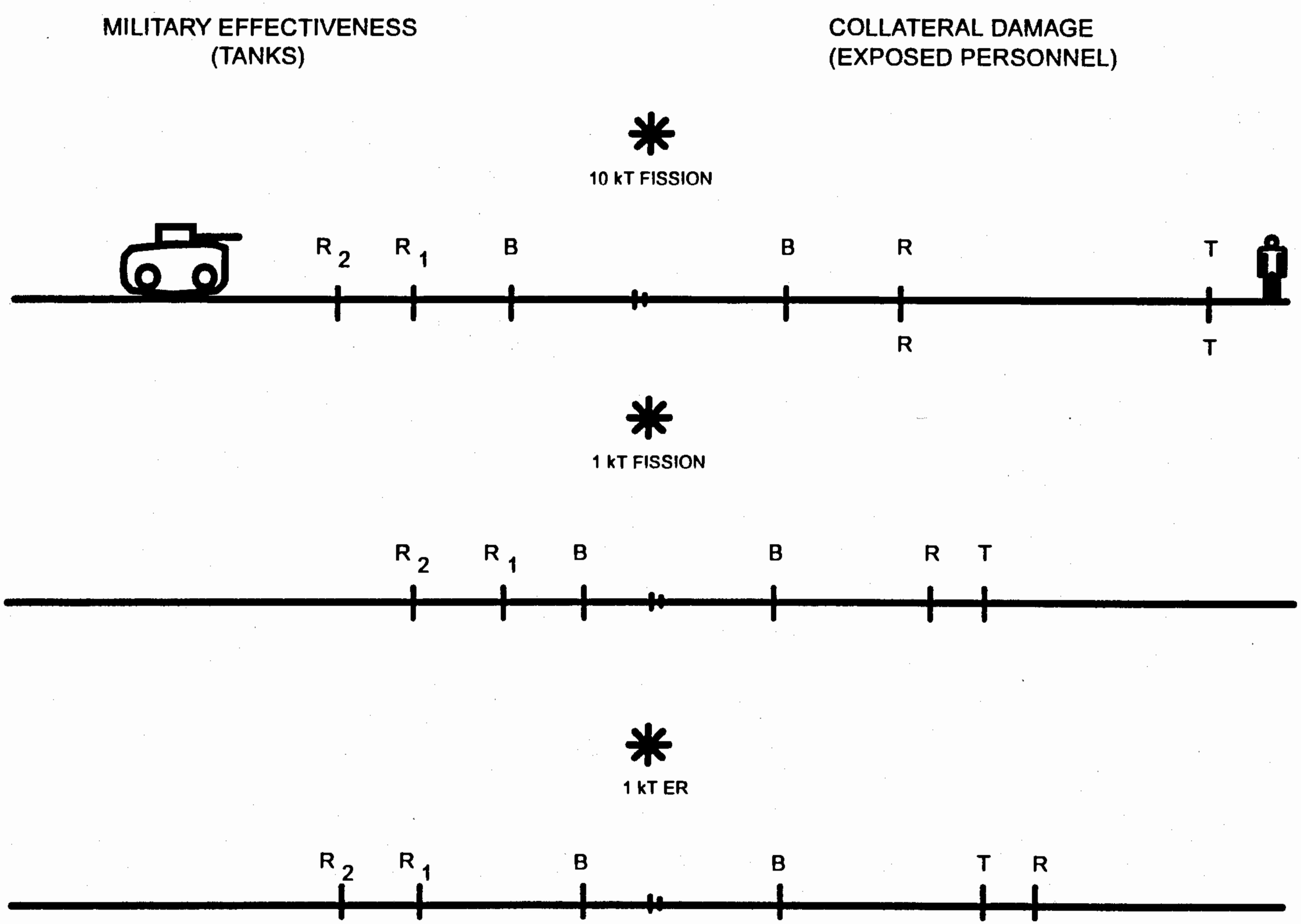
MILITARY EFFECTIVENESS
(TANKS)
COLLATERAL DAMAGE
(EXPOSED PERSONNEL)
10 kT FISSION
R 2
R 1
B
B
R
T
R
T
1 kT FISSION
R 2
R 1
B
B
R
T
1 kT ER
R 2
R 1
B
B
T
R

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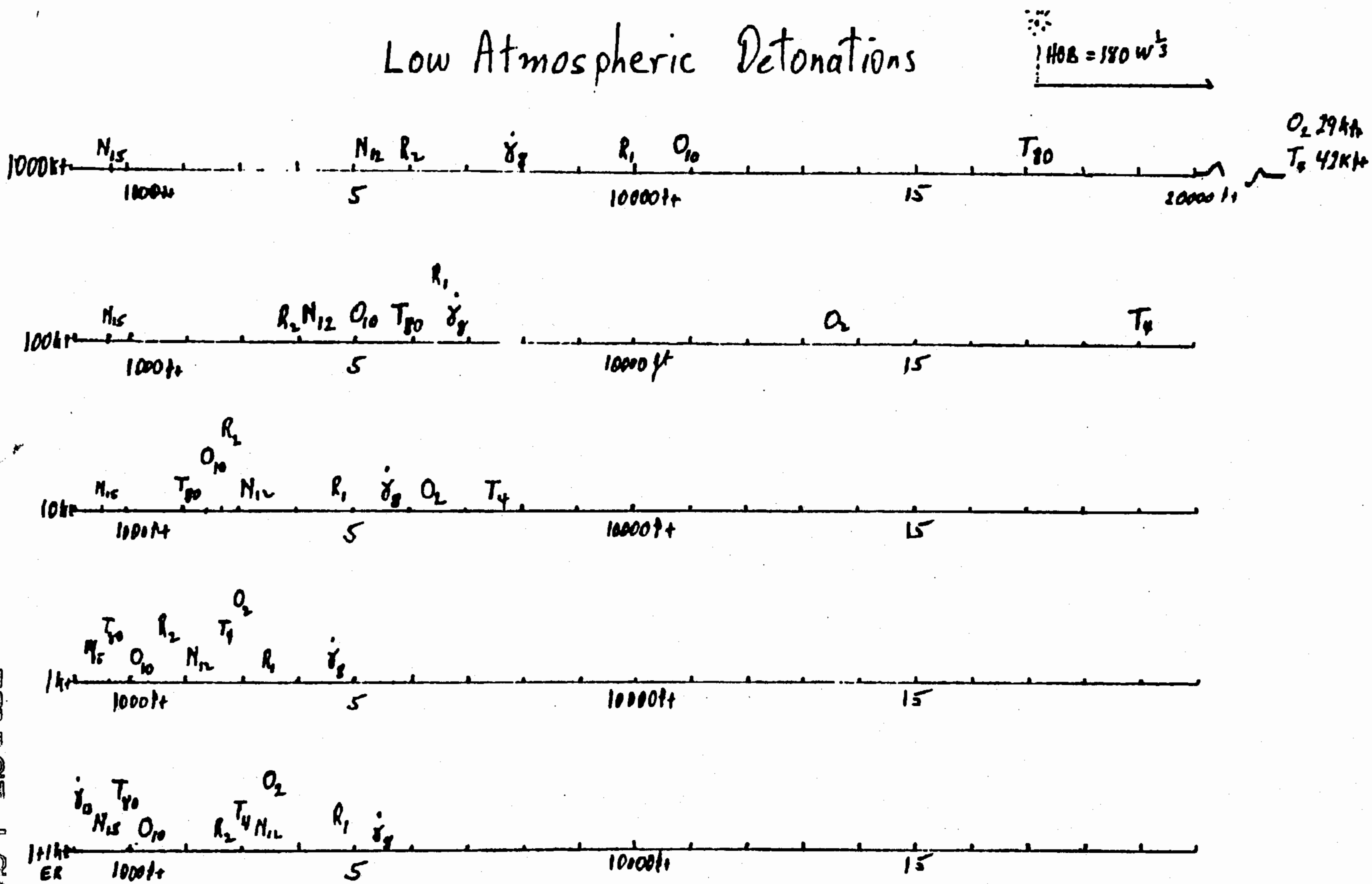
Low Atmospheric Detonations



$N_{12} = 10^{12}\ n/cm^2$ $\quad \dot{\gamma}_8 = 10^8\ rads/sec$ $\quad T_4 = 4\ cal/cm^2$ $\quad O_2 = 2\ psi$ $\quad R_1 = 350\ rads$

$N_{15} = 10^{15}\ n/cm^2$ $\quad \dot{\gamma}_{13} = 10^{13}\ rads/sec$ $\quad T_{80} = 80\ cal/cm^2$ $\quad O_{10} = 10\ psi$ $\quad R_2 = 13000\ rads$

$O_{3000} = 3000\ psi$

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1 MT DETONATIONS AT VARIOUS HOB's (CO-Altitude)

	N 10^{12} n/cm^2	N 10^{15} n/cm^2	$\dot{\gamma}$ 10^8 rad/sec	$\dot{\gamma}$ 10^{13} rad/sec	X-ray 20 cal/cm^2	X-ray 130 cal/cm^2	Thermal 4 cal/cm^2	Thermal 80 cal/cm^2	Over 2 psi	Over 10 psi	Over 3000 psi
Exoatmospheric	157	5.6	760	2.4	56.8	22.2	-----	-----	-----	-----	-----
100,000 ft	12.5	5.5	190	2.3	10.4	6.0	98	22	8.5	4.6	.7
1,800 ft	6.2	2.5	9.0	1.3	-----	-----	49	19	29.5	10.8	.8
Surface	5.6	2.3	8.5	1.3	-----	-----	40.4	12.1	25	10	1.1

Distances to Effect Levels in kilo-feet

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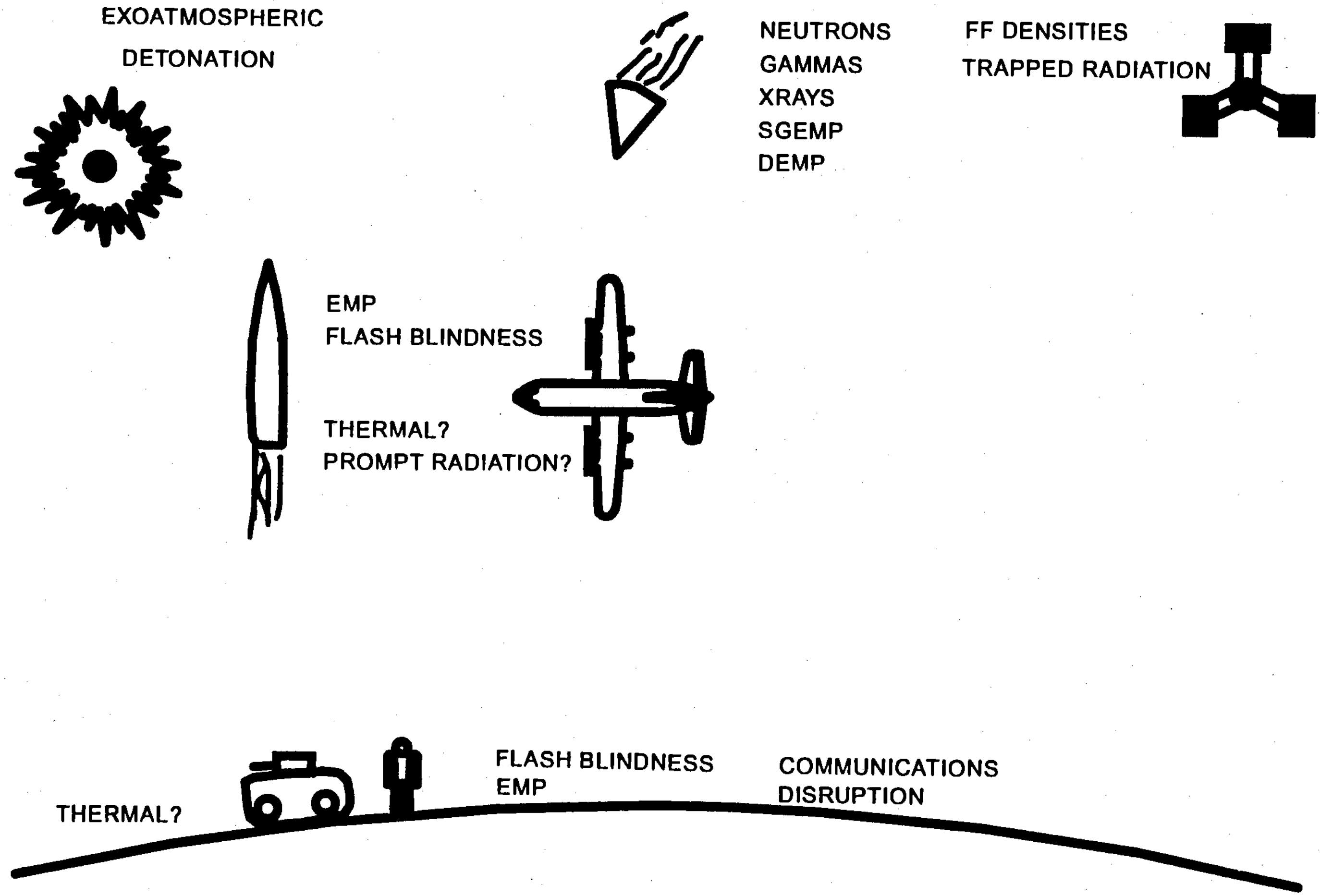
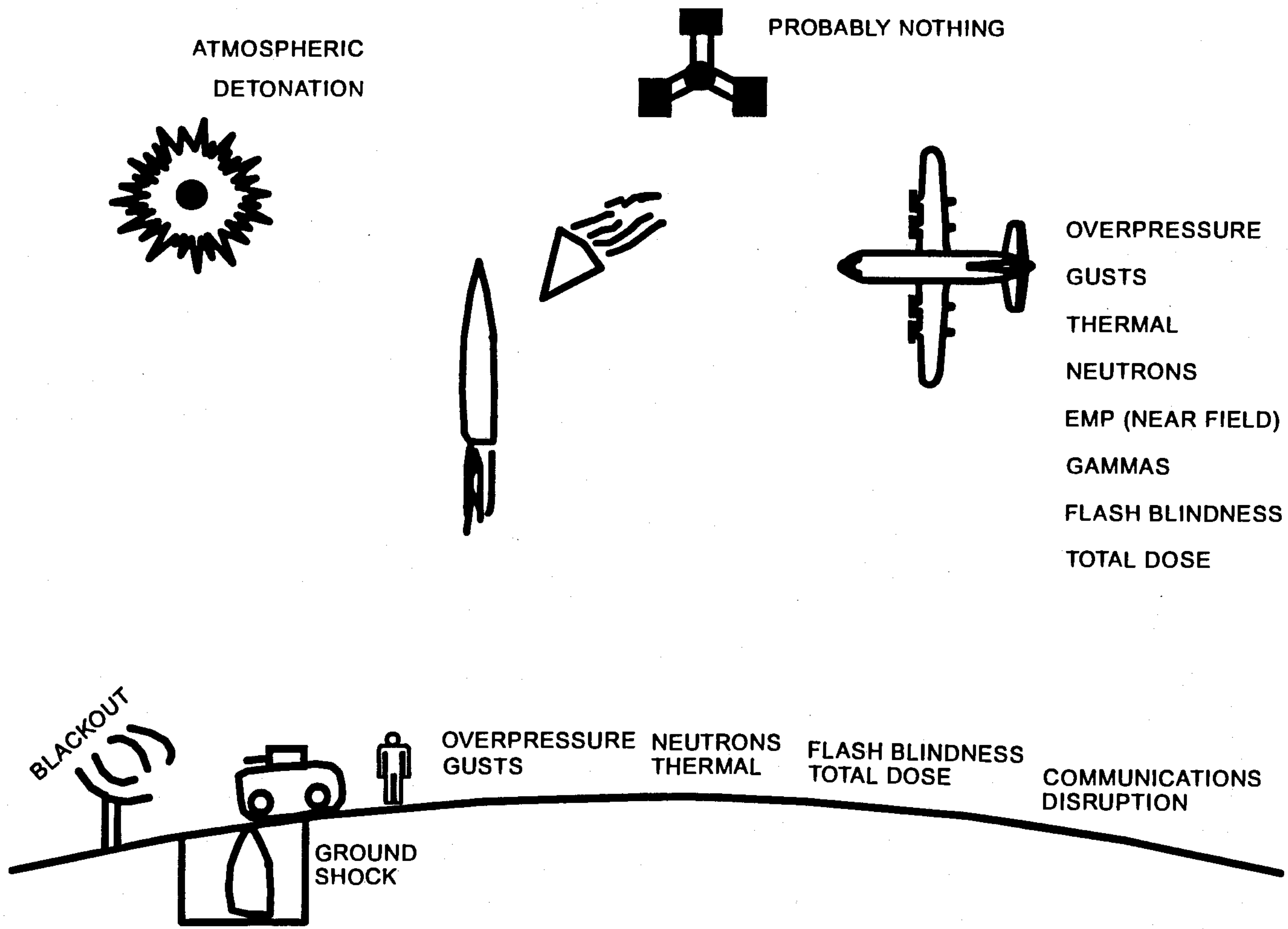

EXOATMOSPHERIC
DETONATION
NEUTRONS
GAMMAS
XRAYS
SGEMP
DEMP
FF DENSITIES
TRAPPED RADIATION
EMP
FLASH BLINDNESS
THERMAL?
PROMPT RADIATION?
THERMAL?
FLASH BLINDNESS
EMP
COMMUNICATIONS
DISRUPTION

SECRET UNCLASSIFIED



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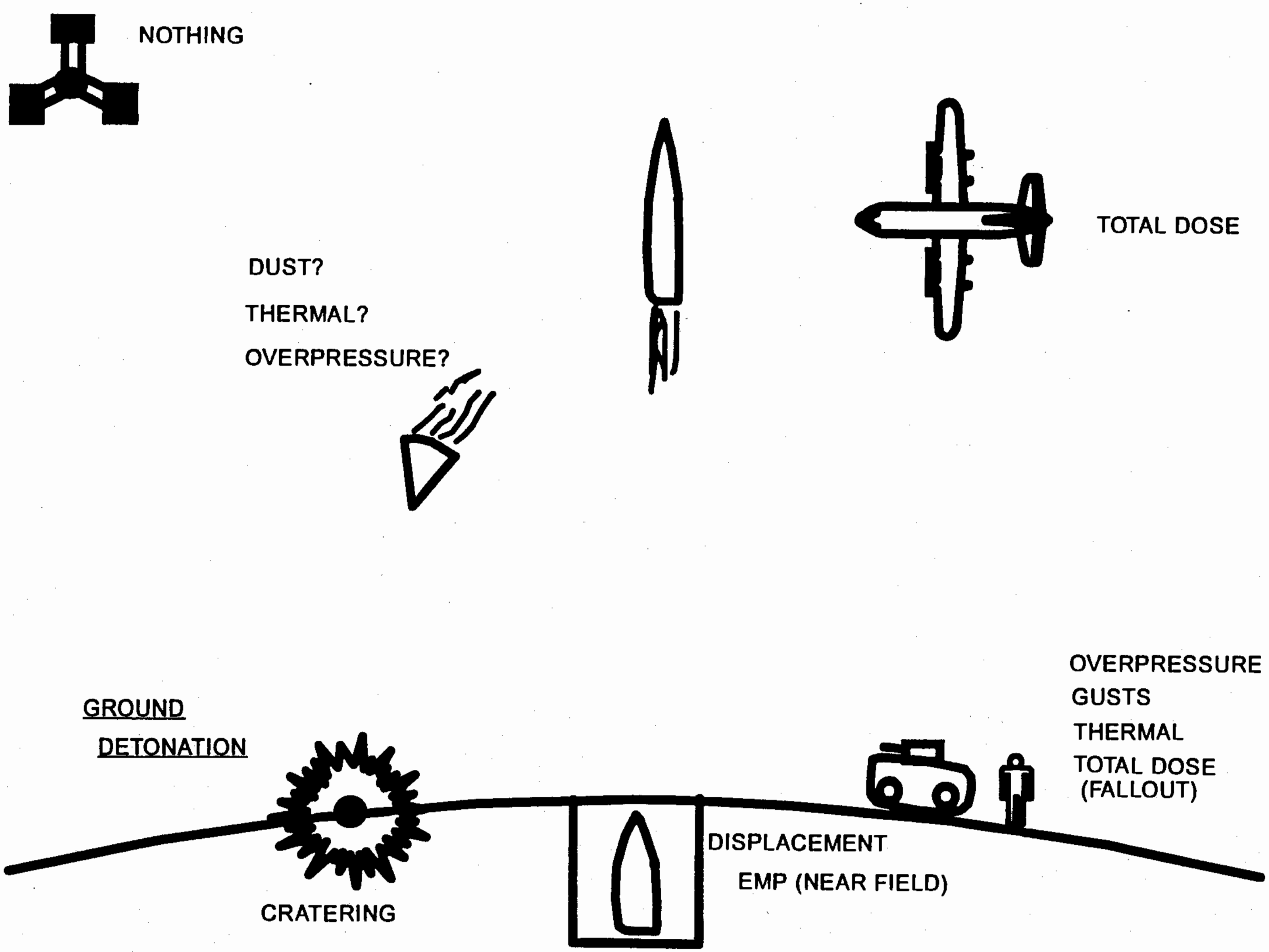
NOTHING
DUST?
THERMAL?
OVERPRESSURE?
TOTAL DOSE
GROUND
DETONATION
CRATERING
DISPLACEMENT
EMP (NEAR FIELD)
OVERPRESSURE
GUSTS
THERMAL
TOTAL DOSE
(FALLOUT)

SOME EFFECTS LEVELS OF INTEREST

PEOPLE		SATELLITES
THERMAL	2-5 CAL/CM^2	
OVERPRESSURE	>7 PSI	
RADIATION	>100 RADS	

Nuclear Targeting

- Through intelligence data, the targets have a vulnerability number associated with it that allows the DoD to assign a weapon.
- Vulnerability Number (VN)

  XXPA   XXQA

  First 2 digits are related to the amount of pressure:
  - P = over pressure (smash)
  - Q = dynamic pressure (winds)
  - A = adjustment for yield (tables geared to 20 KT)
- A typical VN:

  Airfield = 12 P0 ~ 10 psi

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REFERENCES

- THE EFFECTS OF NUCLEAR WEAPONS 3RD EDITION, GLASSTONE AND DOLAN, 1977, <u>UNC</u>

- CAPABILITIES OF NUCLEAR WEAPONS, DNA EM-1 PARTS I & II, SRD RS-3141 8798

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION IV

- HIGH EXPLOSIVES
- DETONATORS

PRIMARY	SECONDARY
•EASILY IGNITED WITH QUICK TRANSITION TO DETONATION	•INSENSITIVITY
	•HIGH ENERGY DENSITY
•SMALL QUANTITY REQUIRED	

PHYSICAL SEPARATION - TETRYL

Material[a]	Chemical name	Other designations	Color
*BTF	Benzotris-[1,2,5] oxadiazole-[4,4,7]-trioxide	Benzotrifuroxan, hexanitrosobenzene	Buff
*DATB	1,3-Diamino-2,4,6-trinitrobenzene		Yellow
*DIPAM	3,3-Diamino-2,2',4,4',6,6'-hexanitrobiphenyl	Hexanitrodiphenyl-amine hexite, dipicrylamine	—
*DNPA	2,2-Dinitropropyl acrylate		Off-white
*EDNP	Ethyl-4,4-dinitropentanoate		Yellow
*FEFO	Bis(2-fluoro-2,2-dinitroethyl)-formal		Straw
**HMX	1,3,5,7-Tetranitro-1,3,5,7-tetraazacyclooctane	Cyclotetramethylene tetranitramine, octogen	White
*HNAB	2,2',4,4',6,6'-Hexanitroazo-benzene		Orange
*HNS	2,2',4,4',6,6'-Hexanitrostilbene		Yellow
**NC (12% N)[b]	Partially nitrated cellulose	Nitrocellulose (lacquer grade), cellulose trinitrate, piroksilin	White
*NC (13,35% N, min)[b]	Partially nitrated cellulose	Nitrocellulose, guncotton	White
*NG	1,2,3-Propanetriol trinitrate	Nitroglycerin	Clear
*NM	Nitromethane		Clear
*NQ	Nitroguanidine	Aminomethaneamidine	White
**PETN	Pentaerythritol tetranitrate	Penthrite, TEN	White
**RDX	1,3,5-Trinitro-1,3,5-triaza-cyclohexane, hexahydro-1,3,5-trinitro-s-triazine	Cyclotrimethylene trinitramine, hexogen cyclonite,Gh	White
*TACOT	Tetranitro-1,2,5,6-tetraazadi-benzocyclooctatetrene	Tetranitrodibenzo-1,3a,4,6a-tetraazapentalene	Red-orange
**TATB	1,3,5-Triamino-2,4,6-trinitro benzene		Bright yellow
**Tetryl	2,4,6-Trinitrophenylmethyl-nitramine		Yellow
**TNM	Tetranitromethane		Clear
**TNT	2,4,6-Trinitrotoluene	Trotyl,T,tol	buff to brown

**Denotes it has been used in nuclear weapons

Cast explosives: names and formulations.

Explosive[a]	Formulation (wt%)[b]			
	TNT	RDX	Other ingredients	
Baratol	24		$Ba(NO_3)_2$	76
Boracitol	40		Boric Acid	60
*Comp B, Grade A[c]	36	63	Wax	1
Comp B-3	40	60		
*Cyclotol[d]	25	75		
H-6	30	45	Wax	5
			Al	20
			$CaCl_2$	0.5
*Octol	25		HMX	75
*Pentolite[d]	50		PETN	50
Tritonal	80		Al	20

[a]Properties of materials marked with asterisks are summarized in data sheets (Section IV).

[b]The weight percent values given in the table are nominal and subject to some variation.

[c]Comp B, Grade A is formulated as a 60/40 RDX/TNT mixture, but high-quality castings usually are higher in RDX content due to the removal of a TNT-rich section at the top of the casting.

[d]There are several cyclotols and pentolites. The most common cyclotol is RDX/TNT 75/25. The most common pentolite is PETN/TNT 50/50.

Plastic-bonded explosives: Names and formulations.

Explosive[a]	Other ingredients	Formulation: Ingredient	wt%	Color
*LX-04-1	PBHV-85/15	HMX	85	Yellow
		Viton A	15	
*LX-07-2	RX-04-BA	HMX	90	Orange
		Viton A	10	
*LX-09-0	RX-09-CB	HMX	93	Purple
		pDNPA	4.6	
		FEFO	2.4	
LX-09-1		HMX	93.3	Purple
		pDNPA	4.4	
		FEFO	2.3	
*LX-10-0	RX-04-DE	HMX	95	Blue-green spots on white
		Viton A	5	
LX-10-1		HMX	94.5	Blue-green spots on white
		Viton A	4.5	
*LX-11-0	RX-04-PI	HMX	80	White
		Viton A	20	
*LX-14-0		HMX	95.5	Violet spots on white
		Estane 5702-FI		4.5
*PBX-9007	PBX-9007 Type B	RDX	90	White or mottled gray[b]
		Polystyrene	9.1	
		Di(2-ethylhexyl)-phthalate	0.5	

Plastic-bonded explosives: Names and formulations. (cont.)

		Formulation		
		Rosin	0.4	
*PBX-9010		RDX	90	White
		Kel-F	10	
*PBX-9011	X-0008	HMX	90	Off-white
		Estane 5740-X2		
*PBX-9205		RDX	92	White
		Polystyrene	6	
		Di(2-ethyl-hexyl)-phthalate	2	
*PBX-9404	PBX-9404-03	HMX	94	White or blue
		NC (12.0% N)	3	
		Tris (B-chloro-ehtyl)-phosphate	3	
*PBX-9407		RDX	94	White or black[b]
		Exon 461		6
*PBX-9501		HMX	95	White
		Estane	2.5	
		BDNPA	1.25	
		BDNPF	1.25	
PBX-9502		TATB	.05 Kel F	
LX-17		TATB	.075 Kel F	

DoE
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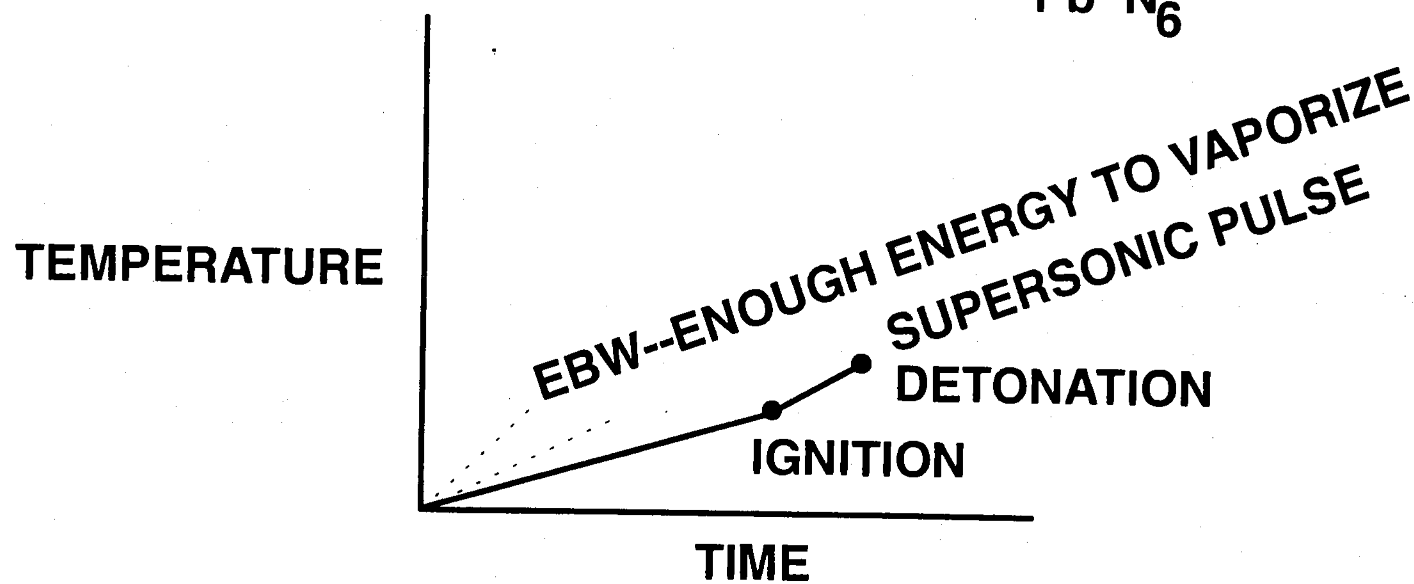
LEAD AZIDE
$Pb\ N_6$



EBW (EXPLODING BRIDGEWIRE) EVOLVED

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DoE
b(3)

[redacted] UNCLASSIFIED

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[redacted] UNCLASSIFIED

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REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED; GLASSTONE, JUNE 1972
- PROPERTIES OF CHEMICAL EXPLOSIVES AND EXPLOSIVE SIMULANTS; LLL JULY 31, 1974, DOBRATZ UCRL - 51319, REV 1
- SENSITIVITY OF INITIATION-SYSTEM DETONATORS: REVIEW OF CURRENT AND ADVANCED TECHNOLOGIES; R. E. SETCHELL; SAND91-1590

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SESSION 5

THIS SECTION WILL BE MADE AVAILABLE FOR USE DURING THE CLASS PERIOD ONLY.

REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED, GLASSTONE, JUNE 1972
- SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE, 3rd EDITION
- NUCLEAR TEST SUMMARY TRINITY — HARDTACK DASA 1220; RS3141/10349
- VARIOUS WEAPON DEVELOPMENT REPORTS

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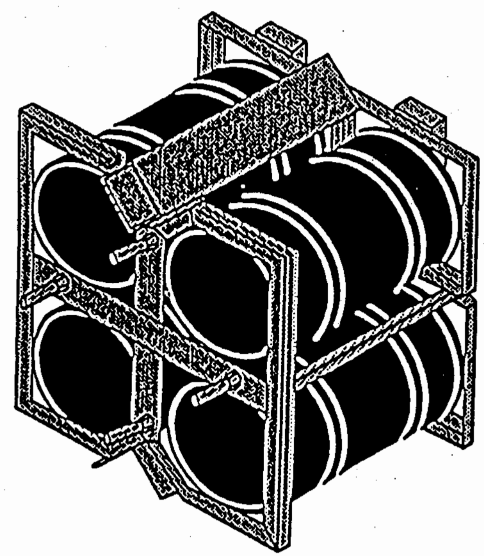
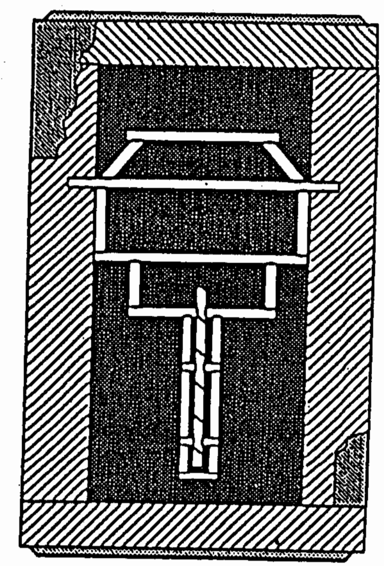
Project Stage Right Storage





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SNM Storage Problem

- Present Storage Magazines
  - Containers stored vertically in planar array
  - At present rate magazines full in March 1994
- Proposed Changes
  - Containers stored horizontally in multi-layers
  - Activate additional magazines
  - Problem Created
    - High radiation levels
    - Worker could receive yearly allowable dose in approximately one day
- Solution
  - Use machines to load, retrieve, and inventory

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MMSC Demilitarization/Sanitization

Part Nomenclature	Demilitarization	Sanitization	Render Safe	Method
Actuators/Squibs	Yes	No/Yes	Yes	Fire or explosive disposal (Some Use Control items may require sanitization)
Connectors	No	No/Yes	No	None (Unless Rad hardening potting used, then sanitization required)
Detonators and Cable Assemblies	Yes	Yes	Yes	Fire - Shred cable/crush header or explosive disposal (protect # info)
Foams, cushions, compression pads, desiccants, plastics, etc.	No	No/Yes	No	None (Shred, melt, or burn if show classified contours or shock mitigation info.)
Mechanical Hardware (O-rings, brackets, bolts, cover plates, rings, etc.	No	No	No	None (Part identifier removed if association makes classified)
Neutron Generator, Electronic	Yes	Yes	Yes	Crush (Remove rad tube?)
Neutron Generator, Explosive	Yes	Yes	Yes	Fire (mixed waste) or timer driver to explosive disposal/tube to rad waste
Reservoir	Yes	Yes	Yes	Bury (Remove rad material if appropriate)
Thermal Battery	Yes	No	Yes	Fire
Timers	No	No	No/Yes	None (Fire/Remove explosives if appropriate)
Use Control, PAL, CD Hardware	Yes	Yes	Yes	Expend, crush, shred, bury as appropriate

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Nuclear Material Storage/Disposal

- All pits put in interim storage
- Yet to determine ultimate fate of plutonium

- Secondaries under study
  - Portion to be stored
  - Portion to be disassembled into basic materials

DOE
b(3)

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Information Systems

- Developing database for material identification and characterization
- Compatible with each DOE design agency and production agency
- Allows Pantex to receive information electronically
- Allows each DA and PA to enter their desired data
- Replaces old scrapbook system at Pantex

DOE Dismantlement Policy
Component Retention, Reuse, or Evaluation

- For each weapon in the dismantlement process, a laboratory study will be conducted to determine if any of the major assemblies, components, or their subcomponents should be:
  - (1) Retained for reuse
  - (2) Salvaged for their strategic or economic value
  - (3) Retained for safety and use-control effectiveness evaluations
  - (4) Evaluated to provide further statistical data regarding the quality and reliability of comparable hardware in the enduring stockpile

Non-Nuclear Hardware From Dismantled Weapons

- All hardware scheduled for disposal unless otherwise requested
- Sandia plans to request designated hardware to be returned for evaluation
- Possible storage of Sandia hardware for future use when a direct replacement in the enduring stockpile, e.g., mods of B61
- Los Alamos plans no storage of hardware except for Detonators
- LLNL plans no storage of hardware
- Evaluation units for LANL and LLNL will be requested as needed

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Component Commonality Matrix, A Few Examples

Dismantled Weapons	Enduring Stockpile			
	B61	W78	B83	W76,W80,W87,W80
B57	Solder Conn		Para chute	
W68	Trig Ckt	Trig Ckt	Trig Ckt	
W70	LAC	LAC N.G.	LAC	

W56, B61-0,
W69,
W71, W79

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DOE Dismantlement Policy
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  (2) Salvaged for their strategic or economic value
  (3) Retained for safety and use-control effectiveness evaluations
  (4) Evaluated to provide further statistical data regarding the quality and reliability of comparable hardware in the enduring stockpile

DSD Manual

The Demilitarization and Sanitization for Disposition (DSD) Manual defines the process to be utilized in the nuclear weapons complex for applying the general guidelines to define and document a demilitarization, sanitization, and/or render-safe process. The process description covers the use of the Demilitarization/Sanitization Table, the Weapon Component Data Sheets, and the issue resolution process.

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Survey of Weapon Development and Technology (WR708) (U)

~~Restricted Data~~
~~This document contains Restricted Data as defined in the Atomic Energy Act of 1954. Unauthorized disclosure subject to Administrative and Criminal Sanctions.~~

Classified by: S. J. Barnes Dept. 3522
Title : Manager Date: June 6, 1995

CRITICAL NUCLEAR WEAPON DESIGN INFORMATION
-- DOD DIRECTIVE 5210.2 APPLIES --

~~NUCLEAR WEAPON DATA~~

~~SIGMA~~

DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW

	DETERMINATION [CIRCLE NUMBER(S)]
1ST REVIEW-DATE: 5/23/96	1. CLASSIFICATION RETAINED
AUTHORITY: DC DD	2. CLASSIFICATION CHANGED TO:
NAME: Richard R. Crauer SCA	3. CONTAINS NO DOE CLASSIFIED INFO
2ND REVIEW-DATE: 11/1/99	4. COORDINATE WITH: DoD
AUTHORITY: DD	5. CLASSIFICATION CANCELED
NAME: Jim Gr...	6. CLASSIFIED INFO BRACKETED
	7. OTHER (SPECIFY): DoD brackets purple

USAF brackets green
Army agree
Navy agree

Corporate Training & Development 3522

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION I

- COURSE OVERVIEW
- WEAPON COMPLEX & DEVELOPMENT PROCESS

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

Day	Time	Session	Title	Instructor
Monday	8:30 - 12:00	1	Course Overview - Introduction	Hogan/Layne
		2	Physics - Explosion Theory	Hogan/Layne
	1:00 - 4:00	2	Physics - Explosion Theory (cont)	Hogan/Layne
		3	Nuclear Effects	Hogan/Layne
Tuesday	8:00 - 12:00	4	High Explosives - Detonators	Hogan/Layne
		5	Fission	Hogan/Layne
	1:00 - 4:00	5	Fisson (cont)	Hogan/Layne
		6	Thermonuclear	Hogan/Layne
Wednesday	8:00 - 12:00	6	Thermonuclear (cont)	Hogan/Layne
		7	Safety	Hogan/Layne
	1:00 - 3:00	7	Safety (cont)	Hogan/Layne
		8	Use Control - Access Control	Hogan/Layne
	3:00 - 4:00	9	Weapons Systems	Rogulich
Thursday	8:00 - 12:00	10	Dismantlement	Longmire
		11	Arming, Firing, and Initiation	Longmire
		12	Nuclear Testing	Hogan/Layne
	1:00 - 4:00	13	Transfer Systems	Robinson
		14	Fuzing	Hartwig
		15	Arms Control	Hogan/Layne
Friday	8:00 - 9:30	15	Arms Control (cont)	Hogan/Layne
	9:45 - 10:45	16	Non-Proliferation/Counter Proliferation	Taylor
	11:00 - 12:30	17	Stockpile Matters	Hogan/Layne
	1:30 - 4:30	18	Nuclear Weapons Musuem Tour	Hogan/Layne

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Course Themes

- Stockpile Surety
- Stewardship
- Historical Teaching Approach
- Extensive Use of Hardware
- Survey of almost all aspects of nuclear weapons

OVERVIEW

- Nuclear Surety - safety, command and control, and security is of paramount importance and should be viewed collectively.
- [redacted]
- The physics of fission, the nuclear properties of fissile material, and the understanding of basic concepts will be very important in understanding the weaponization.

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OVERVIEW (Continued)

- There have been weapon system, aircraft and missile trades which have over the last 40 years driven the nuclear weapons community to design smaller, lighter, yet higher-yield weapons.
- A systems engineering approach is required when viewing nuclear weapons.
- Arms control is a major driver for weapons reduction.
- History and early weapon development is extremely important to the understanding of third world proliferation.

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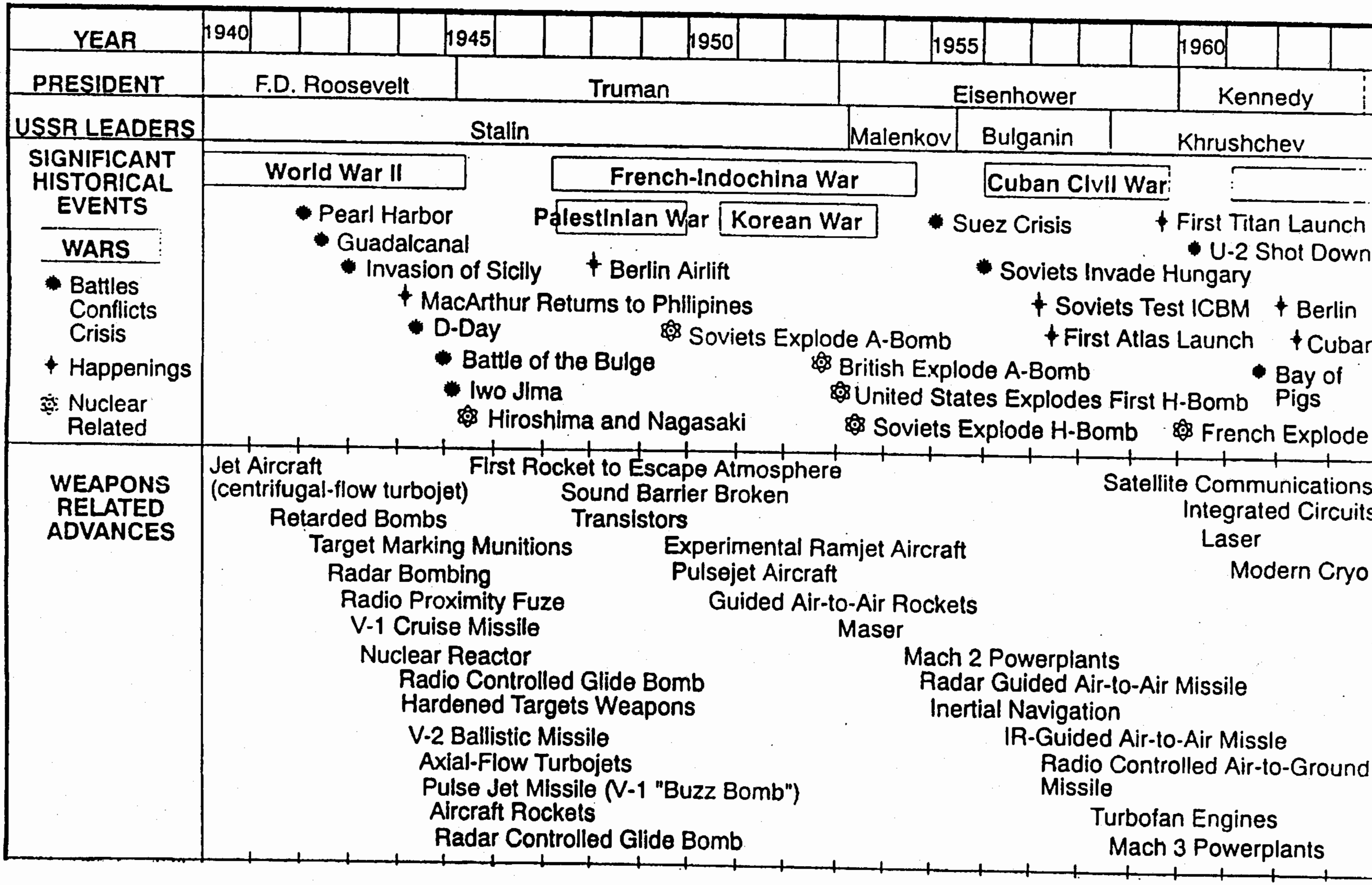
Nuclear Weapons Development Drivers

- Nuclear Surety
- Service Requirements/Weapon System Interfaces.
  - less manpower intensive wooden round
  - less weight and volume
- National Security Strategy/Policy
  - United States
  - CINC's
  - NATO
- Arms Control
  - Limit Technology
  - Limit Growth
  - Eliminate Categories
  - Reduce Numbers

National Security Strategy: Deterrence

Decade	Implementation
1950	Massive Retaliation
1960	Flexible Response
1970	Flexible Response
1980	Flexible Response
1990	Last Resort

SIGNIFICANT HISTORICAL EVENTS RELATIVE TO NUCLEAR WEAPONS



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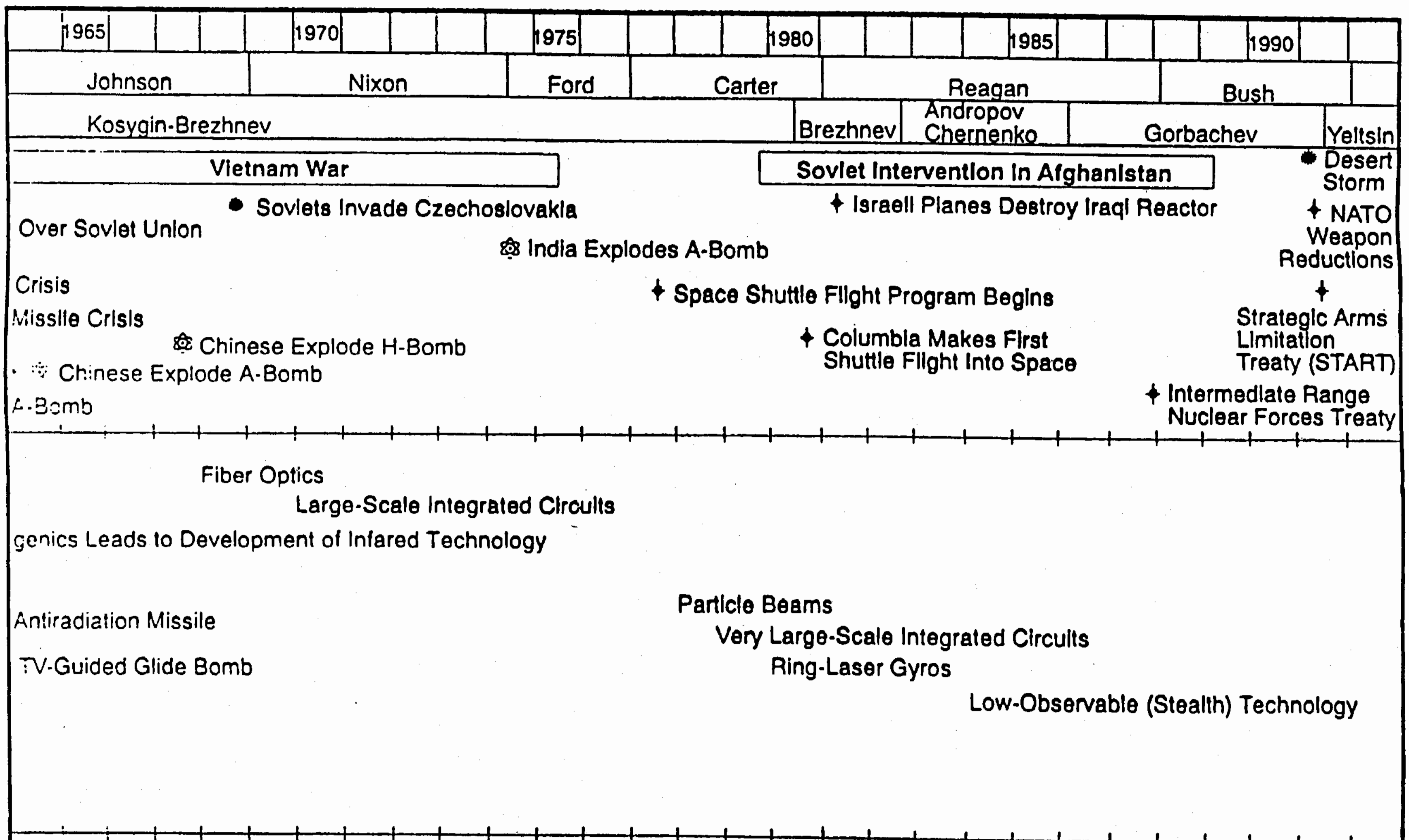
SIGNIFICANT HISTORICAL EVENTS RELATIVE TO NUCLEAR WEAPONS



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Strategy, Arms Control, and Weapon Systems Technology Drive Stockpile Requirements

Strategy	Threat	Tech.	Size/Wt.	Yield	Arms Control	Number
1950 Massive retaliation	Global	A/C & missiles inaccurate	Large	Very high	Very limited talks	Growing
1960 Flexible response	Global Theater	A/C & missiles improve	Decrease	Decrease	Limited talks	Growing
1970 Flexible response	Global Theater	A/C & missiles improve accuracy	Decrease even more	Tactical needed lower yields	SALT ABM limitations	Decline
1980 Flexible response	Global Theater	A/C & missiles very accurate	Large decrease	Continued decrease	Mutual elimination & reduce	Decline more
1990 Last resort	Theater Global	A/C & missiles very accurate	Remain small	Remain same	Large cuts mutual elimination/ unilateral	Large reduction

DOE b(3)

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— "Nuclear weapons are an enduring reality and are not likely to disappear in the foreseeable future."

— "... deterrence will remain central to U.S. national security strategy."

Report of the Secretary of Defense
to the President and the Congress
January 1994

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A New Era Has Arrived for the Nuclear Weapons Program

- "Today's Weapons Are Probably Tomorrow's" (STRATCOM)
- No New DoD Delivery Systems Planned
- DOE Production Complex Downsizing
- Nuclear Test Moratorium ⟶ Test Ban

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SELECTED HARDWARE ORIENTATION

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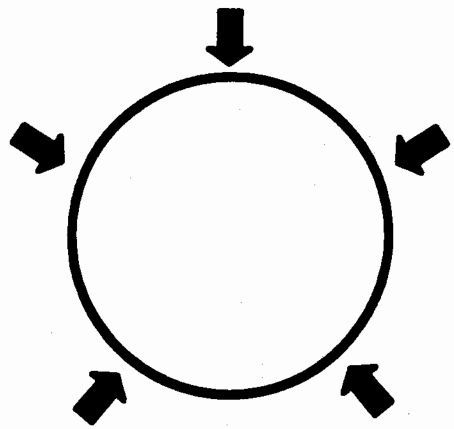
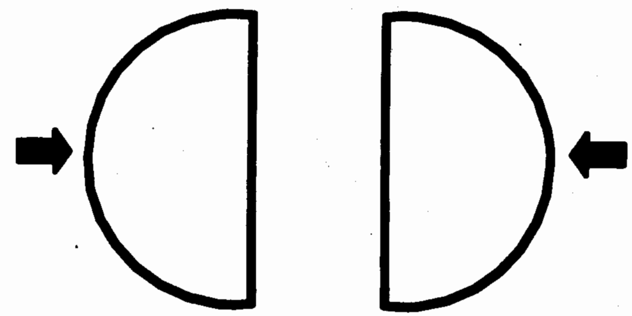
Fission Primaries

IMPLOSION



Critical Mass Achieved
with Compression from HE

GUN TYPE



Critical Mass Achieved with
"Lots of Special Nuclear Material"

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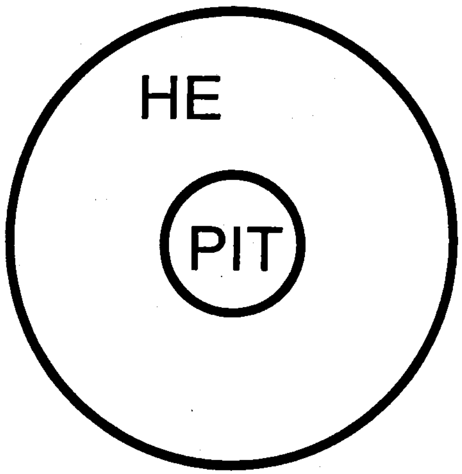
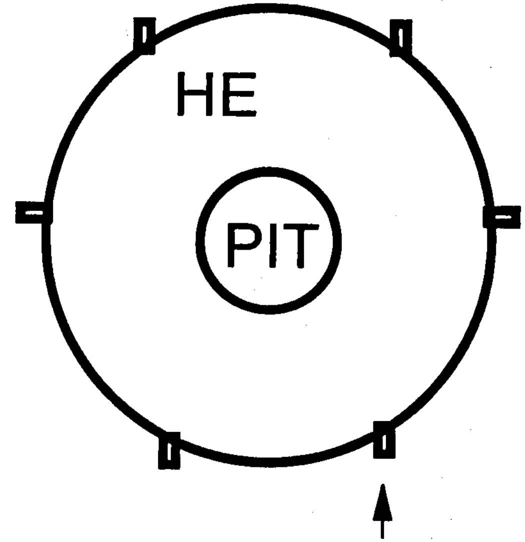
Fission Primary



Detonators Required to Fire the HE



Original Detonators Large

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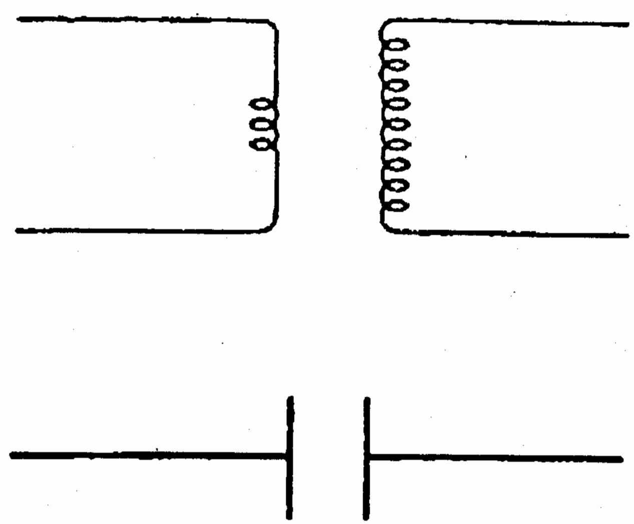
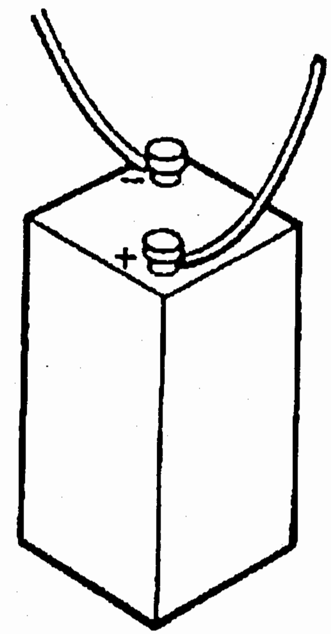
Basic Electronics Needed to Fire the Detonations





FIRE SET
Evolved from Large to Compact

POWER SOURCES
Originally Lead Acid (car battery style)
Evolved to Thermal Batteries

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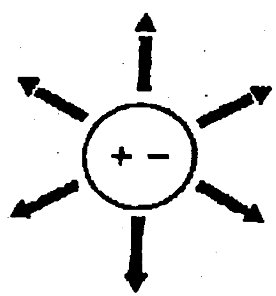
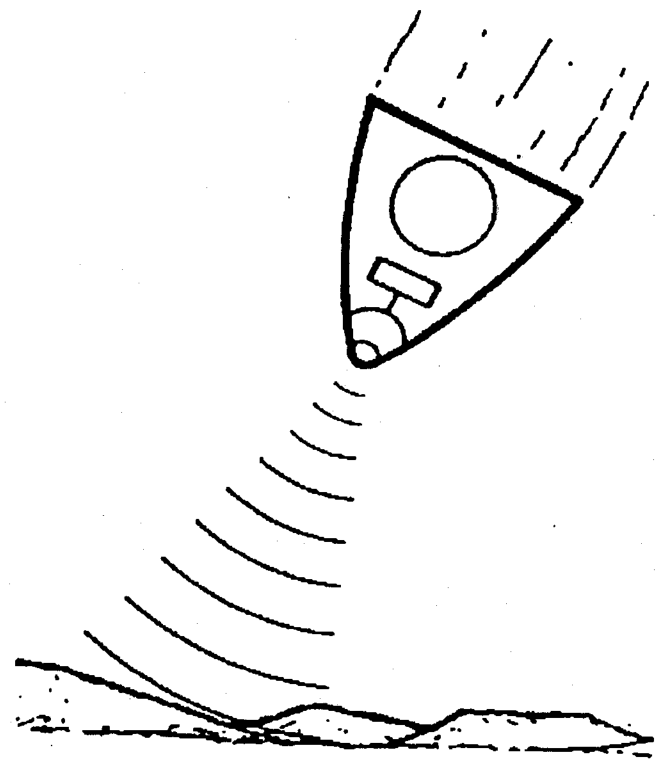
Additional Elements Required for Detonation



Neutron Source



Fuzes
- Height of Burst
- Impact

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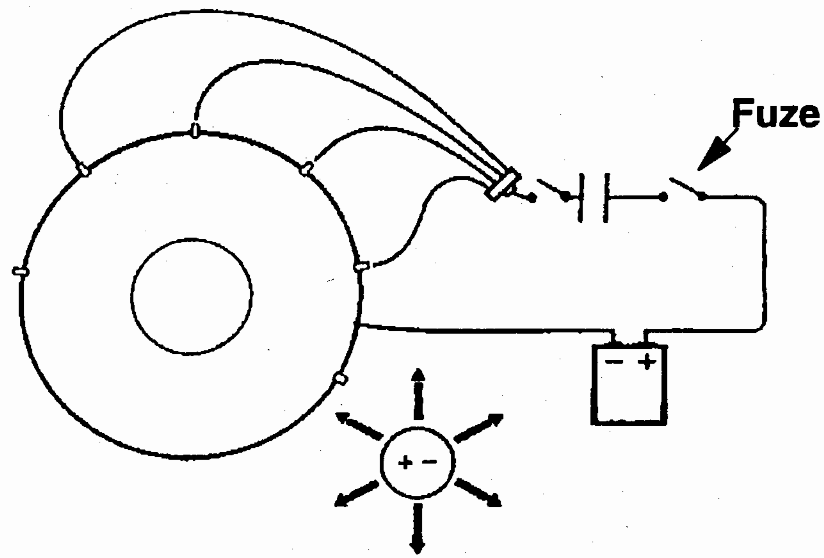
Basic Elements of a Nuclear Weapon



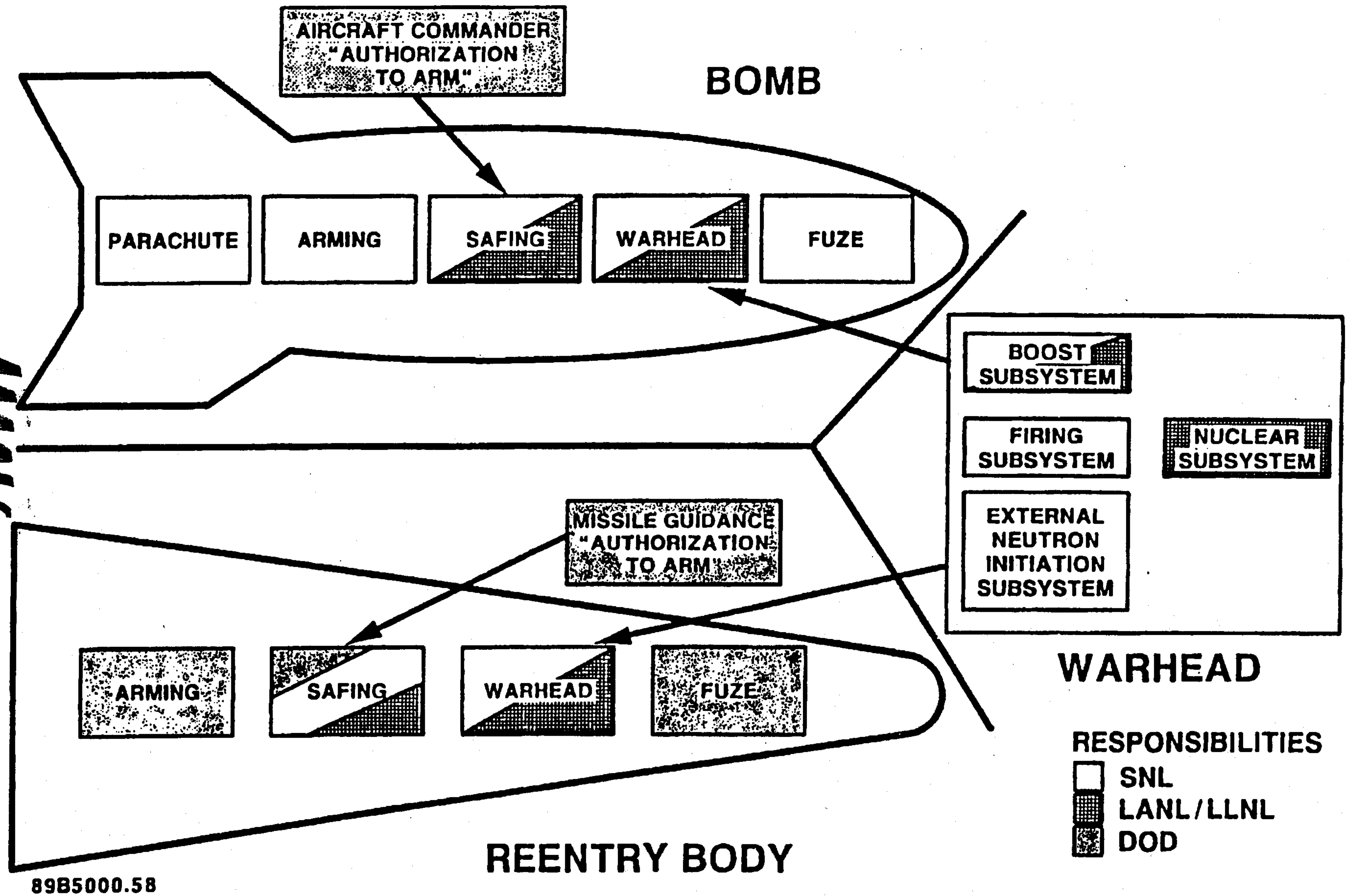
GAS BOOSTING

— INITIAL FISSION RAISES BOOST GAS TO FUSION TEMPERATURES

— D•T REACTIONS RELEASE A FLOOD OF HIGH ENERGY NEUTRONS FOR FISSIONING OF Oy AND/OR Pu

DOE b(3)

DIVISION OF RESPONSIBILITIES



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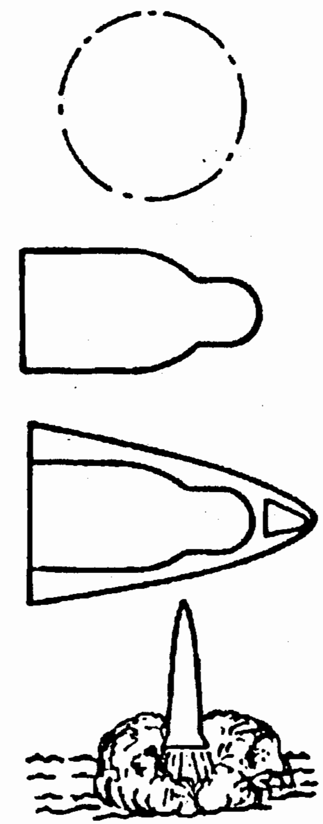
As the nuclear weapons systems integrator for the DOE, Sandia has unique responsibility for:

- Fire Set Development--neutron generator-batteries-capacitors etc.
- Electrical & Mechanical Interface Compatibility
- Electrical Detonation Safety
- Use Control & Use Control Equipment
- Handling and Aneillary Equipment
- Stockpile Surveillance (reliability)--Testing & Evaluation
- Military traning & manuals
- Field Support
- Weapon Systems (including DoD hardware) independent evaluations
- DOE & DoD Security Facility Upgrade
- Safe Secure Trailers (total life cycle) & DOE courier training
- Safe Secure Trailers (toal life cycle) & DOE courier training
- Neutron generator production

TERMINOLOGY

NUCLEAR PACKAGE PHYSICS PACKAGE	⇨	PRIMARY/SECONDARY (Includes High Explosive)
NUCLEAR WARHEAD	⇨	NUCLEAR PACKAGE & WEAPON ELECTRICAL SYSTEM & PLUMBING
NUCLEAR WEAPON	⇨	NUCLEAR WARHEAD & ARMING & FUZING & AERODYNAMIC CASE, ALSO REENTRY VEHICLE
NUCLEAR WEAPON SYSTEM	⇨	NUCLEAR WEAPON & DOD DELIVERY SYSTEM



–THE TERM <u>NUCLEAR DEVICE</u> USUALLY IMPLIES A TEST WARHEAD BUT IS SOMETIMES USED IN A PLACE OF EITHER NUCLEAR PACKAGE OR WARHEAD

–THE ARMY USED THE TERM NUCLEAR WARHEAD SECTION TO INCLUDE WARHEAD + AK + BALLISTIC BASE

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WEAPON PROGRAM OBLIGATIONS

STOCKPILE MANAGEMENT:

MAINTENANCE OF THE NATIONAL STOCKPILE OF NUCLEAR WEAPONS IN A SAFE, SECURE, RELIABLE, READY CONDITION

WEAPONIZATION:

DEVELOP AND PRODUCE NUCLEAR WEAPONS FOR STOCKPILE AS JOINTLY AGREED TO BY DOD & DOE AND AS AUTHORIZED BY THE PRESIDENT

WEAPON TECHNOLOGY:

PURSUE TECHNOLOGY IN THE SCIENCE & ENGINEERING OF NUCLEAR WEAPONS SO THAT OUR UNDERSTANDING & ABILITY TO DEVELOP IS SECOND TO NONE

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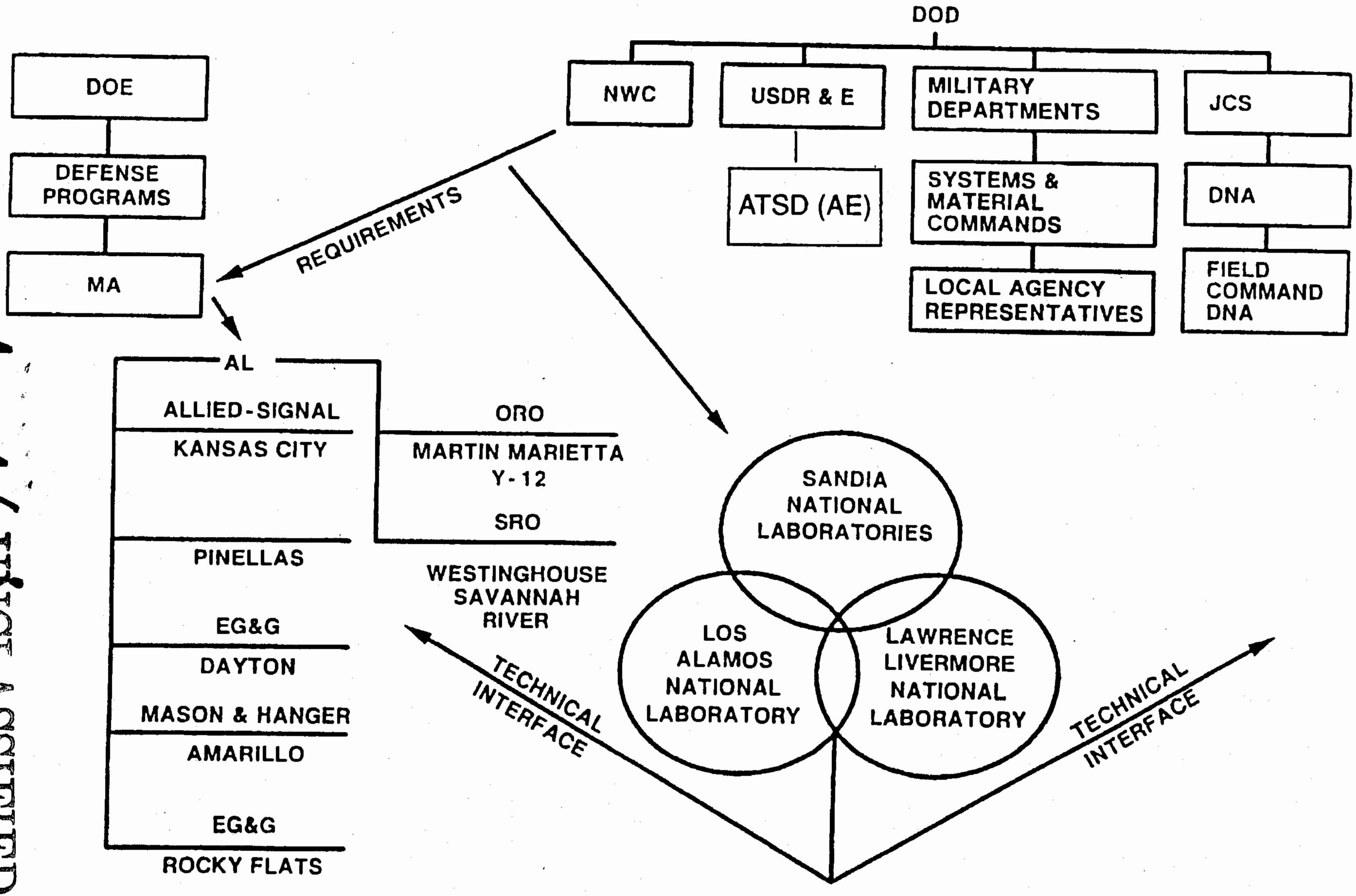
SANDIA-DOE/DOD INTERFACES
WEAPON PROGRAM



Rocky Flats
Golden, Colorado

Contractor:	**EG&G**
Employment:	**5100**
Principal Missions:	**Fabrication of beryllium, plutonium recovery and research;** **Fabrication of pressure vessels**

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Kansas City Plant
Kansas City, Missouri

Contractor:	**Allied-Signal**
Employment:	**4700**
Principal Missions:	**Fabrication and assembly of electrical, electronic, electro-mechanical, precision mechanical, rubber and plastic components;** **Heavy machining**

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Y-12 Plant
Oak Ridge, Tennessee

Contractor:	Martin Marietta
Employment:	6000
Principal Missions:	Fabrication of test and stockpile secondary assemblies; Fabrication and research in uranium; Machining

DOE b(3)

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Pinellas Plant
St. Petersburg, Florida

Contractor:	Martin Marietta speciality components, inc.
Employment:	1100
Principal Missions:	Neutron generators, thermal batteries, BTGs, lightning arrestor connectors, capacitor, neutron detectors

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Savannah River Plant
Aiken, South Carolina

Contractor:	**Westinghouse**
Employment:	**355**
Principal Missions:	**Production of tritium and plutonium; Fill reservoirs with tritium**

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Pantex Plant
Amarillo, Texas

Contractor:	Mason and Hanger
Employment:	2500
Principal Missions:	Fabricate high explosive system; Final assembly, disassembly and retirement of weapons

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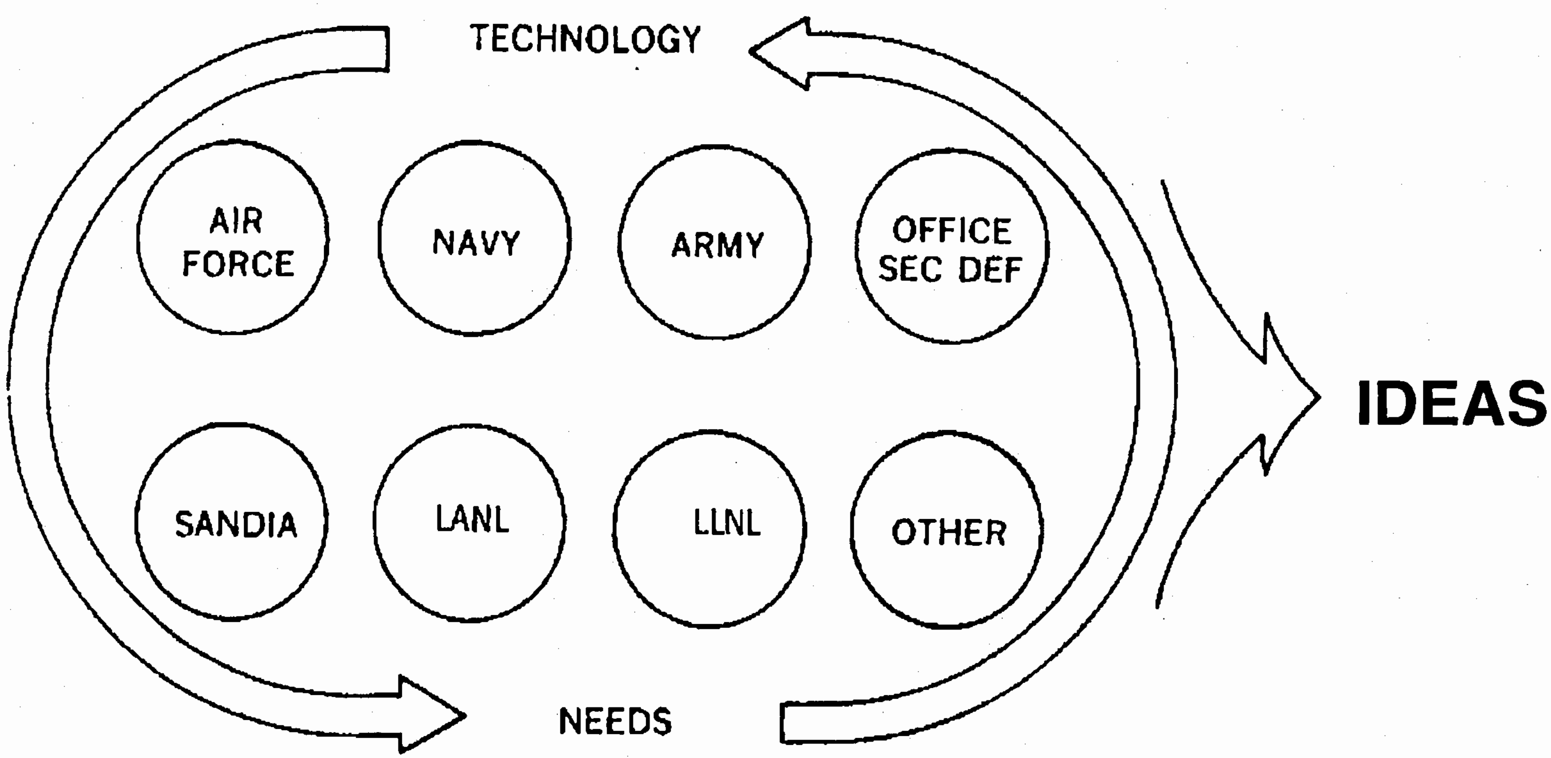
PHASE 1 CONCEPT FORMULATION

(ϕ1)



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Phase 1 - Weapon Conception

DOE

Continuing studies by DOE agencies. Studies may be informal and independent from DoD or may be conducted jointly with DoD. May result in the focusing of sufficient DoD interest in a modification of a present weapon or in the development of a new type weapon to warrant formal study.

DoD

Continuing studies by DoD agencies. May be independent of the DOE or may be conducted jointly with DOE. Sufficient attention may become focused on an item to warrant a formal program study. DoD requests DOE to make a program study on a new idea for a weapon or component or may initiate its own study.

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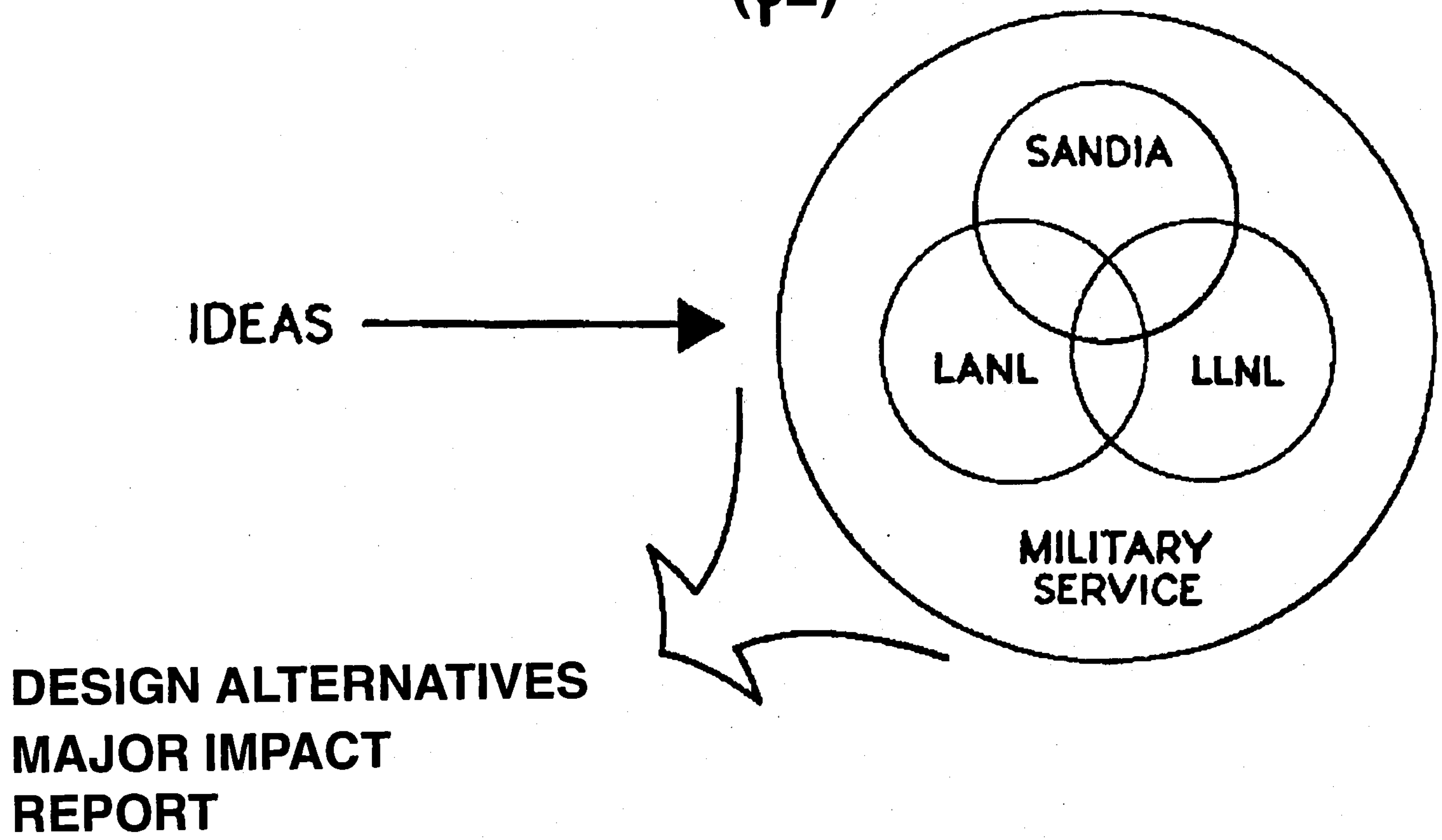
Historical Pressure on Nuclear Designs

	PEACETIME EMPHASIS	WARTIME EMPHASIS
IMPROVE	SAFETY SECURITY CONTROL	SURVIVABILITY DELIVERABILITY EFFECTIVENESS FLEXIBILITY BATTLE MANAGEMENT
REDUCE	MAINTENANCE MOVEMENT TRAINING	REACTION TIME OPERATIONAL CONSTRAINTS COLLATERAL DAMAGE

PHASE 2 FEASIBILITY

(ϕ2)



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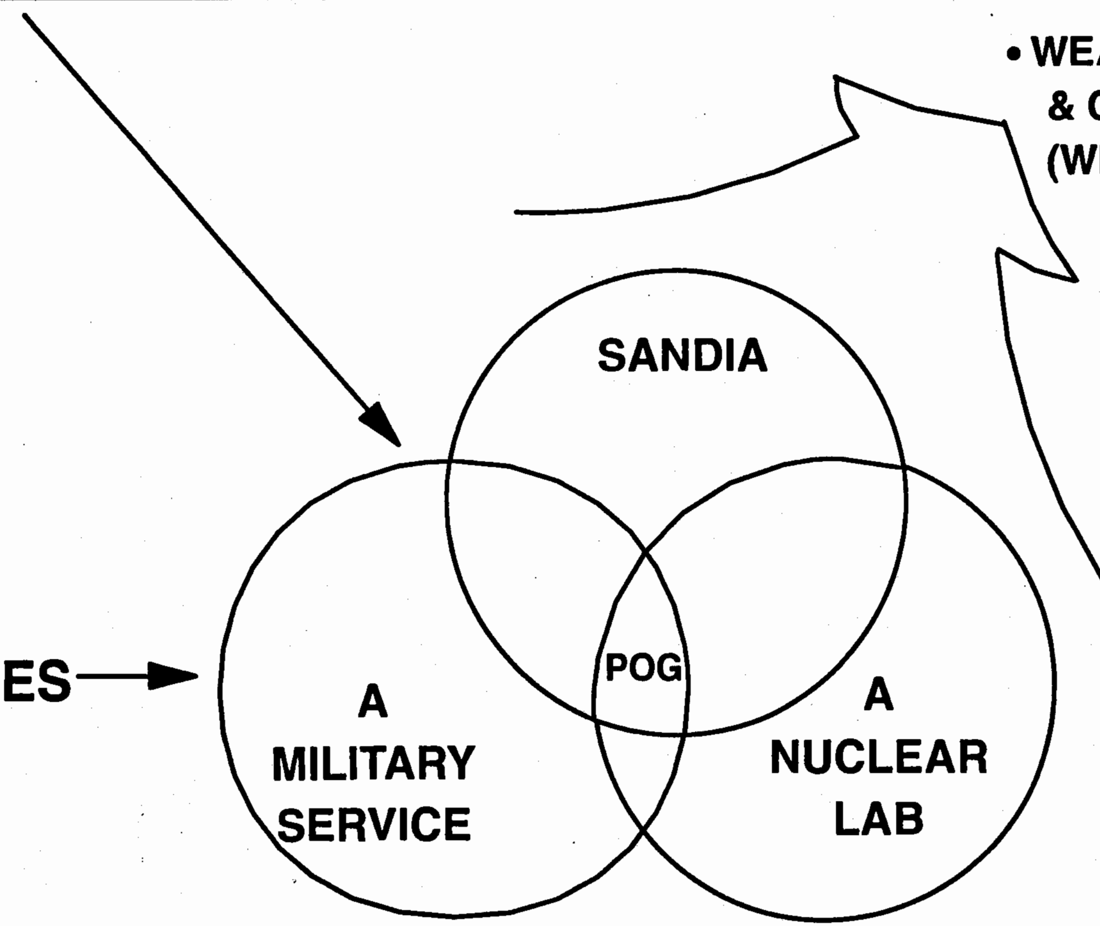
Phase 2A VALIDATION
(Φ2A)

DESIGN TEAM SELECTION

- SELECT BASELINE DESIGN & LAB
- SCHEDULE
- WEAPON DESIGN & COST REPORT (WDCR)



DESIGN ALTERNATIVES

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Phase 2A - Design Definition and Cost Studies

A DOE design team will normally be selected and a Project Officer Group will be formed. The POG will conduct trade-off studies to identify baseline design(s) which best balances resources and requirements. Review and revise draft MCs and STs. Establish tentative development and production schedule and division of responsibilities. A Weapon Design and Cost Report will be prepared.

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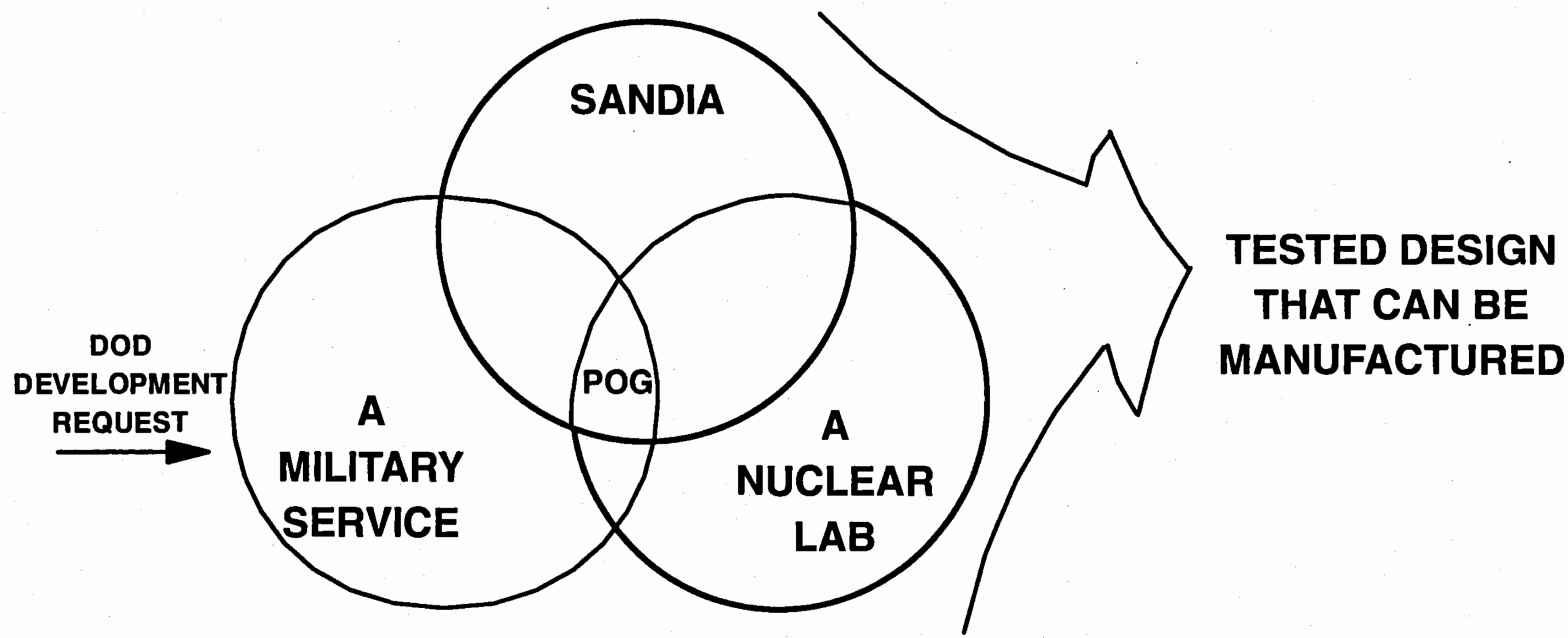
Phase 3 ENGINEERING DEVELOPMENT (ϕ3)



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Phase 3 - Development Engineering

DOE

Launches a development program based on required military characteristics. Produces prototypes for DOE and DOD evaluation.

Provides development specifications to DOD as they become available.

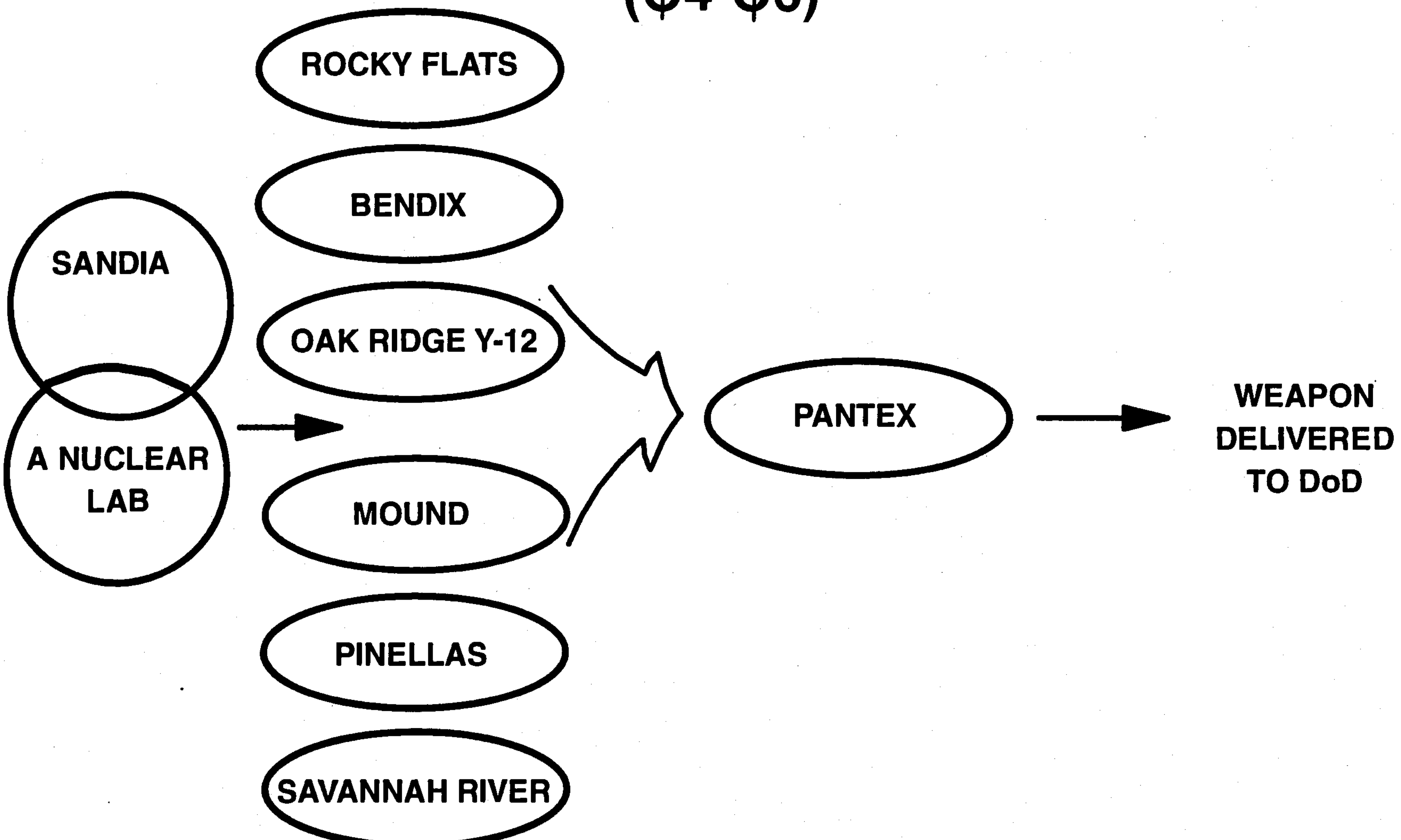
Determines the developmental design release date and submits a final report on the development design to the DOD.

DoD

Maintains liaison with DOE field agencies and conducts independent evaluation of prototypes as considered necessary.

Studies the development specifications of the weapon design and gives appropriate guidance to the DOE.

Phase 4-6 PRODUCTION
(Φ4-Φ6)



- Historical Production Complex
- Reconfiguration Will Impact

Phase 4 - Production Engineering

DOE

Proceeds with production engineering of weapon, tooling, and layout of manufacturing facilities, without waiting for formal comments of DoD on the developmental design. Such guidance is integrated when received. Further prototype evaluation is performed during this phase.

Prepares product specifications for production release and furnishes these specifications to the DoD for review.

DoD

Reviews product specification.

Maintains liaison with appropriate DOE agencies on product design changes and specifications and gives appropriate guidance to DOE.

Continues evaluation of prototypes as considered necessary.

Phase 5 - First Production

DOE

Initiates manufacture of weapons according to product specifications by production tools, without waiting for DOD's comments on product specifications. DOE performs own evaluation and on basis of preliminary evaluation releases weapons to DOD for testing, training, and other purposes. Makes final evaluation and approves weapon model as suitable for standardization.

DoD

Completes operational suitability tests and makes independent evaluation of production type weapons. If weapon as designed, produced, and approved by DOE is satisfactory, approves the weapon as standard.

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Phase 6 - Quantity Production and Stockpile

DOE

Brings various production facilities up to full production pursuant to DOD requirements. Maintains production, inspection and quality control programs to ensure that each article produced meets specifications.

Maintains quality assurance and functional surveillance programs to ensure the continued quality of weapons in stockpile, in accordance with current agreements with respect to stockpile operations. These programs and the data obtained thereof will be made available to the DoD.

DoD

Maintains liaison with DOE agencies at production facilities. Continues appraisal of weapon performance.

Maintains liaison with DOE to review performance and technical advances in anticipation of modernization changes.

Reviews DOEs quality assurance and functional surveillance programs and results and submits appropriate comments and recommendations to the DOE. Maintains functional surveillance program in accordance with current agreements with respect to stockpile operations.

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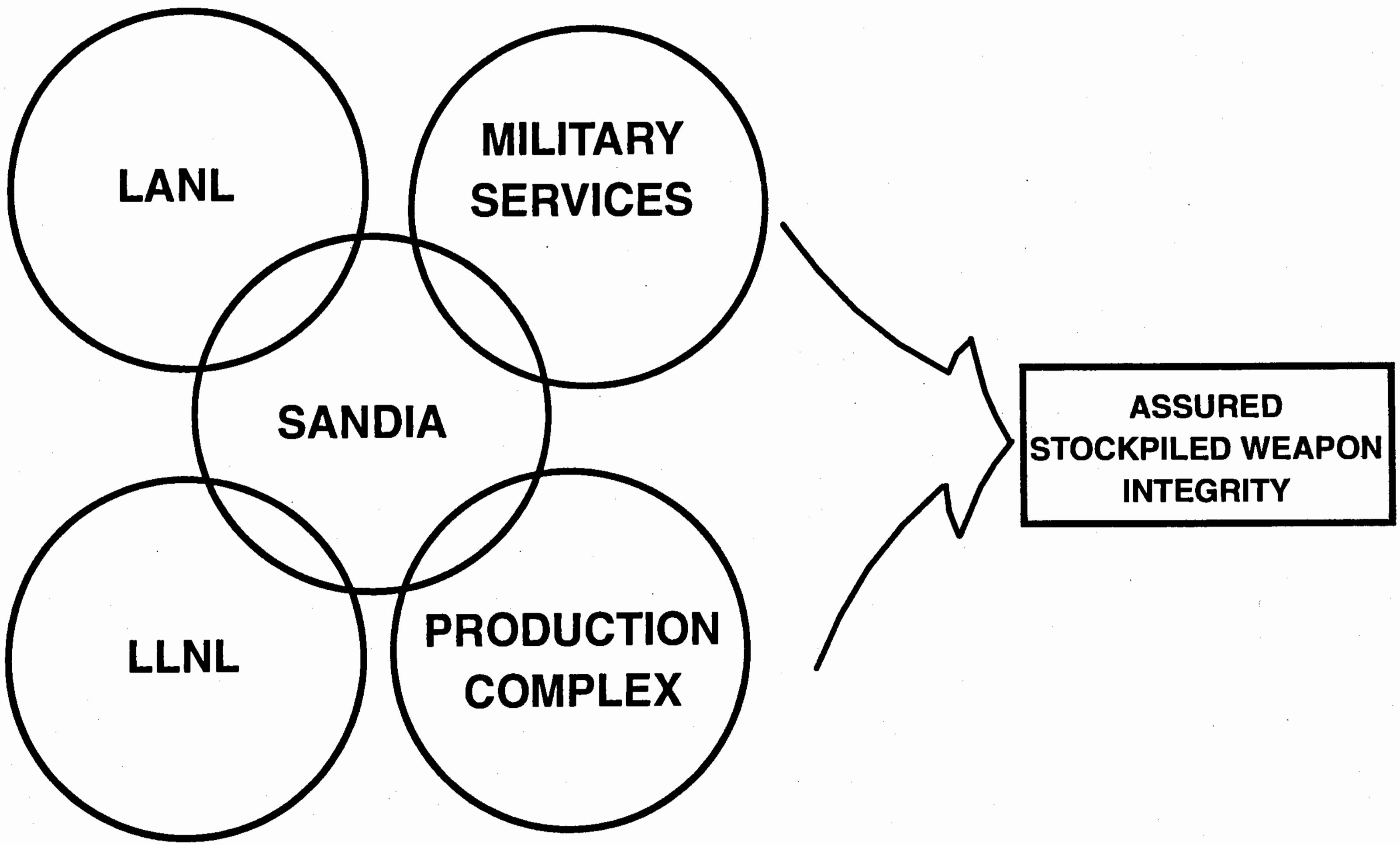
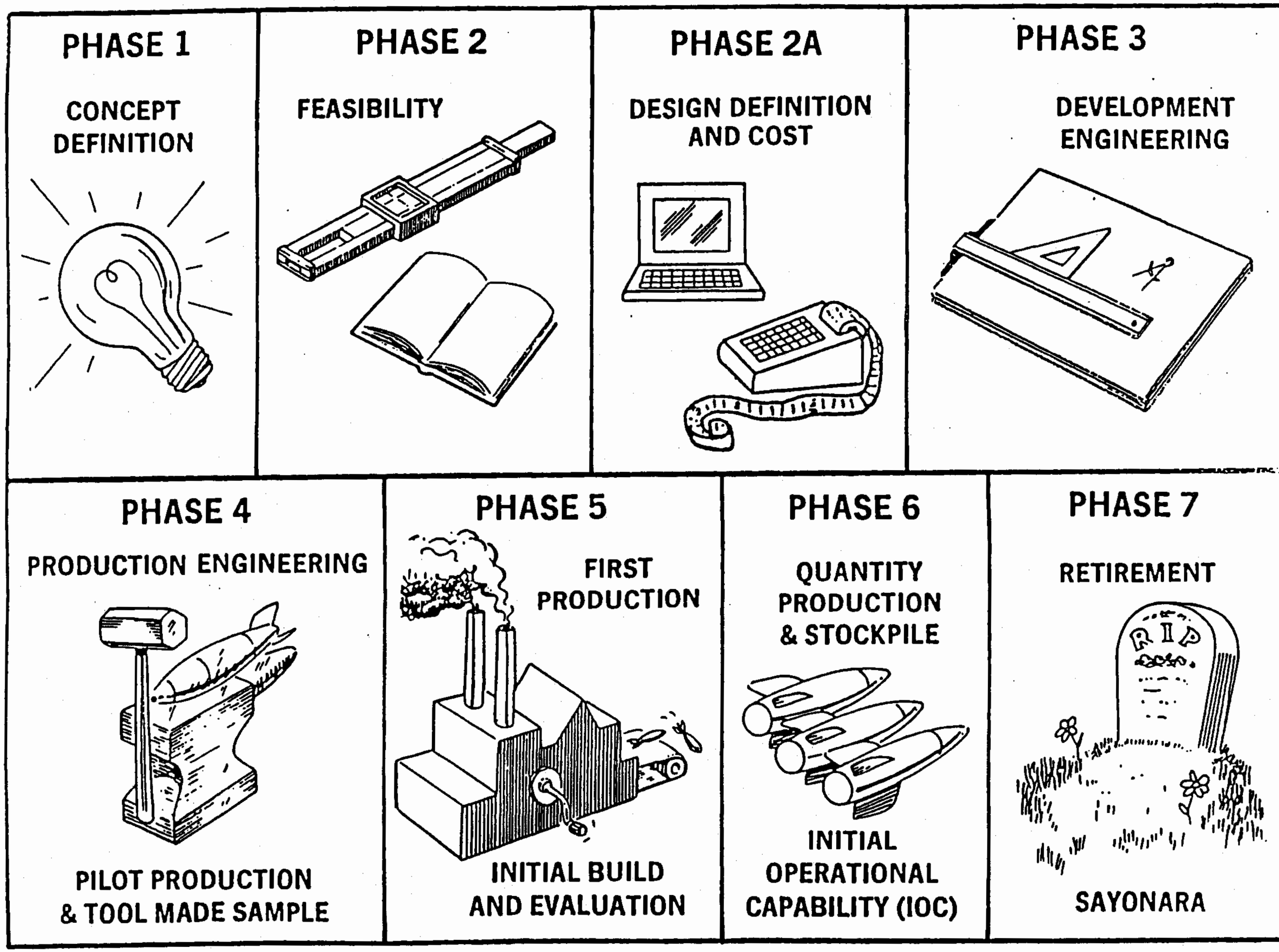
Phase 6 STOCKPILE SURVEILLANCE
(φ6)



Nuclear Weapon Life Cycle

WEAPON DEVELOPMENT



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Phase 1 -- Concept Definition

Initiation: Informal agreement between participants to undertake study

Purpose: Study a Service requirement or DOE technological breakthrough/innovation for weapon application

Organization: Joint DoD/DOE Study Group with appropriate working groups. (Note: it can be a DOE or DoD-only study group.) Working Groups: Surety, Requirements Analysis, Mission Analysis, Warhead Design, and Systems Engineering

Deliverables: Phase 1 Study Report [In some cases: Draft Military Characteristics (MCs) & Draft Stockpile-to-Target Sequence (STS)]

Phase 1 Activities

<u>Military Characteristics</u>

Warhead performance requirements

Warhead physical characteristics

Requirements for nuclear safety

Phase 1 Activities

<u>Stockpile-to-Target Sequence</u>

Logistical employment concepts

Operational employment concepts

Normal & abnormal environments applicable to MC safety requirements

Phase 1 -- Concept Definition

Initiation:	Informal agreement between participants to undertake study
Purpose:	Study a service requirement or DOE technological breakthrough/innovation for weapon application.
Organization:	Joint DoD/DOE Study Group with appropriate working groups. (Note: it can be a DOE or DoD-only study group.) Working Groups: surety, requirements analysis, mission analysis, warhead design, and systems engineering
Deliverables:	Phase 1 study report [In some cases: Draft Military Characteristics (MCs) & Draft Stockpile-to-Target Sequence (STS)]
Duration & Cost:	Normally 1 year and low cost

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Phase 2 -- Weapon Feasibility

Initiation:	Formal request from DoD [ASTD (AE)] to DOE to participate with DoD in study.
Purpose:	Develop various weapon alternatives to fulfill service requirements.
Organization:	Joint DoD/DOE Study Group with appropriate working groups. [Sometimes a Project Office Group, (POG) is formed.] Working Groups: Surety, requirements analysis, mission analysis, warhead design, and systems engineering.
Deliverables:	Phase 2 study report with warhead alternatives Draft Military Characteristics (MCs) Draft Stockpile-to-Target Sequence (STS) Nuclear Safety & Use Control Themes Major Impact Report (MIR) Decision Cost Estimates
Duration & Cost:	Normally 2 years and low cost.
Parallel DoD Activities:	Milestone 1 Concept Demonstration Approval precedes Phase 2.

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Phase 2A -- Design Definition & Cost

Initiation: Normal includes as part of Phase 2 authorization. If, not, then formal ATSD (AE) request to DOE is required

Purpose: Develop a definitive cost estimate of the selected warhead design

Organization: Formal project officers group with appropriate subgroups. Subgroups: Safety 7 Surety, Maintenance & Logistics, Command & Control, Military Characteristics, Interface, and Stockpile-to-Target Sequence, among many

Deliverables:
Phase 2A Study Report
Final Military Characteristics (MCs)
Final Stockpile-to-Target Sequence (STS).
DoD/DOE Memorandum of Understanding

Duration & Cost: Normally 6 months and low cost

Phase 3 -- Development Engineering

Initiation:	**ATSD (EA) formally passes MCs, STS, and MOU to DOE/DP requesting their acceptance and requesting DOE participation in Phase 3 activities**
Purpose:	**Develop a finalized and tested weapon design that meets MC and STS criteria and that can be produced by the DOE production complex**
Organization:	**Formal project officers group with appropriate subgroups. Subgroups: Safety & Surety, Maintenance & Logistics, Command & Control, Military Characteristics, Interface, and Stockpile-to-Target Sequence, among many**
Deliverables:	**Phase 3 study report** **Final tested weapon design to include all required H & T gear.**
Duration & Cost:	**Normally 2.5 - 3 years and high cost**
Other Activities:	**DRAAG begins its activities, reviews PWDR. JNWPS manual begun**

Phase 4 -- Production Engineering

Purpose:	DOE production complex determines how it will produce the warhead. DOE production complex tools up necessary production lines
Duration & Cost:	Normally 2.5 years and high cost
Other Activities:	All weapons manual produced First generation training of military initiated DRAAG continues its activities, reviews IWDR

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Phase 4 Activities

DOE Production Complex

Allied Signal, Kansas City Division

Location: Kansas City Missouri

DOE Contractor: Allied Signal Corporation

Product:

Non-nuclear electrical, electronic, electromechanical, mechanical, plastic, and nonfissionable metal components

Pinellas - Neutron detectors, LACs, among others

Rocky Flats - Reservoirs and SST construction

Mound - Flat & round cables and ACORNS

Phase 4 Activities

b(3)

Phase 4 Activities

DOE Production Complex

Savannah River Plant

Location: Aiken, South Carolina

DOE Contractor: Westinghouse Corporation

Product:

- Tritium, special isotopes, targets, and naval reactor fuel material
- Fill boost reservoirs and ship them to the military
- Mound - Gas transfer systems

Phase 4 Activities

DOE Production Complex

Sandia National Laboratories

Location: Albuquerque, New Mexico

DOE Contractor: Martin-Marietta Corporation

Product:

Pinellas - Thermal batteries, neutron generators, CAP assemblies, capacitors, and frequency devices/clocks

Phase 4 Activities

DOE Production Complex

Los Alamos National Laboratory

Location: Los Alamos, New Mexico

DOE Contractor: University of California

Product:

- Pinellas - Neutron tube target loading
- Rocky Flats - Beryllium technology and pit support functions
- Mound - High power detonators and calorimeters frequency devices/clocks

Phase 4 Activities

DOE Production Complex

Pantex Plant

- Location: Amarillo, Texas
- DOE Contractor: Mason & Hanger
- Product:
  - Explosive components
  - Assemble all nuclear weapons
  - Disassemble all weapons

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Phase 4 -- Production Engineering

Purpose:	DOE production complex determines how it will produce the warhead. DOE production complex tools up necessary production lines
Duration & Cost:	Normally 2.5 years and high cost
Other Activities:	All weapons manual produced First generation training of military initiated DRAAG continues its activities, reviews IWDR

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Phase 5 -- First Production

Purpose: Produce initial products for new material evaluation testing. Refine production lines as a result of new material testing. Increase production rate to that required in Phase 6

Duration & Cost: Normally 6 months and low cost

Other Activities: DRAAG completes its activities. Nuclear certification of receiving service units

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Nuclear Weapons Safety Study Group (NWSSG)

Chaired by representative service

Membership includes DOE, Defense Nuclear Agency, and representatives from service operational and developmental commands

Performs safety studies

- Initial safety study - as early as possible in weapon development
- Pre-operational safety study - at least 120 days before IOC
- Operational safety review - within 2 yrs of fielding and every 5 yrs thereafter
- Special safety study - whenever system changes or problems require it

Phase 6 -- Quantity Production & Stockpile

Purpose: Produce War Reserve (WR) warheads in quantities directed by the Nuclear Weapons Stockpile Memorandum (NWSM) to support military IOC

Other Activities:

- Operational activities
- Logistics activities
- Nuclear accident/incident activities
- Technical inspections of nuclear-certified units
- Stockpile quality assurance and reliability testing
- Weapon modifications and retrofits
- Inactive stockpile

Phase 6 Activities

<u>Nuclear Weapon Operations</u>

Nuclear weapon stockpile demonstrable element of nuclear deterrent strategy
- Ability to employ effectively
- Surety

Deployment

Peacetime threat	Peacetime storage
Wartime threat	Wartime storage

Employment
- Rigorously controlled process
- Presidential release to a unified commander
- Conveyance of presidential release to executing commander
- Execution of nuclear mission by delivery units

Phase 6 Activities

<u>Nuclear Weapon Operations (cont.)</u>

Command and Control
- Provides critical link and positive control by the President
- Designated communications systems
- Specific authentication procedures and codes

Training
- Ensure maximum unit and force readiness
- Exercises are still conducted

Personnel Reliability and Assurance Program
- Ensures highest possible standards of individual realiability
- DoD (PRP) DOE (PAP)

Phase 6 Activities

Logistics Activities

Transportation

- Logistic movements (DOE and DoD)
- Operational movements (DoD)
- Safety and Security are important considerations

Storage

DOE   DoD   Security Areas

Maintenance

- Normally accomplished by the custodial service
- Accomplished at weapon storage area maintenance facilities
- LLCE--boost reservoirs, neutron generators, RTGs

Phase 6 Activities

<u>Accident/Incident Activities</u>

Nuclear Weapon Accident unexpected event involving:]
- Accidental or unauthorized launching, firing, or use by US forces or U.S. supported allied forces of a nuclear capable system
- An accidental, unauthorized, or unexplained nuclear detonation
- Non-nuclear detonation or burning of a nuclear weapon or nuclear component
- Radioactive contamination
- Jettisoning of a nuclear weapon or nuclear component
- Public hazard, actual or perceived

Nuclear Weapon Significant Incident--unexpected event involving:
- Evident damage to a nuclear weapon]
- Immediate action for safety or security
- Adverse public reaction
- A situation that could lead to a nuclear weapon accident

Accident/Incident Response Preparation
- DoD (EOD) and DOE (ARG) personnel continuously trained
- EOD manual and ARG procedures kept updated
- Joint DoD/DOE Accident/Incident training exercises held

Phase 6 Activities

Technical Inspections

Performed by service or field command, defense nuclear agency teams

Conducted at least annually

Used to recertify nuclear capable units

Emphasis on safety as well as operational requirements

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Phase 6 Activities

STOCKPILE QUALITY ASSURANCE and RELIABILITY TESTING

- ☐ Begun after the system has been in the field for a year.
- ☐ Consists of two types of testing:
  - Stockpile Laboratory Testing (SLT)
  - Stockpile Flight Testing (SFT)
  - Used to include Stockpile Confidence Testing (SCT), but but the UGT Moratorium has effectively cancelled them.
- ☐ Each year test units chosen at random from the active stockpile.
- ☐ Test units disassembled at Pantex Plant.
  - Non-nuclear components tested via SLT and SFT.
  - One nuclear physics package tested non-nuclearly at physics lab.
- ☐ All but one test unit rebuilt and returned to the field.
- ☐ Each Service tests non-DOE system components.

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Phase 6 Activities

WEAPON MODIFICATIONS and RETROFITS

- ☐ Can be done in the field or at Pantex Plant.
- ☐ Modifications and retrofits usually incorporate new technology to increase weapon safety and/or reliability.

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Phase 6 Activities

INACTIVE STOCKPILE (IS)

DoD 1(1)

DoE b(3)

- ☐ Components may be stored to upgrade IS weapons to the status of the same weapons in the active stockpile.

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PHASE 7 - RETIREMENT

PURPOSE: To identify warheads to leave the active stockpile and to be dismantled by the DOE Production Complex.

OTHER ACTIVITIES:

- Temporary storage of retired weapons by military is required as Pantex cannot accept all retired whds.
- Proper disposal of dismantlement waste stream.
- Storage of nuclear components at Pantex due to inability to dispose of them.
- Special nuclear material is reclaimed and retained.

REFERENCES

- AN INTRODUCTION TO NUCLEAR WEAPONS; WASH 1037 REVISED, GLASSTONE, JUNE 1972
- SOURCE BOOK ON ATOMIC ENERGY; GLASSTONE, 3rd EDITION
- NUCLEAR TEST SUMMARY TRINITY — HARDTACK DASA 1220; RS3141/10349
- VARIOUS WEAPON DEVELOPMENT REPORTS

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION VII

- NUCLEAR DETONATION SAFETY
  - MULTI POINT
  - ONE POINT
- NUCLEAR MATERIAL SCATTER

Nuclear Weapon Surety aims to prevent three consequences

Nuclear yield - release of nuclear energy greater than the energy of four pounds of high explosive

Launch or release - sending a nuclear weapon toward a target

Pu dispersal - release of plutonium outside the weapon

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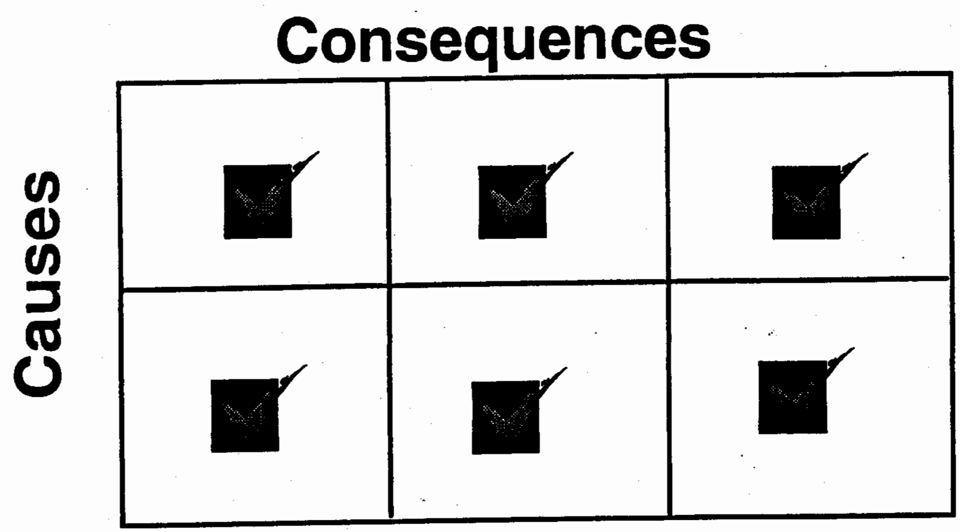
The goal of surety standards

Compliance with nuclear weapon system surety standards
should provide assurance against undesired consequences
(nuclear yield, launch, or Pu dispersal)
resulting from any causes
(either intended or unintended).



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Explanation of normal and abnormal environments

Normal environments (temperature, shock, electrical connections, etc.) are those defined in the weapon or system specifications and intended to be tolerated by the weapon or system. The system is designed to function normally during its entire lifetime if it experiences normal environments.

Abnormal environments are conditions experienced by the weapon or system that are outside the defined normal environments (more extreme temperatures, shocks, voltages, etc.). The weapon or system is not required to function after exposure to an abnormal environment.

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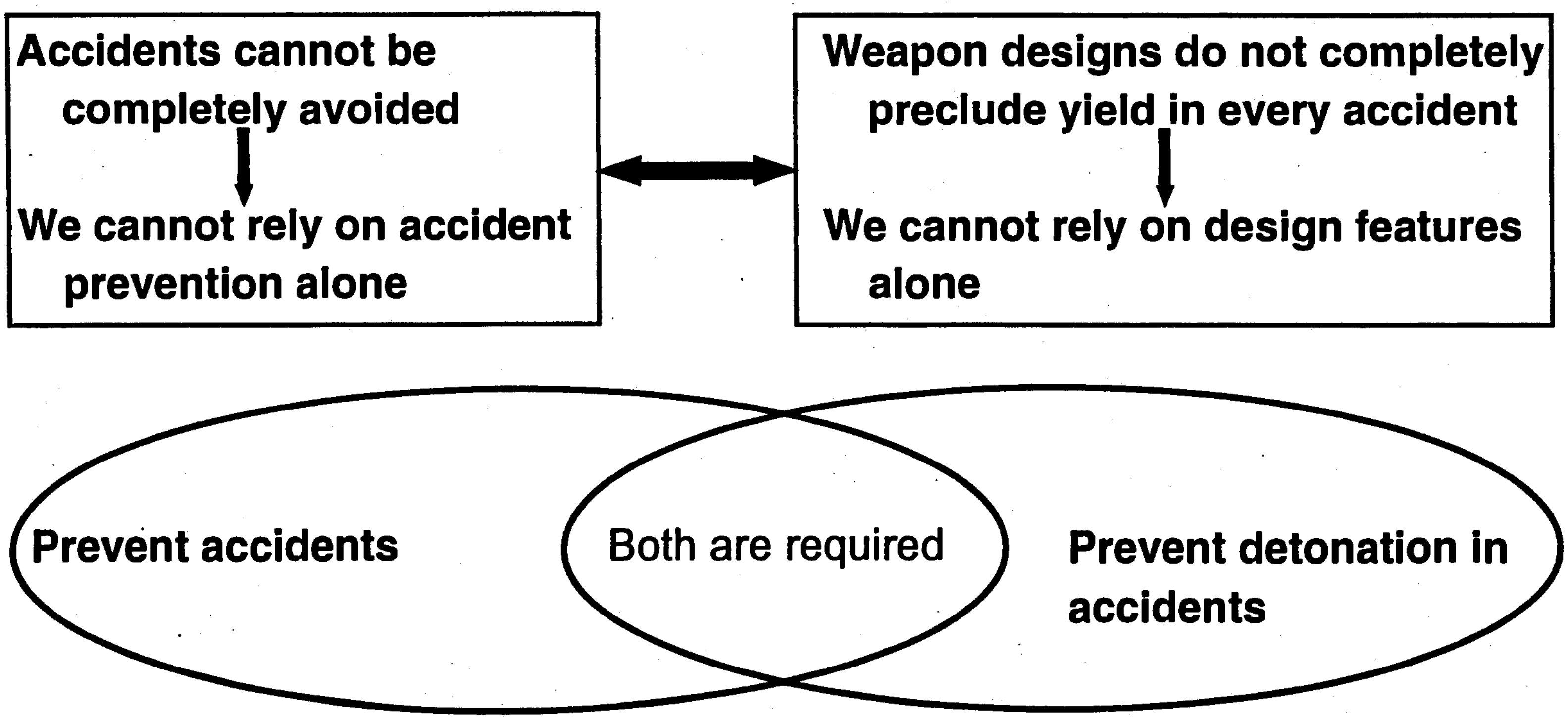
The dual approach to nuclear weapons safety



DOE shares responsibility for safety, security, and control

From the 1983 Memorandum of Understanding between DOE and DoD on Objectives and Responsibilities for Joint Nuclear Weapon Activities

"The obligation of the DoD and the DOE to protect public health and safety provides the basic premise for dual-agency judgment and responsibility for safety, security and control (S^2C) of nuclear weapons. This check-and-balance role shall continue. The DoD and the DOE share the responsibility to:

1) Identify and resolve health and safety problems connected with nuclear weapons. In particular, the DOE has a continuing responsibility to participate with the DoD in the consideration of these health and safety problems for nuclear weapons in DoD custody.

2) Prevent unauthorized use of a nuclear weapon through the use of positive control measure...

3) Determine the adequacy and effectiveness of physical security measures..."

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Department of Defense Directive

3150.2

Replaces DoD 5030.15...February 8, 1984

SAFETY STANDARDS

1. There shall be positive measures to prevent nuclear weapons involved in accidents or incidents, or jettisoned weapons, from producing a nuclear yield.

2. There shall be positive measures to prevent deliberate prearming, arming, launching, firing, or releasing of nuclear weapons, except upon execution of emergency war orders or when directed by competent authority.

3. There shall be positive measures to prevent inadvertent prearming, arming, launching, firing, or releasing of nuclear weapons in all normal and credible abnormal environments.

4. There shall be positive measures to ensure adequate security of nuclear weapons, pursuant to DoD Directive 5210.41.

DOE Order 5610.10
10/10/90
Nuclear Explosive Safety Standards

a. There shall be positive measures to prevent nuclear explosives involved in accidents or incidents from producing a nuclear yield.

b. There shall be positive measures to prevent deliberate prearming, arming, or firing of a nuclear explosive except when directed by competent authority.

c. There shall be positive measures to prevent the inadvertent prearming, arming, launching, firing, or releasing of a nuclear explosive in all normal and credible abnormal environments.

d. There shall be positive measures to ensure adequate security of nuclear explosives pursuant to the DOE safeguards and security requirements.

e. There shall be positive measures to prevent accidents, inadvertent, or deliberate unauthorized dispersal of plutonium to the environment.

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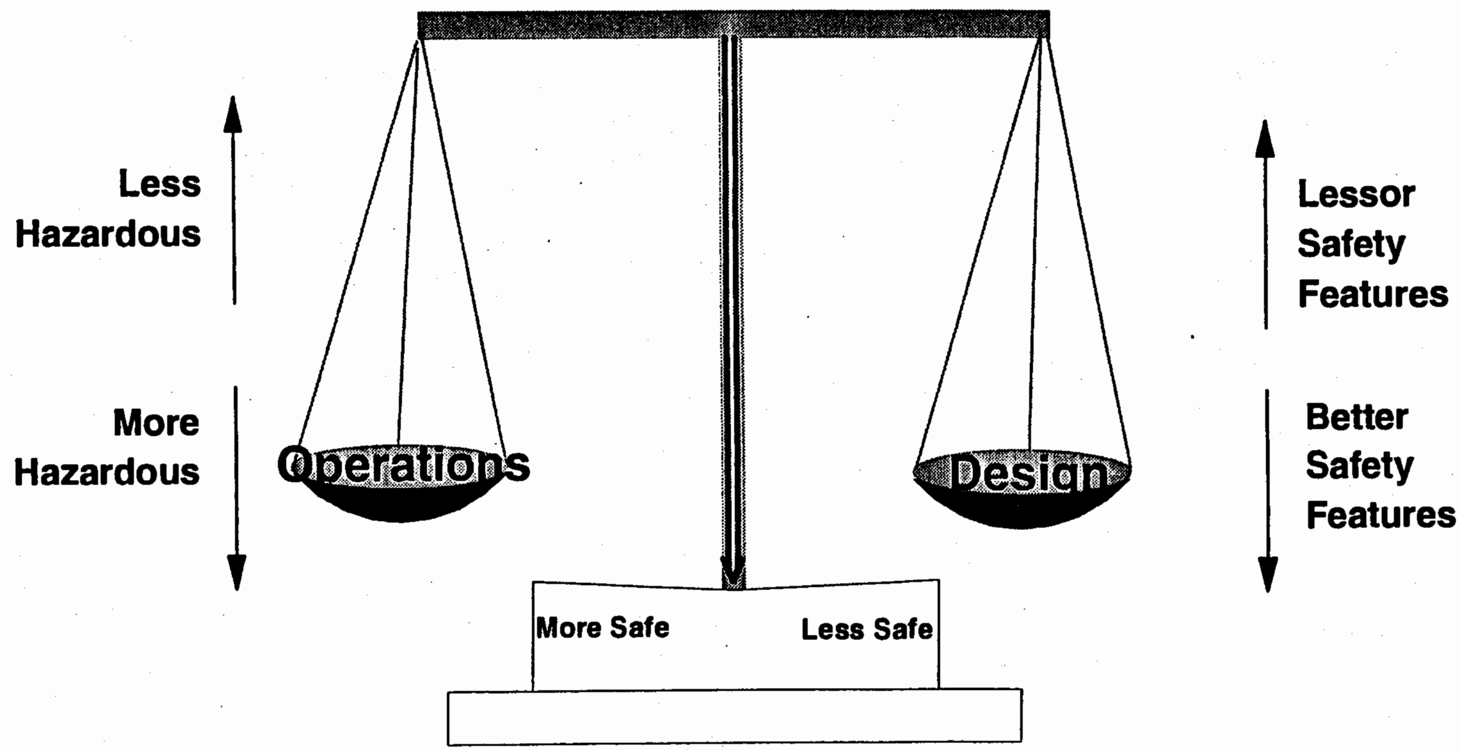
OPERATIONS & SAFETY DESIGN MUST BE BALANCED



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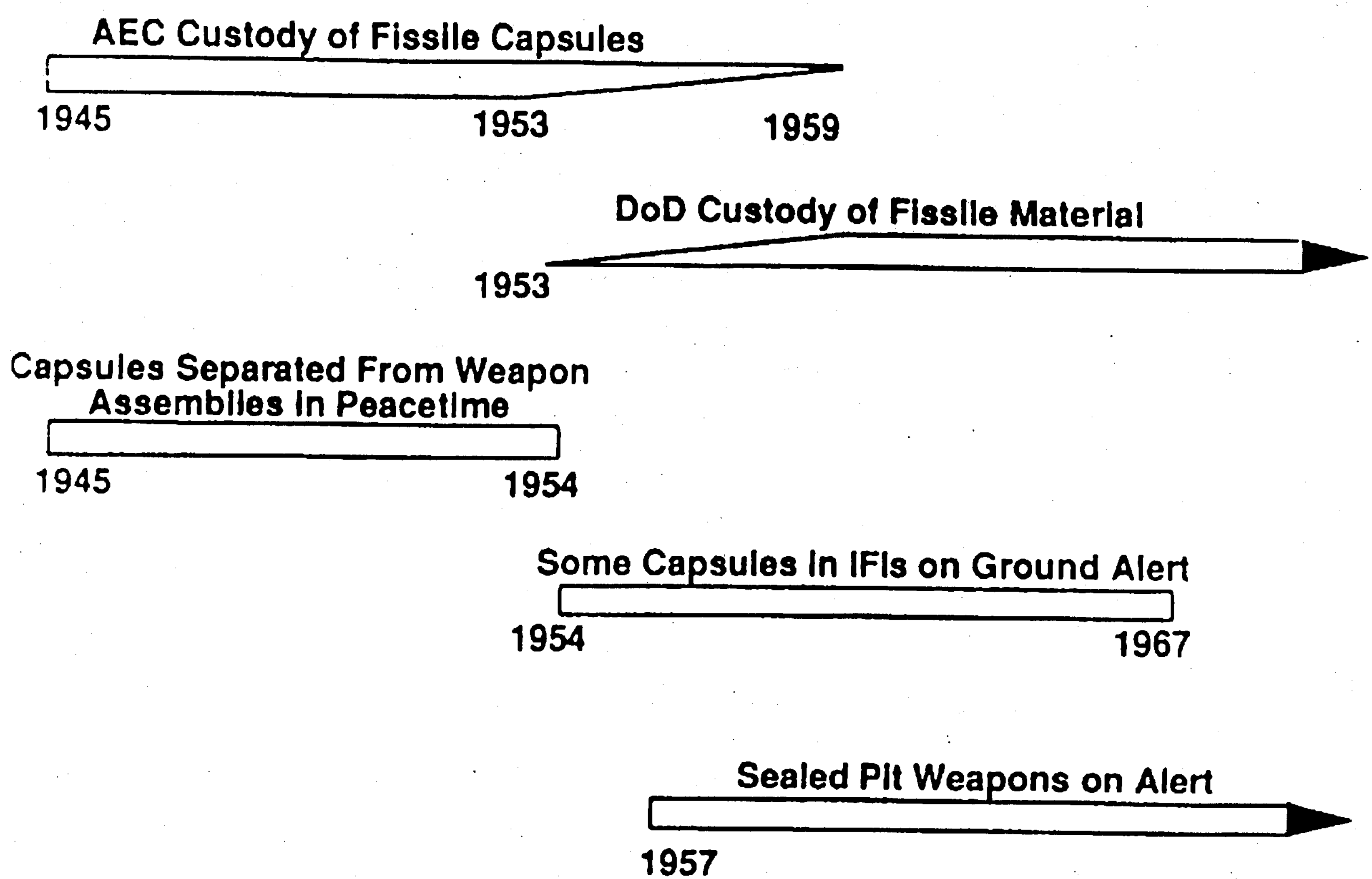
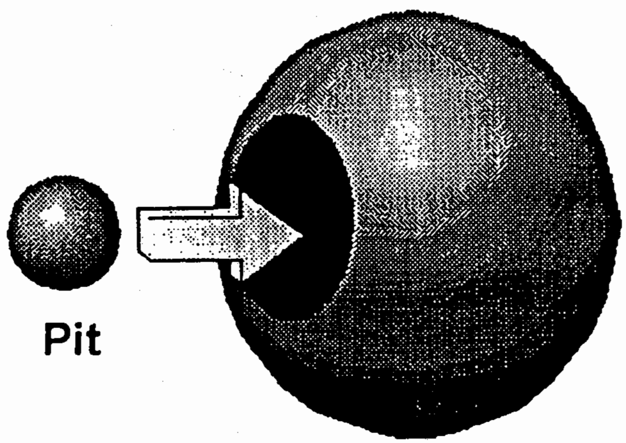
U. S. NUCLEAR DEPLOYMENTS CHANGED



Manually Inserted Capsules

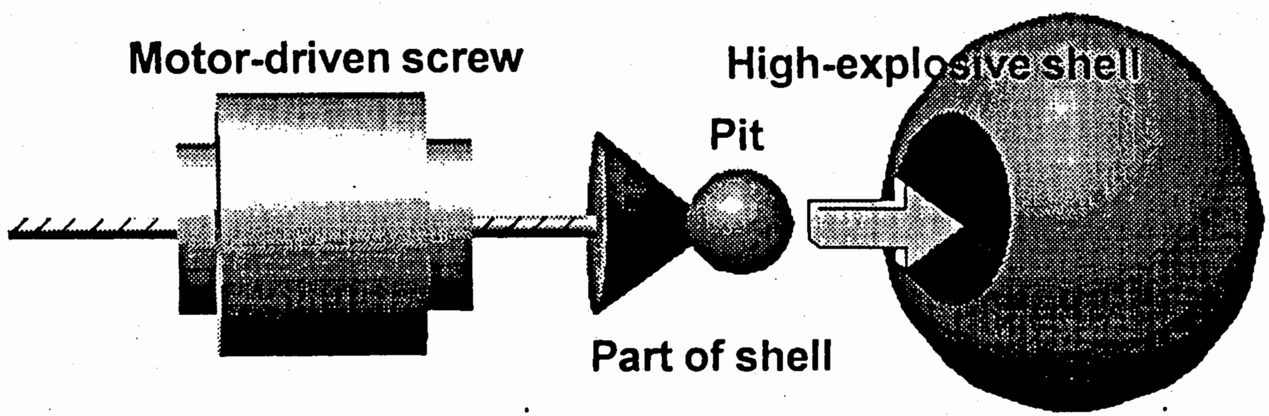
1948 - 1951



- Safety Theme: Separation of fissile material and HE
- Analysis: Accident must assemble weapon

Mechanically Inserted Capsules

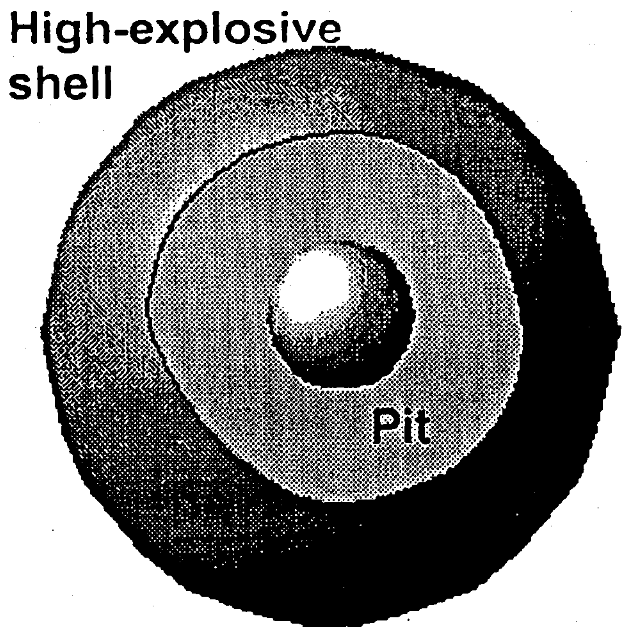
1952 - 1967



- Safety Theme: Separation of fissile material and HE and electrical isolation
- Analysis: Accident could assemble weapon by operating motor or by mechanical damage

Sealed-pit Weapons

1957



- Safety Theme: Electrical isolation and one-point safety
- Analysis: Accident could generate firing signals; not one-point safe

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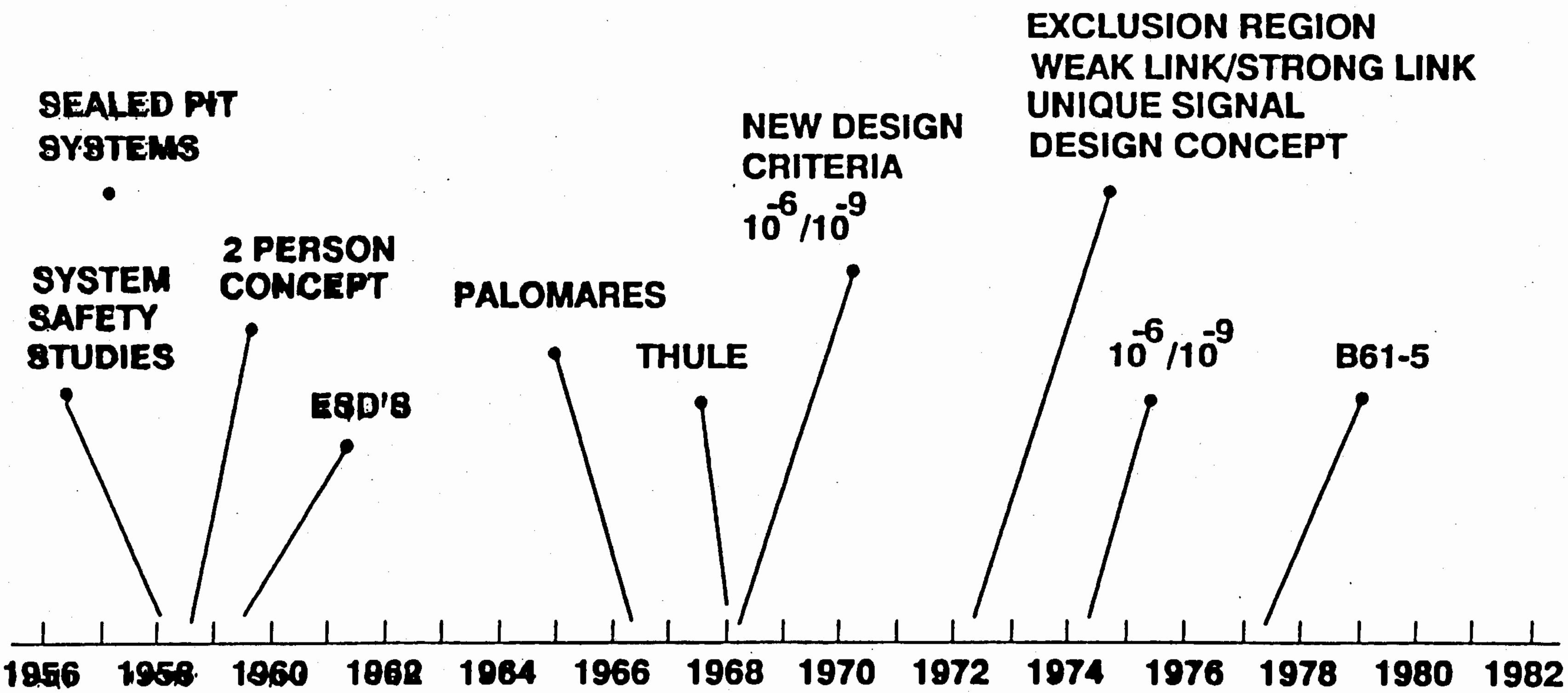
EVOLUTION OF NUCLEAR SAFETY



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Early Electrical Isolation Safety Features

1950 - 1970

- Removable safing plugs
- Circuit board and cable isolation
- Removable or external power supplies
- Ready-safe switches
- Thermal fuses
- Environmental sensing devices

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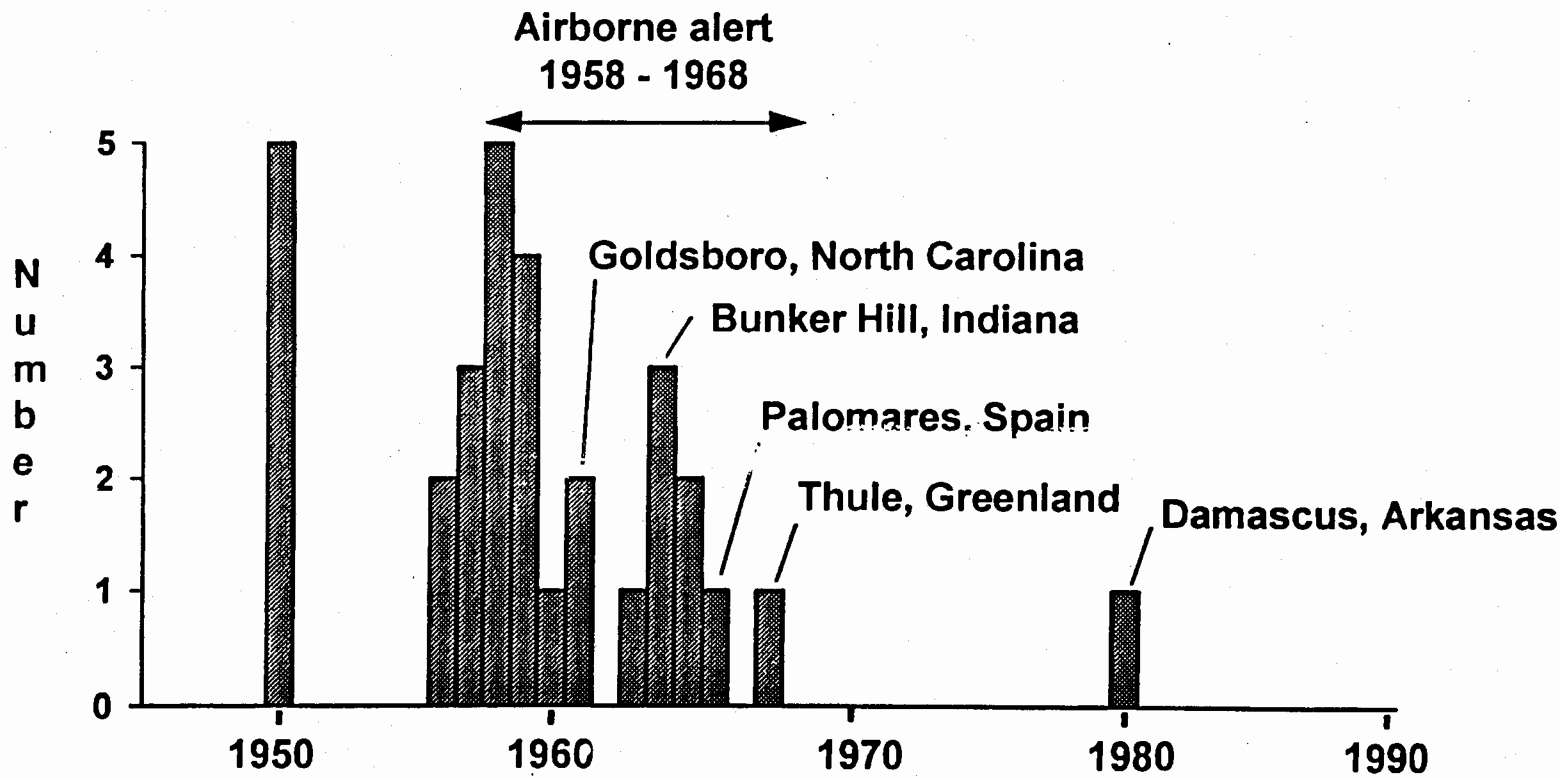
Environmental Sensing Devices (ESDs)

An open switch in the prearming circuits.

It is closed after sensing an environment experiences by the weapon system when enroute to the target.

US Nuclear Weapon Accidents



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Nuclear Weapon Accident--Definition

DOD Directive 5100.52

"An unexpected event involving nuclear weapons or nuclear components that results in any of the following:

(1) Accidental or unauthorized launching, firing, or use by U.S. forces or U.S. supported allied forces of a nuclear capable weapon system.

(2) An accidental, unauthorized, or unexplained nuclear detonation.

(3) Non-nuclear detonation or burning of a nuclear weapon or nuclear component.

(4) Radioactive contamination.

(5) Jettisoning of a nuclear weapon or nuclear component.

(6) Public hazard, actual or perceived."

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Accidents (mainly air-delivered systems) eventually led to reexamination of the premature nuclear yield criteria and to the present nuclear detonation safety design criteria.

Need for a Safety Process

- As the deployment dates for sealed pit weapons approached, the Armed Forces Special Weapons Project (AFSWP) and the Services became uncomfortable with their lack of knowledge and understanding of weapon safety designs.

- 1957, AFSWP convened a safety Board to examine the sealed pit weapon systems becoming available.

- Between 1957 and 1960, the Air Force convened joint safety study groups as weapons entered the stockpile.

- A formal, Joint DoD/DOE Nuclear Weapons System Safety process was established in 1960.

DoD/DOE Nuclear Weapon Safety Process

- Joint Safety Study of Each Weapon System and Operational Concept
  - Determine if Weapon System Meets the 4 Qualitative Standards
  - Develop Operation Safety Rules

    <u>and</u>

  - Ensure Maximum Safety Consistent with Operational Requirements

1968 -- DoD/DOE Agree on Premature Nuclear Detonation Design Safety Criteria

- The probability of a premature nuclear detonation due to component malfunctions, in the absence of any input signals except for specified (e.g. monitoring and control), shall not exceed.

(1) For normal storage and operational environments described in the STS, 1 in 10^9 per weapon lifetime.

(2) For the abnormal environments described in the STS, 1 in 10^6 per weapon exposure or accident.

1968 -- DoD/DOE Agree on One-Point Detonation Design Safety Criteria

One Point Safety

a. In the event of a detonation initiated at any one point in the high explosion system, the probability of achieving a nuclear yield greater than four pounds TNT equivalent shall not exceed one in one million.

b. One-point safety shall be inherent in the nuclear design, that is, it shall be obtained without the use of a nuclear safing device.

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Conclusion of Stockpile Study

New approach to nuclear weapon safety needed

Safety Goals for Abnormal Environments

- Assured, predictable, safe response of the warhead electrical system

- Maintain predictable, safe response until intended use

- Minimize safety critical components and dependence on knowing accident scenario

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Modern Nuclear Safety -- The 4 I's

- Isolation
  - Barriers
  - Stronglink switches
- Incompatibility
  - Unique signals
- Inoperability
  - Co-location of stronglinks and weaklinks
- Independence of safety subsystems

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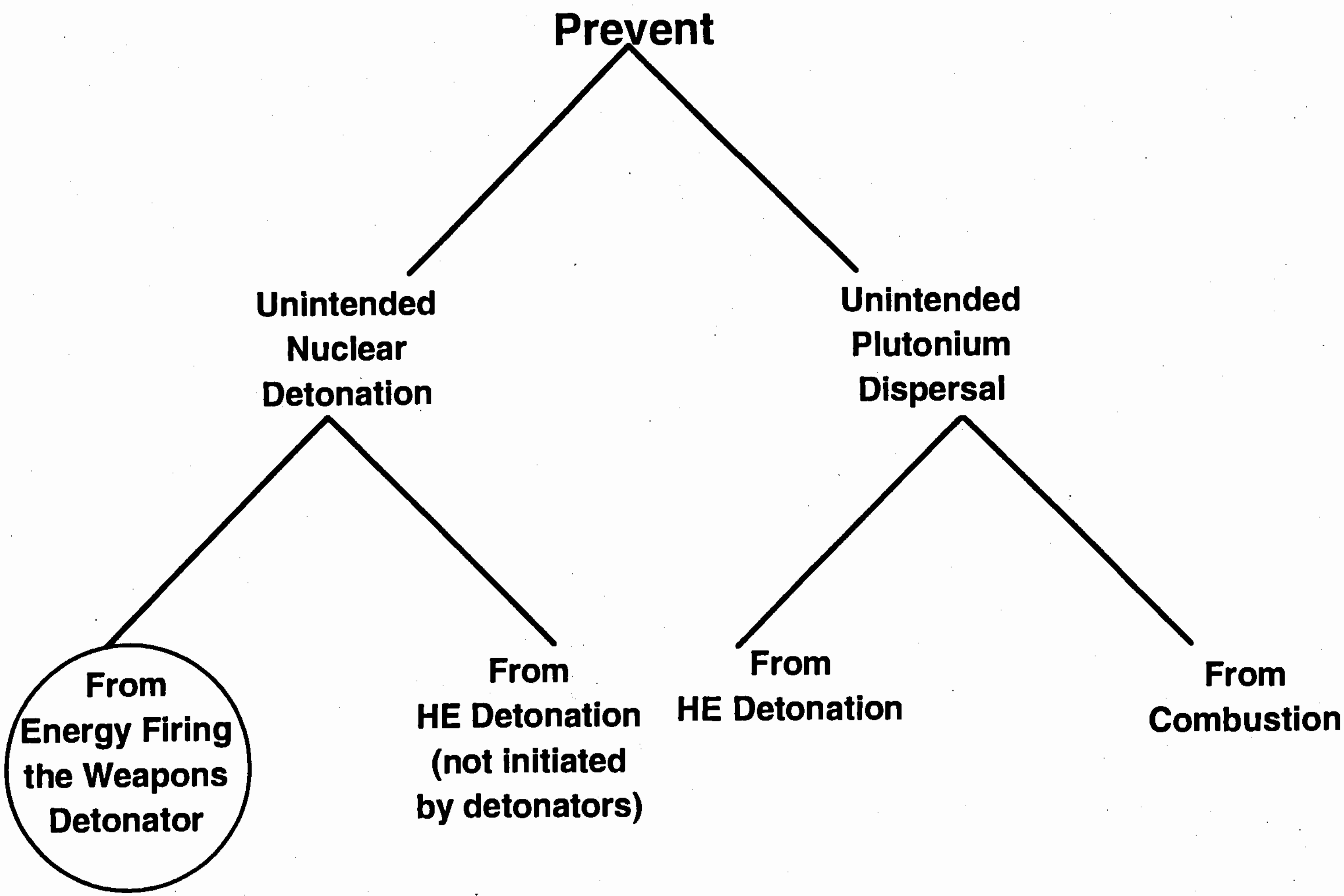
MORE SPECIFICALLY THE SAFETY GOALS ARE TO



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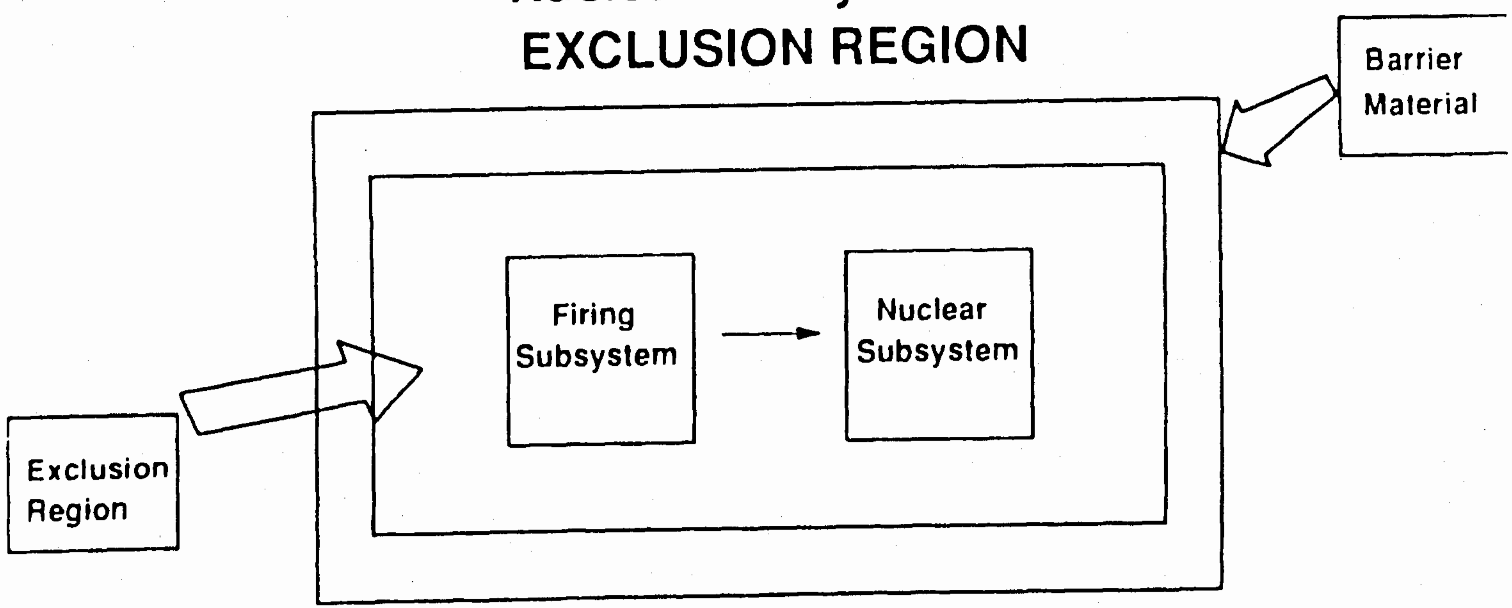
MODERN SAFETY DESIGN PHILOSOPHY

Co-locate detonation-essential components and protect them from abnormal environments by an exclusion region

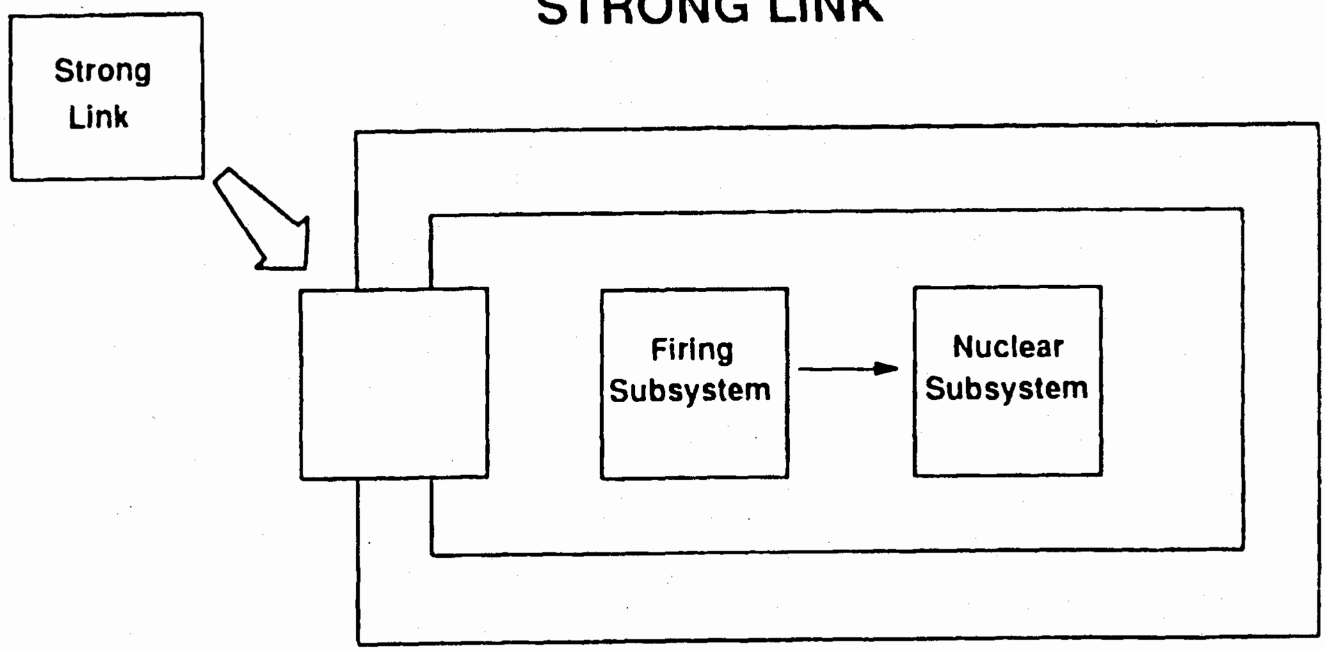
Nuclear Safety Theme
EXCLUSION REGION



MODERN SAFETY DESIGN PHILOSOPHY (cont)

Allow energy/signals into the exclusion region only through a strong link

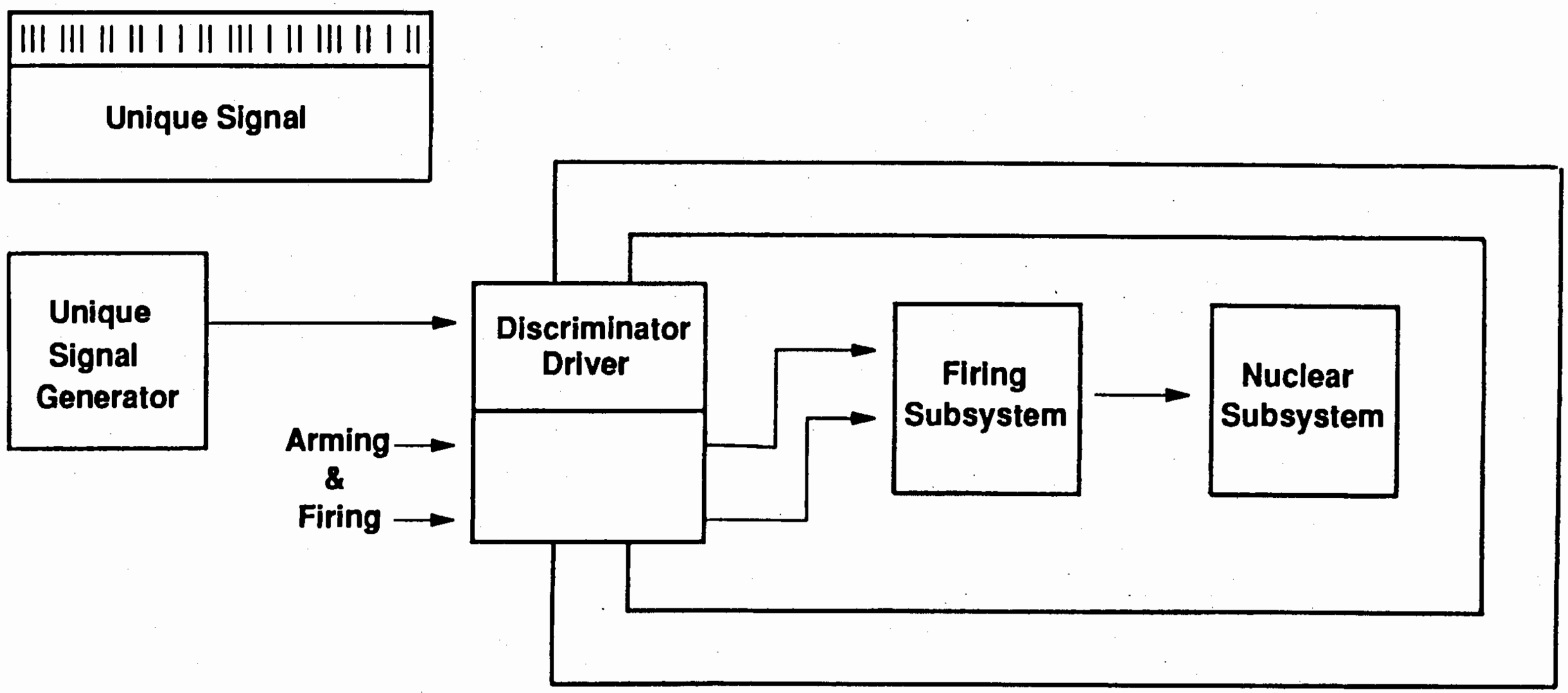
Nuclear Safety Theme
STRONG LINK



MODERN SAFETY DESIGN PHILOSOPHY (cont)

Control the strong link(s) with a unique signal -- not duplicated elsewhere in the system

Nuclear Safety Theme
UNIQUE SIGNALS

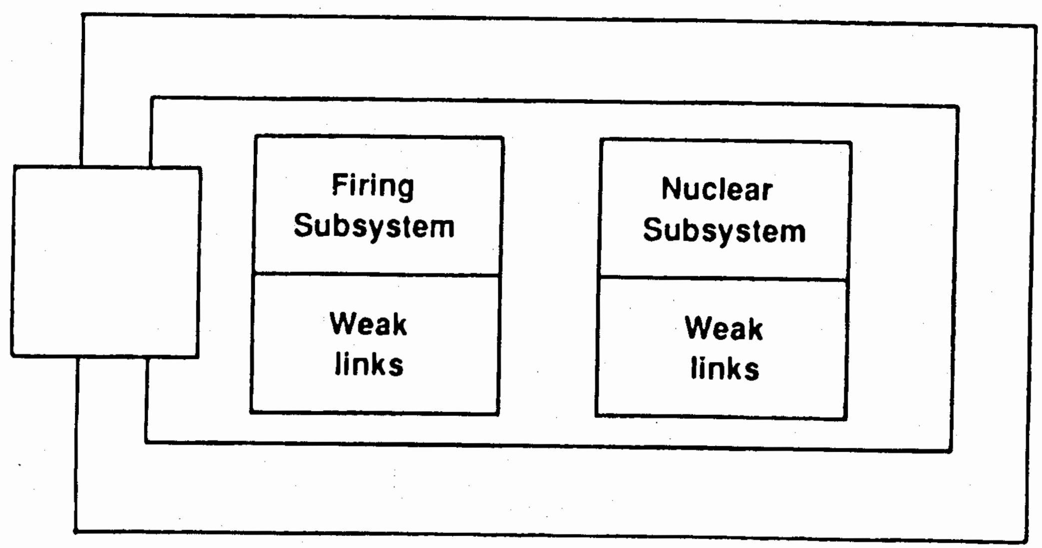


MODERN SAFETY DESIGN PHILOSOPHY (cont)

Finally, to address credible but catastrophically severe environments, co-locate *weak link* detonation-essential components which will predictably become inoperable prior to the barrier or strong links losing their integrity.

Nuclear Safety Theme

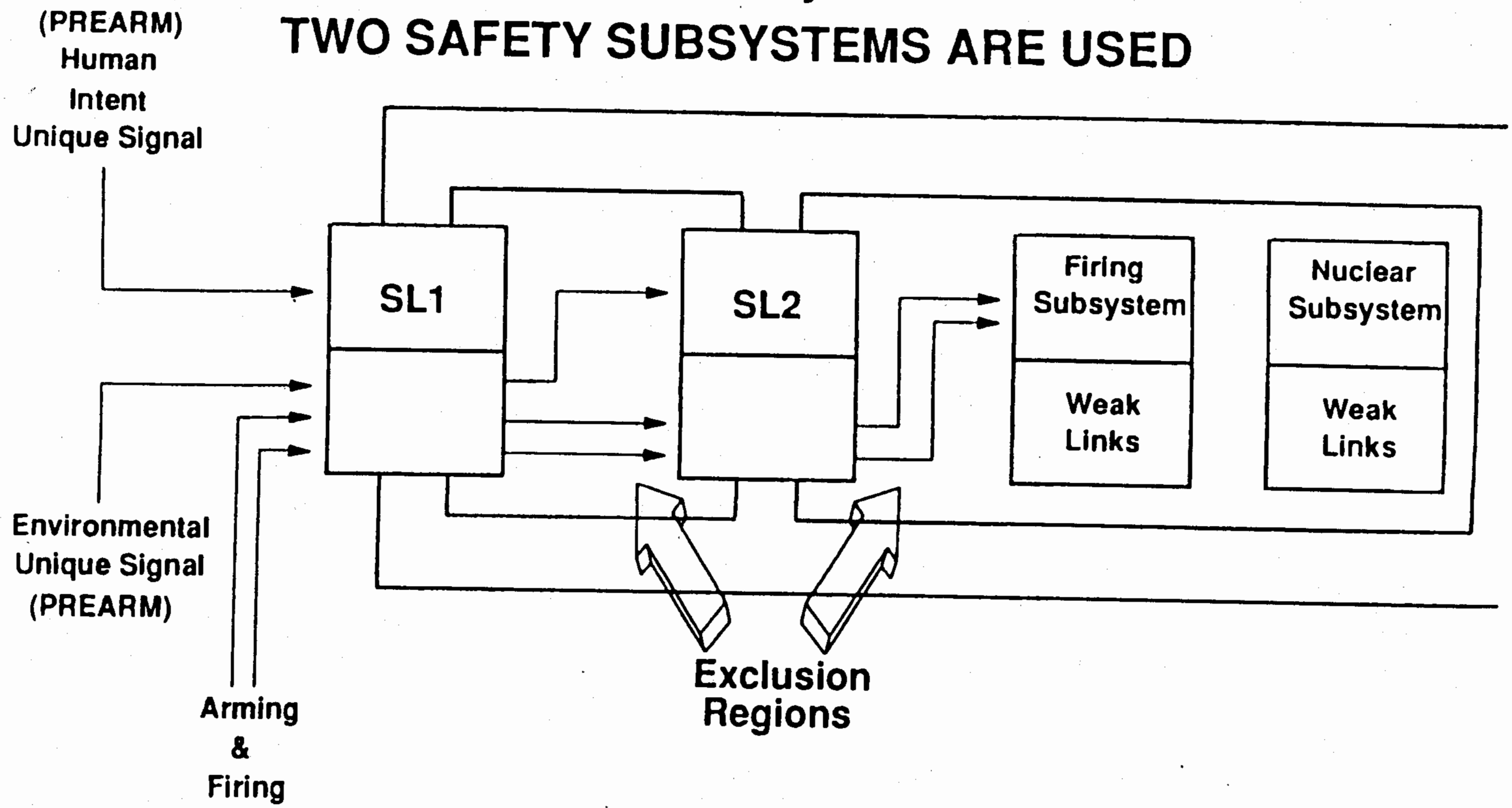
WEAK LINKS



BECAUSE THE REQUIREMENT (LESS THAN ONE-IN-A-MILLION) IS QUITE STRINGENT

Nuclear Safety Theme

TWO SAFETY SUBSYSTEMS ARE USED



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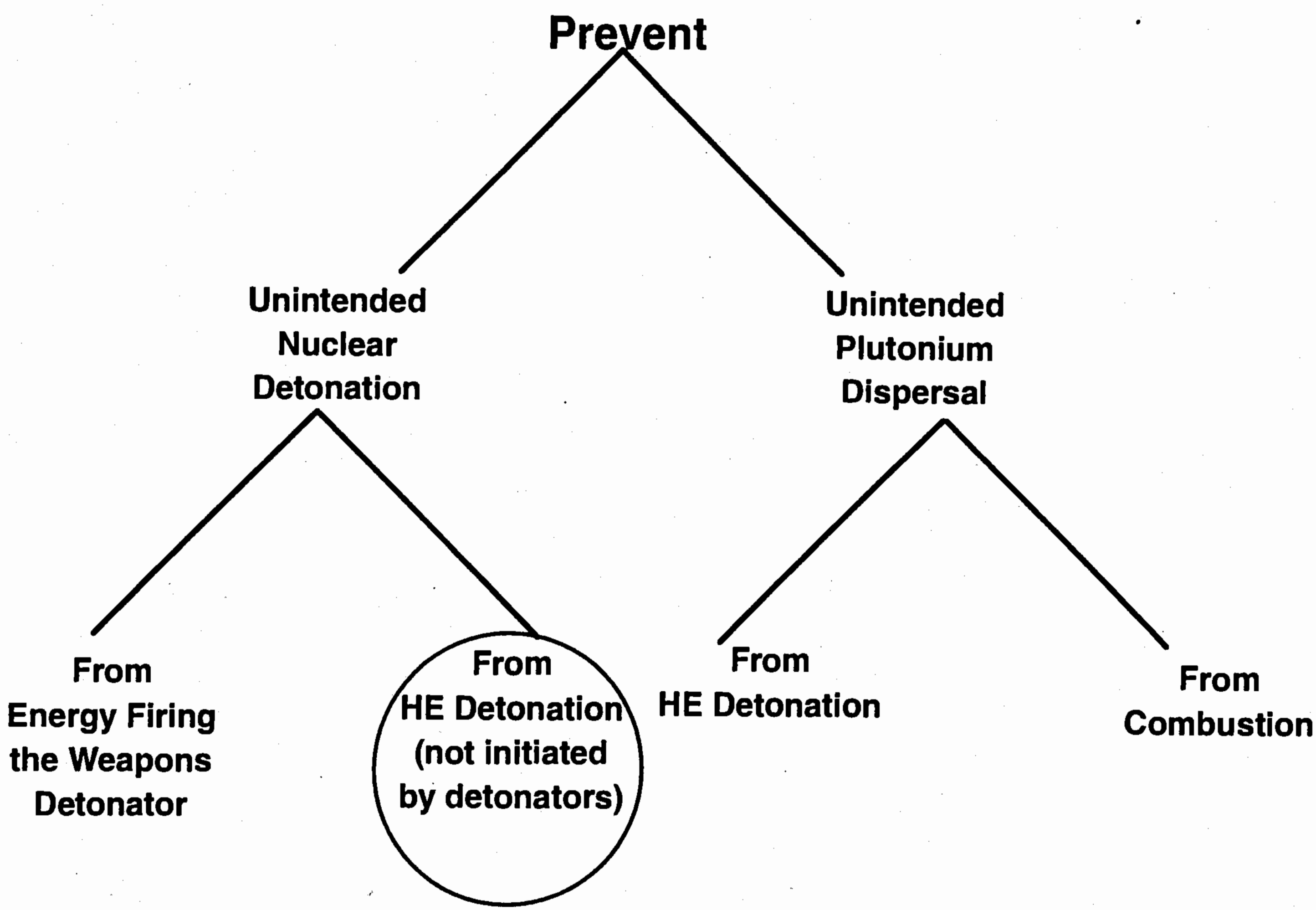
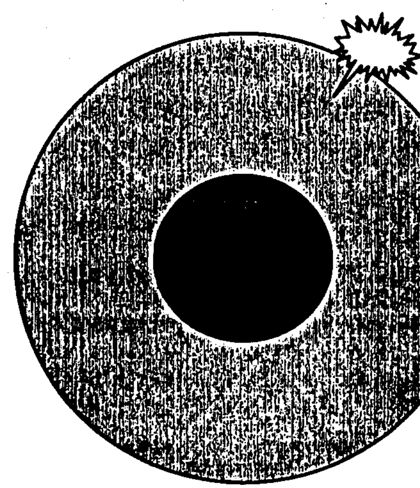

Prevent
Unintended Nuclear Detonation
Unintended Plutonium Dispersal
From Energy Firing the Weapons Detonator
From HE Detonation (not initiated by detonators)
From HE Detonation
From Combustion

ONE POINT SAFETY



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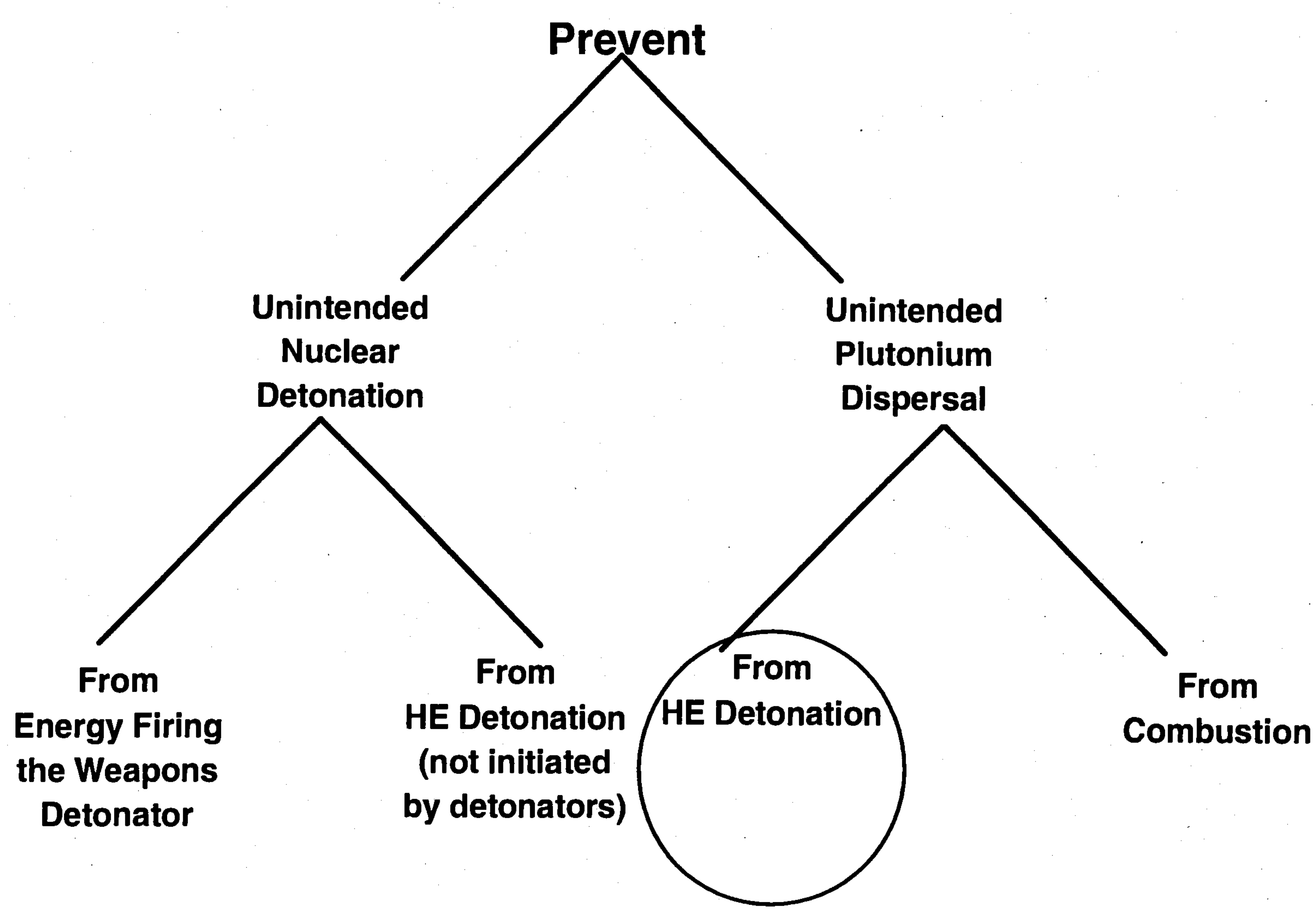

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"Failure to correct actual or perceived deficiencies in the areas of safety, security, and command and control can result in constraints being imposed on our nuclear forces that could greatly reduce their deterrent value."

April 24, 1975 White Paper distributed by ATSD (AE)

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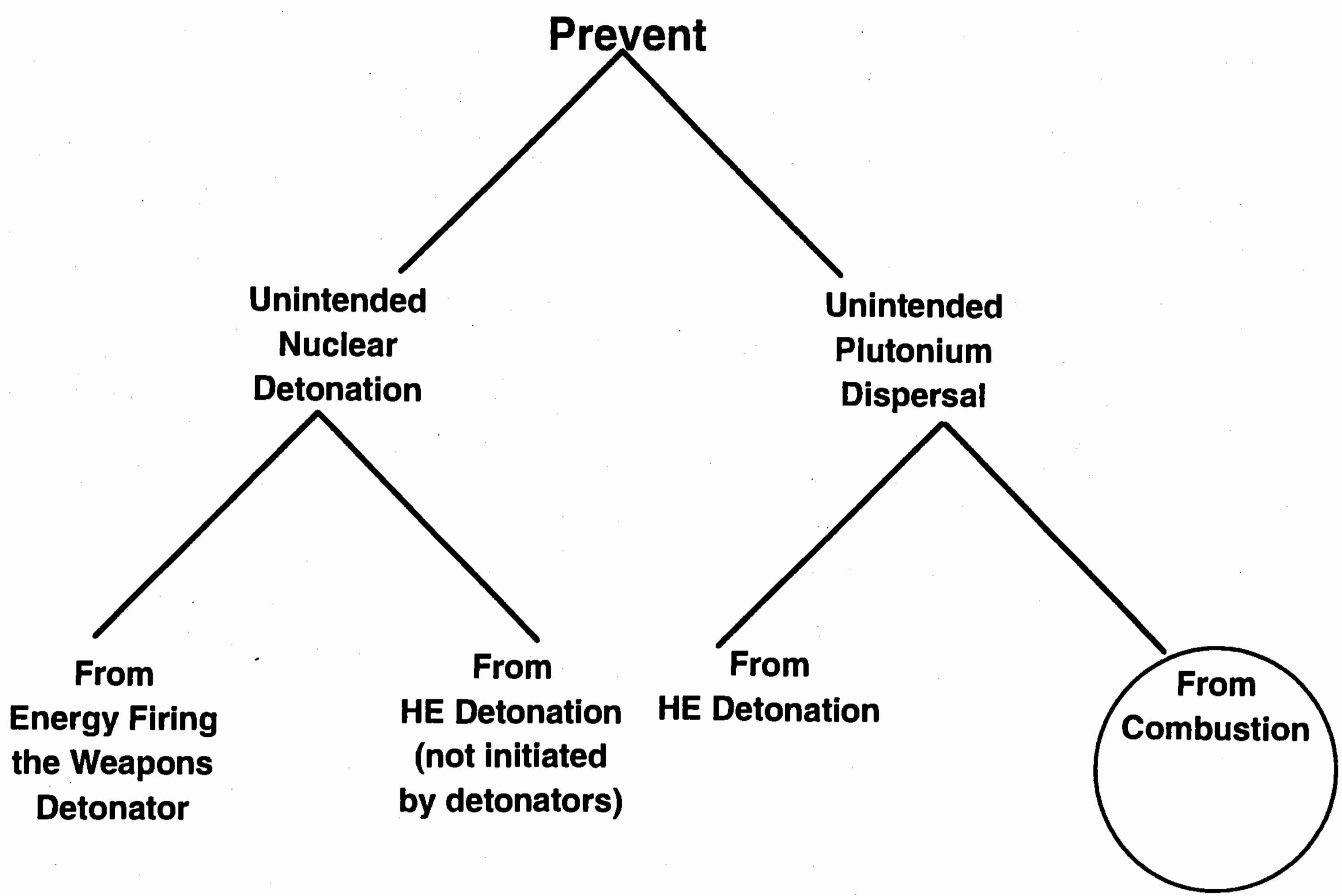

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION VIII

- PROTECTION OF NUCLEAR WEAPONS
- ACCESS CONTROL MEASURES
- USE CONTROL MEASURES

THE NUCLEAR WEAPONS ACCESS CONTROL AND USE CONTROL PROGRAMS TRY TO:

- Prevent unauthorized access to a nuclear weapon
- Prevent loss of custody of a nuclear weapon
- Prevent an intended (but unauthorized) nuclear explosion
- Prevent an intended (but unauthorized) dispersion of SNM

AND...

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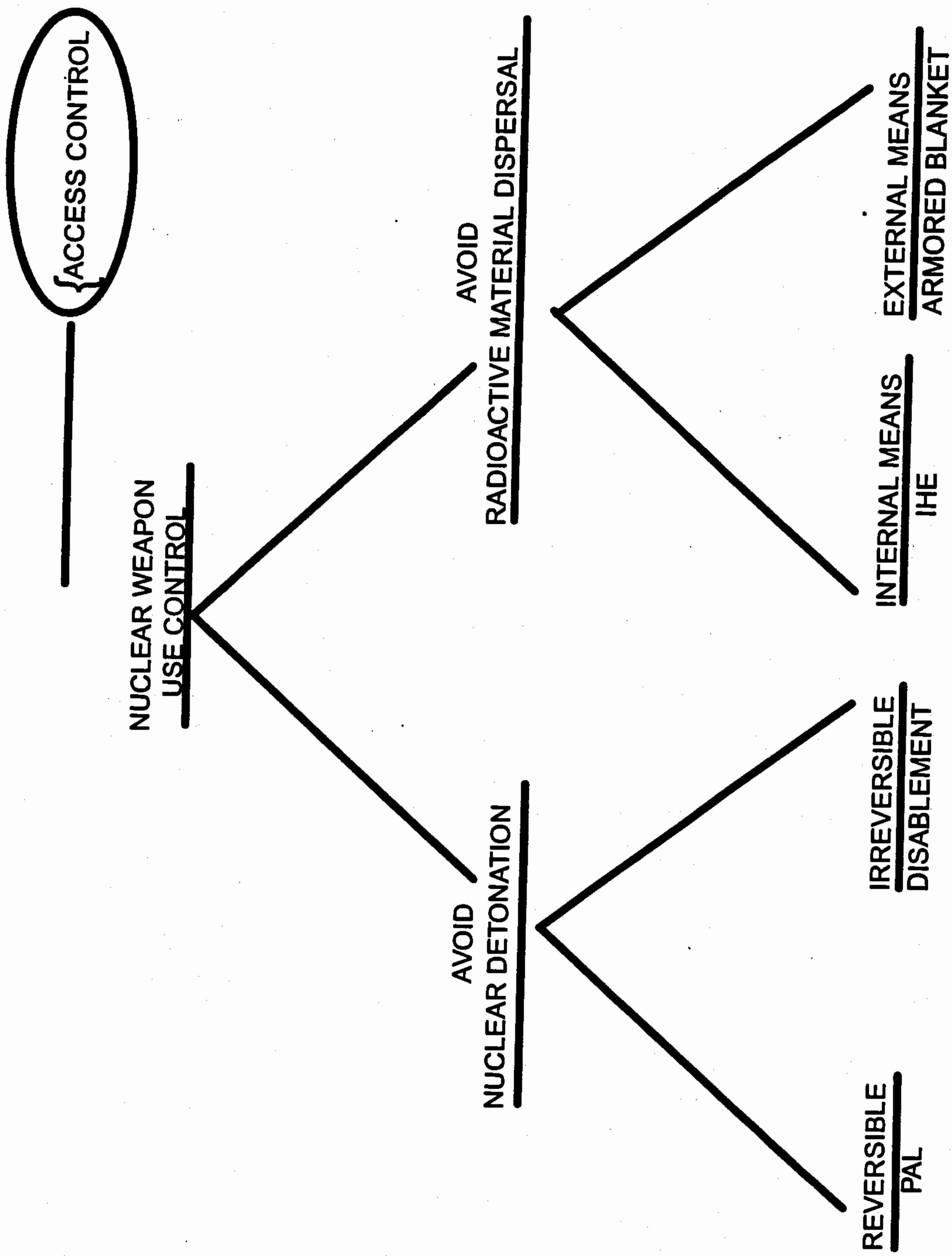
ACCESS CONTROL
NUCLEAR WEAPON
USE CONTROL
AVOID
RADIOACTIVE MATERIAL DISPERSAL
AVOID
NUCLEAR DETONATION
INTERNAL MEANS
IHE
EXTERNAL MEANS
ARMORED BLANKET
REVERSIBLE
PAL
IRREVERSIBLE
DISABLEMENT

ACCESS CONTROL (TO THE WEAPON) IS ANALOGOUS TO ACCIDENT PREVENTION - IF NO UNAUTHORIZED ACCESS (ACCIDENT) OCCURS, THERE IS LESS POTENTIAL FOR A PROBLEM.

HOWEVER, USE CONTROL FEATURES STILL ASSUME SOME LEVEL OF ACCESS CONTROL EXISTS OR CAN BE REESTABLISHED.

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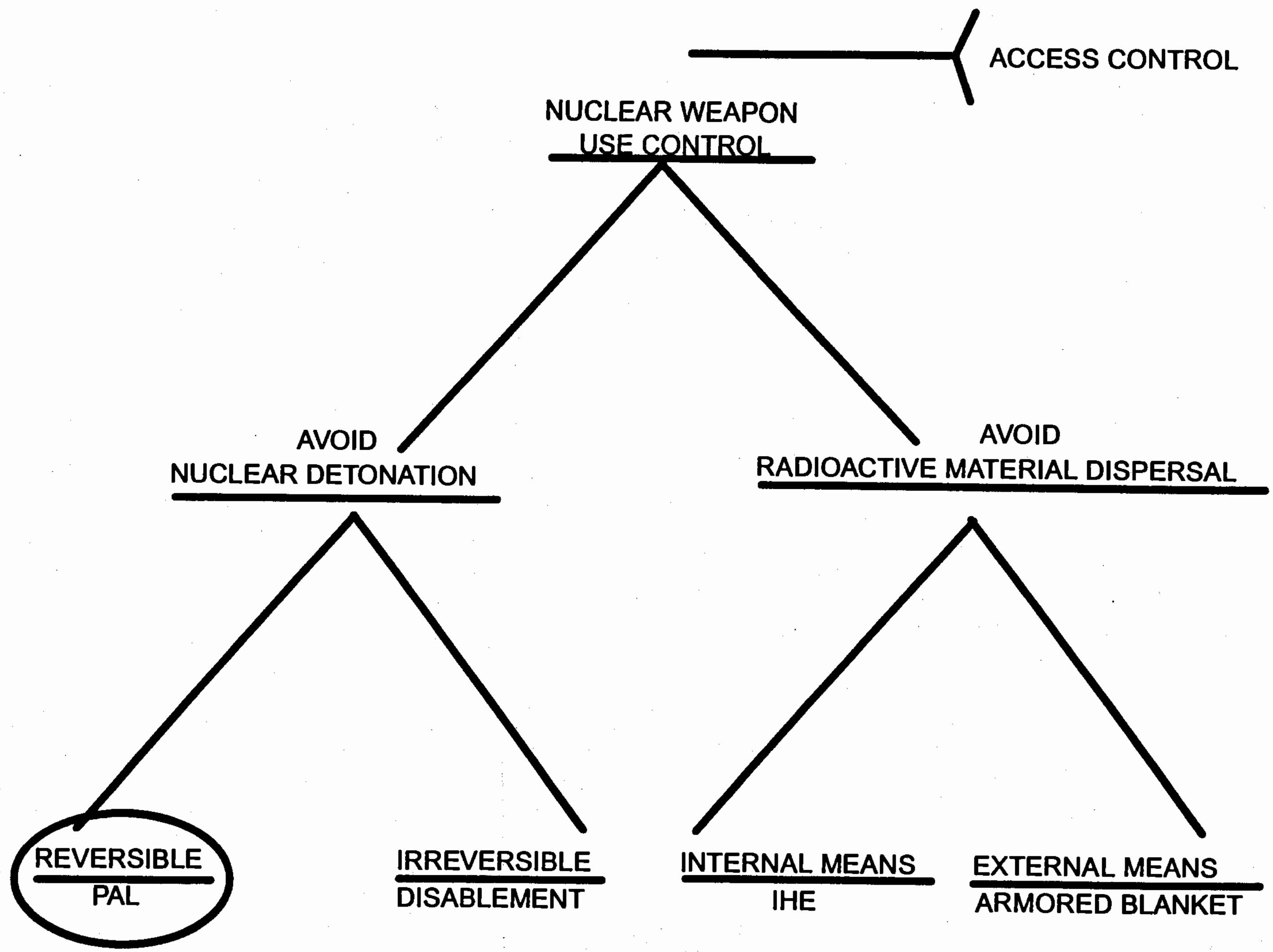

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INTENDED USE AND NON-INTENDED USE MODE OPERATION

- **Intended Use Mode**
  - **—Use of the warhead, weapon and weapon system as designed to operate when used against a target.**
- **Non-Intended Use Mode**
  - **—Detonation "in place"; operation of weapon/weapon system in other than intended use mode.**

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ENVIRONMENTAL SENSING DEVICES (ESDs)

- An open switch in the prearming circuits.

- It is closed after sensing an environment experienced by the weapon system when enroute to the target.

PAL (Permissive Action Link)

A code controlled switch which interrupts the warhead's arming circuit

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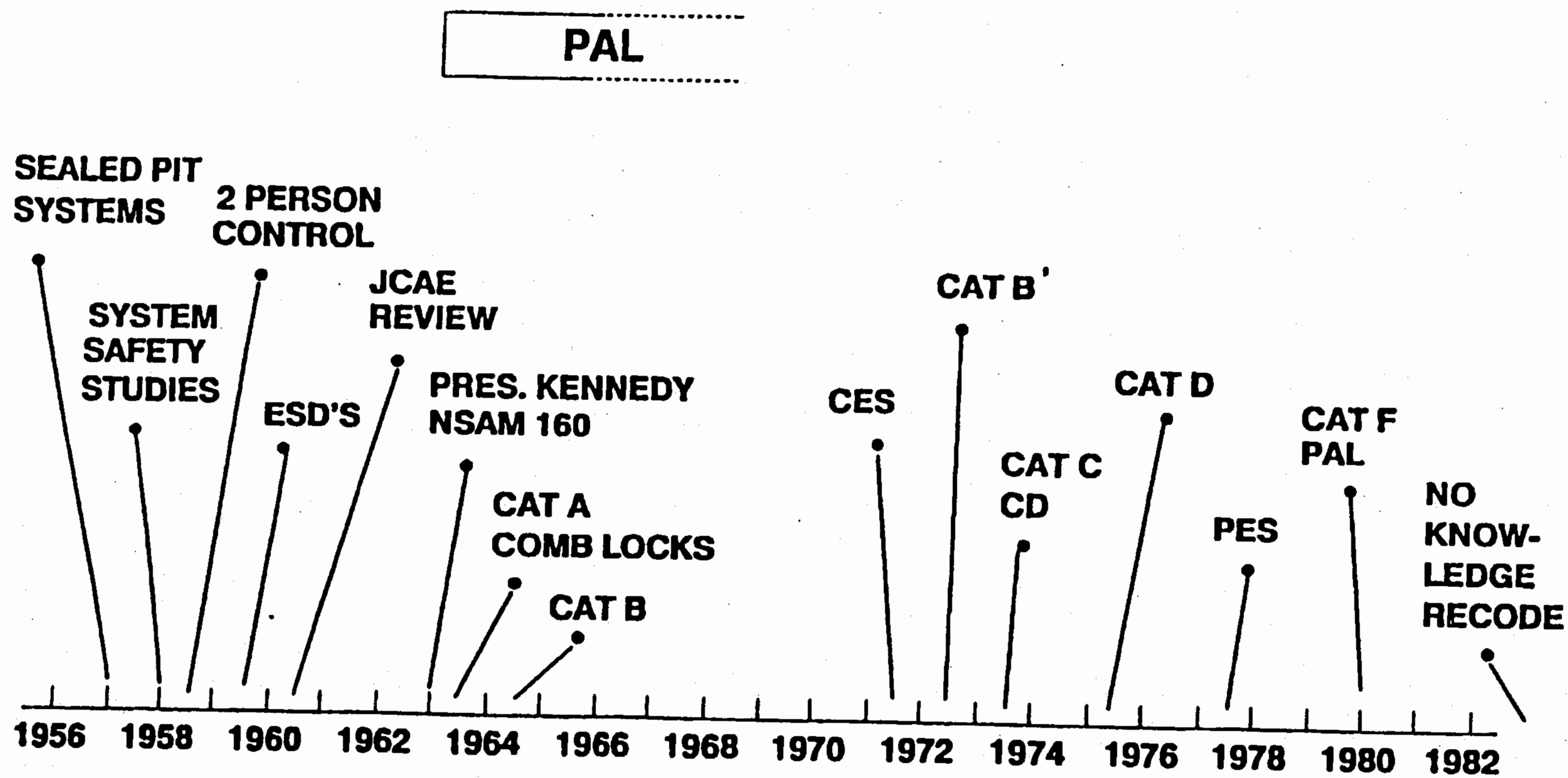
EVOLUTION OF NUCLEAR WEAPON USE CONTROL



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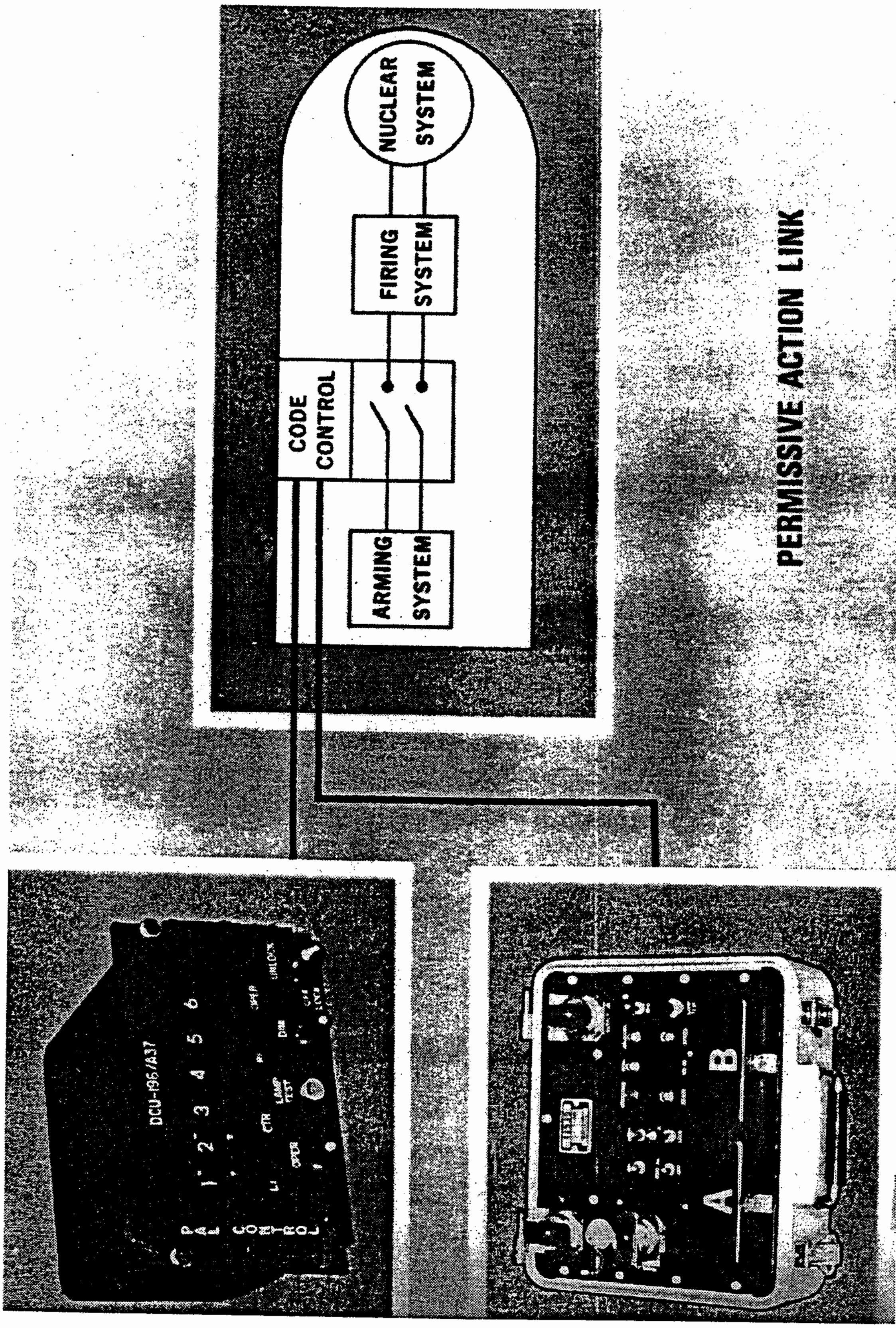

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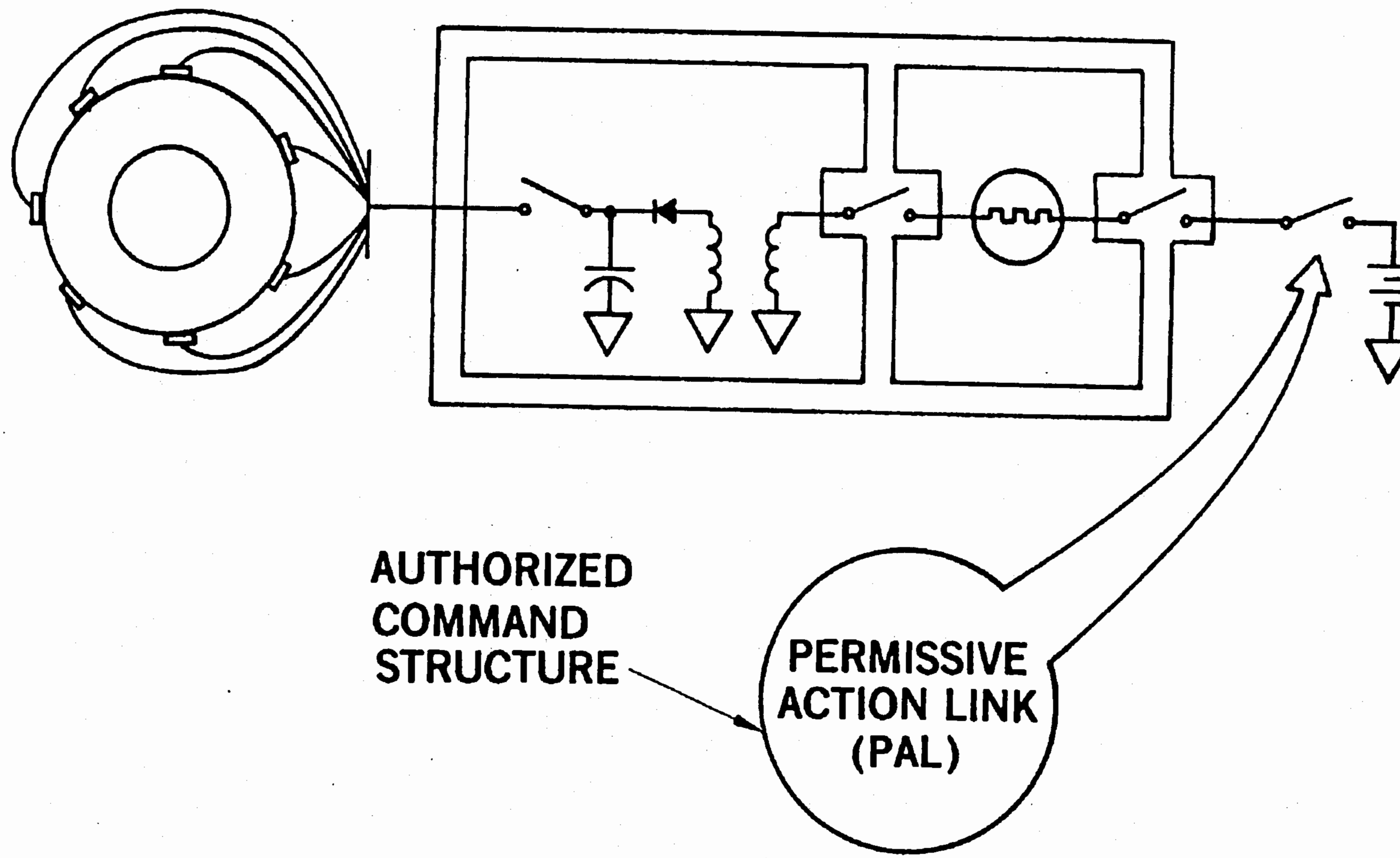
CONTROL - USE DENIAL



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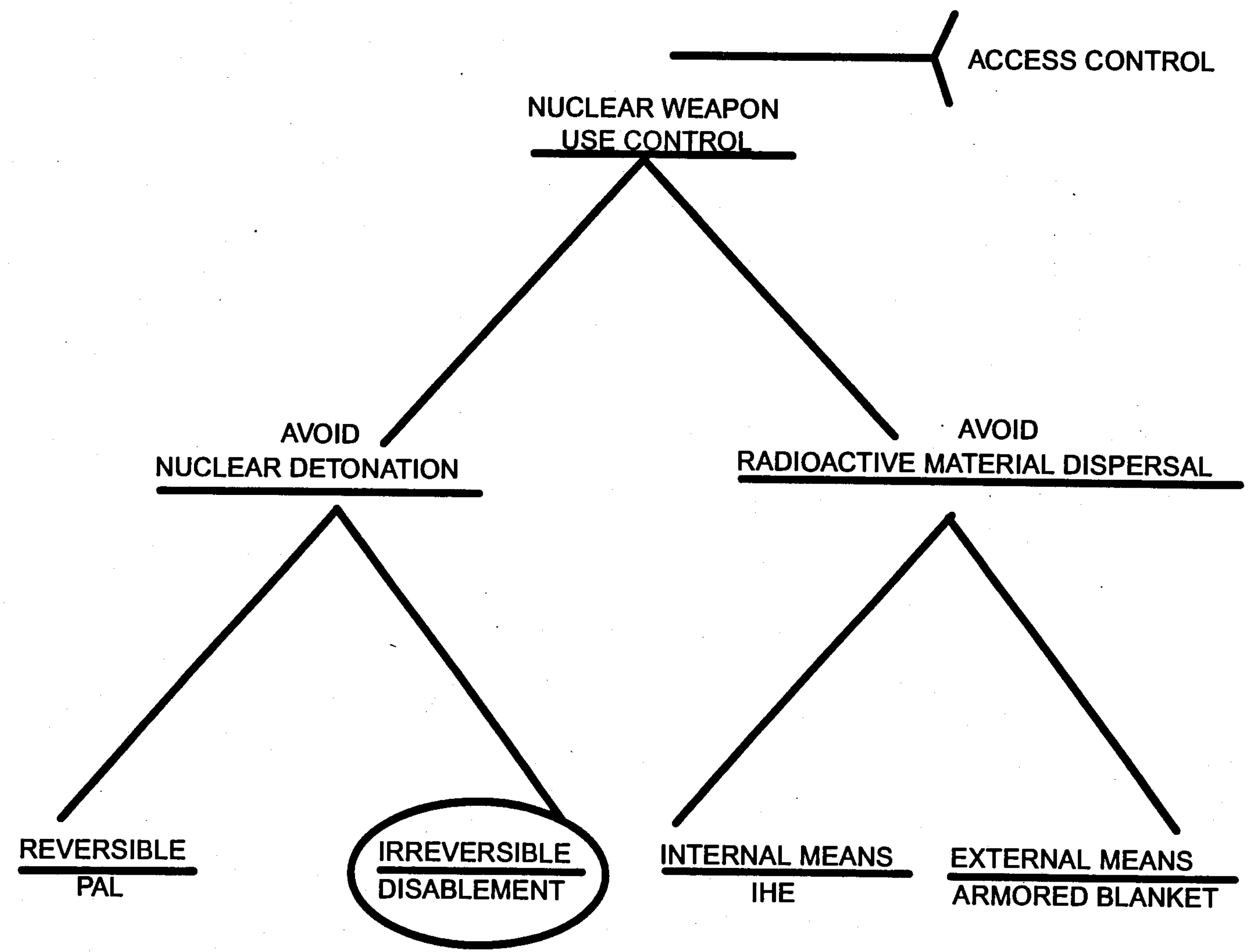

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DISABLEMENT

- When initiated, disables certain key nuclear detonation-essential components.

- Non-violent outside the weapon case.

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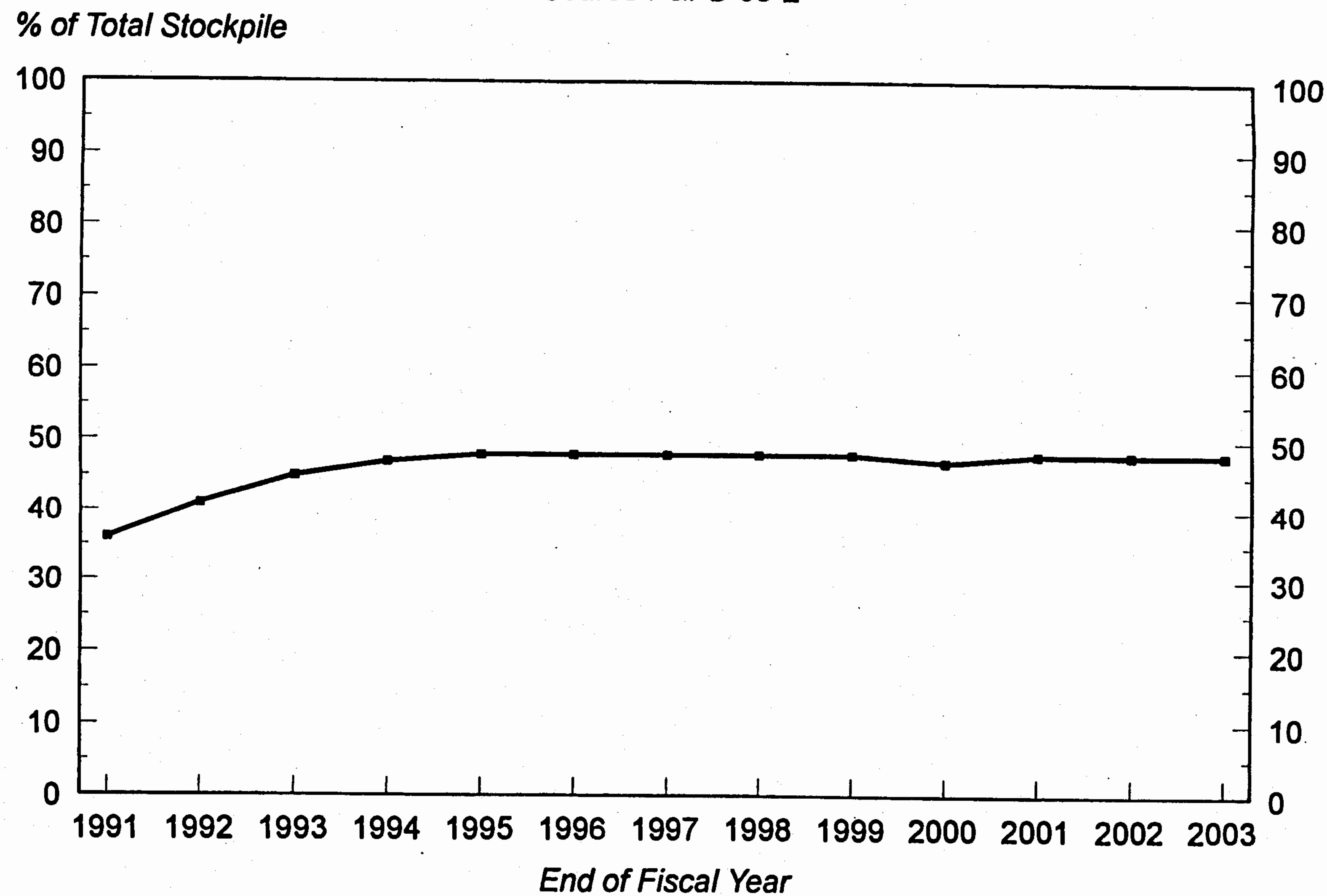
COMMAND DISABLEMENT

Source P&PD 93-2



DOE b(3)

DOE b(3)

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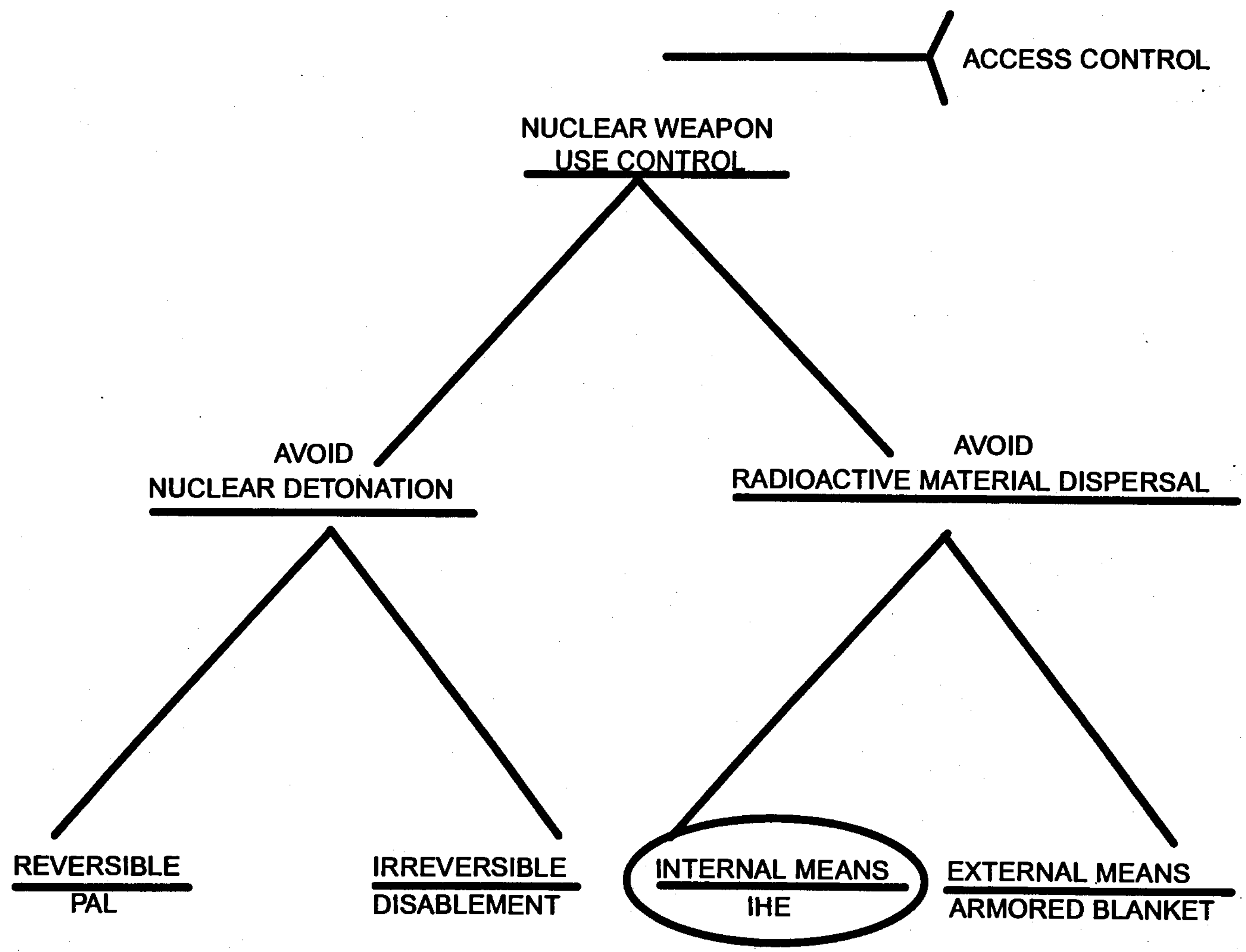

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An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

- System 1 offered many improved features in safety and compatibility.
- The requirements for a Unique Signal Generator (USG) first appeared in July 1975 to enhance weapon safety in abnormal environments.
- The requirements for CAT D PAL first appeared in August 1975.
- The requirements for Command Disable (CD) first appeared in October 1981 to provide the ability to render a weapon useless from the cockpit.
- All aircraft nuclear weapon interfaces built to date have been analog.
- A system 2 AMAC specification exists that defines a digital interface for possible use in future nuclear weapons.

[redacted] UNCLASSIFIED

An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

- The result of this effort resulted in the T249 AMAC for bomber and fighter aircraft usage.

- New bombs designed during the mid to late '50s were made compatible with the T249 rather than building a unique AMAC for a specific bomb.

- AMAC design specifications, defined jointly by the DOE and DoD, first appeared in December 1961.

- The requirements for Category (CAT) B Permissive Action Link (PAL) first appeared in June 1963 to enhance weapon security.

- Today's nuclear-capable aircraft, with few exceptions, have what is known as a System 1 AMAC interface.

- The System 1 specification first appeared in September 1963.

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An Overview of the Evolution of Aircraft Monitor and Control (AMAC) Systems

–The AMAC acronym was created to describe the unique "black boxes" that monitor and control nuclear weapons.

–As bomb technology evolved in the late 1940s so did the "black boxes."

–The Mk5 bomb (1950) was the first bomb to incorporate a remote control arm-safe switch.

–1952 saw the first fighter-carried bombs with external carriage versions of the Mk7, Mk8, and Mk12. At this time there were three different AMAC controllers (T18, T19, and T35) for bomber aircraft and one for fighter aircraft (T145).

–Early AMACs were burdensome for the fighter pilot to use due to multiple switching functions.

–In 1954 Sandia started a program to simplify AMAC functions for new weapons under development.

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Sandia Has Total Responsibility for Bombs
--Scans Nuclear--

- Design to include case, radar, non nuclear components, parachute, etc.
- Testing
- Weapons interface
- Stockpile support
- Command and control - electrical and mechanical

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(COLOR PHOTOGRAPHS OF THE 9 WEAPON SYSTEMS OF THE ENDURING STOCKPILE)

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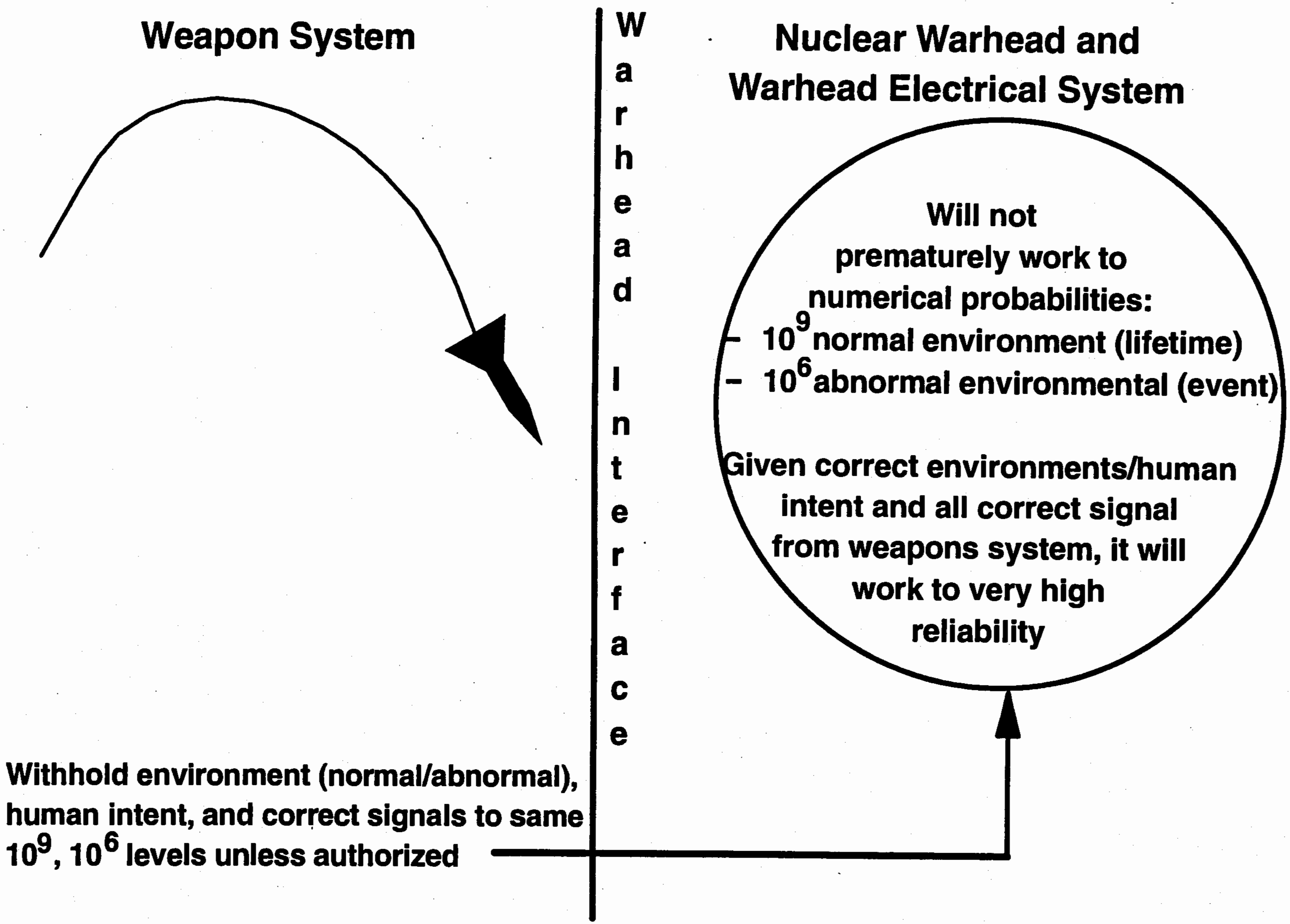
BALANCED NUCLEAR SAFETY CONCEPT



Documents Establishing DoD's Program Requirements

- Military Characteristics (MCs)
- Stockpile-To-Target Sequence (STS)
- Military Department/DOE agreement on the division of responsibilities for the specific weapons program
- Initial Operational Capability (IOC) & warhead quantities per Nuclear Weapons Stockpile Memo (NWSM)

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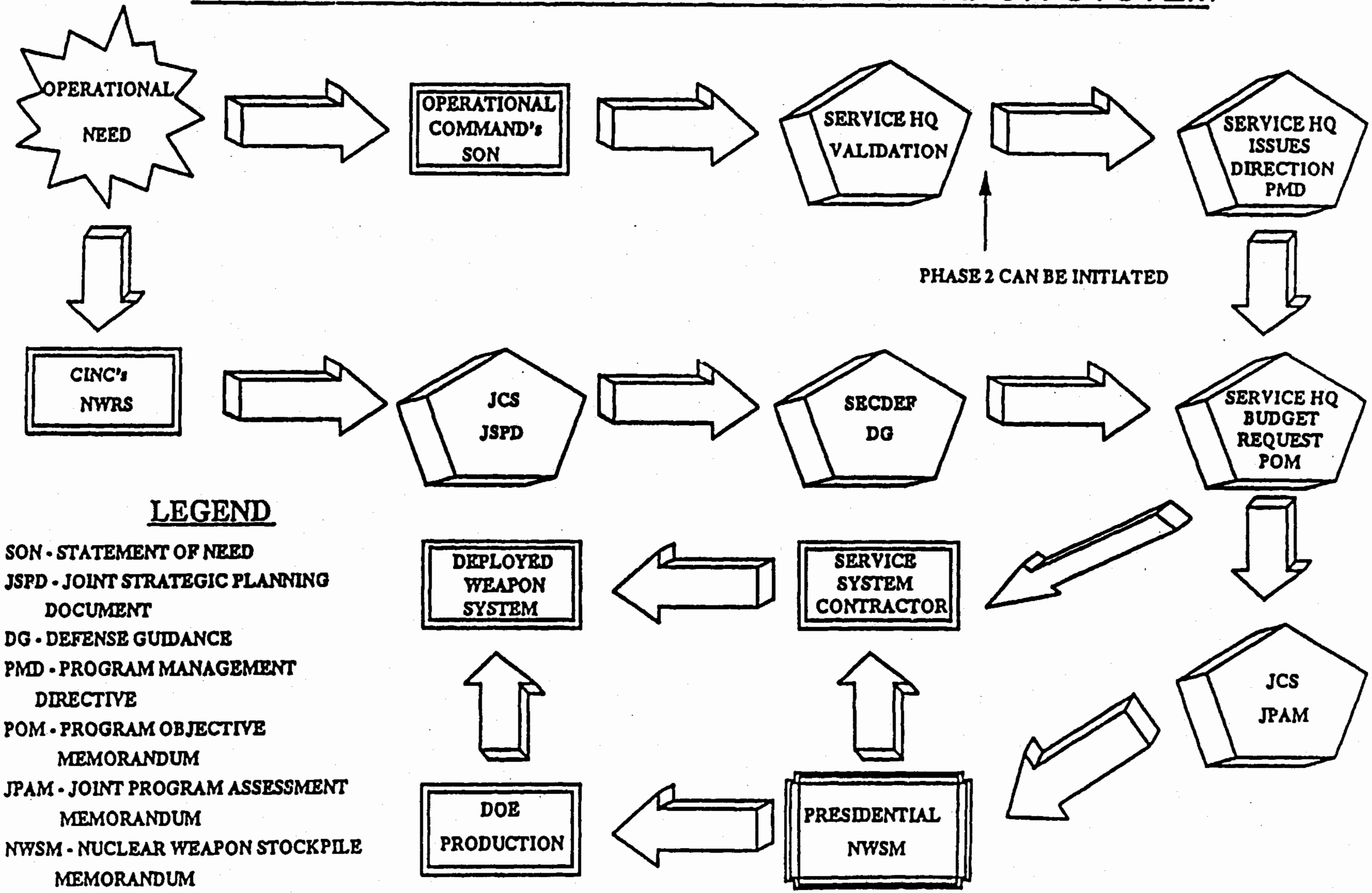
PROCESS LEADING TO A DEPLOYED WEAPON SYSTEM



LEGEND

SON - STATEMENT OF NEED
JSPD - JOINT STRATEGIC PLANNING DOCUMENT
DG - DEFENSE GUIDANCE
PMD - PROGRAM MANAGEMENT DIRECTIVE
POM - PROGRAM OBJECTIVE MEMORANDUM
JPAM - JOINT PROGRAM ASSESSMENT MEMORANDUM
NWSM - NUCLEAR WEAPON STOCKPILE MEMORANDUM
NWRS - NUCLEAR WEAPON REQUIREMENT STUDY

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Nuclear Weapons Council Staff

- NWCSC established by Secretary of Defense memo
- Members:
  - DOE/Deputy Assistance Secretary Military Application (DASMA)
  - Office of Secretary of Defense (OSD) - Assistant to the Secretary of Defense - Atomic Energy (ASTD (AE))
  - Joint Chiefs of Staff (JCS)
  - Military Services (2 each - 1 vote)
  - United States Marine Corps has separate vote from Navy
- Observers:
  - DNA, PA&E, TWP/OM, S&TNF, ISP, SDIO, OASD (C), C31/NSS

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Nuclear Weapons Council History

- First meeting occurred February 1987
- Established interim procedures;
  - Nuclear Weapons Council Standing Committee (NWCSC) "Staffing Body"
  - Tasked NWCSC to propose list of actions and delegated actions
  - NWC will meet by exception (paper staffing)
  - Action items vs. letters between Departments

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Nuclear Weapons Council

- Established by 1987 Authorization Act
- Members
  - Director, Research & Engineering; Chair
  - Vice Chair, Joint Chiefs of Staff
  - DOE Assistant Secretary Defense Programs
- Military Liason Committee abolished

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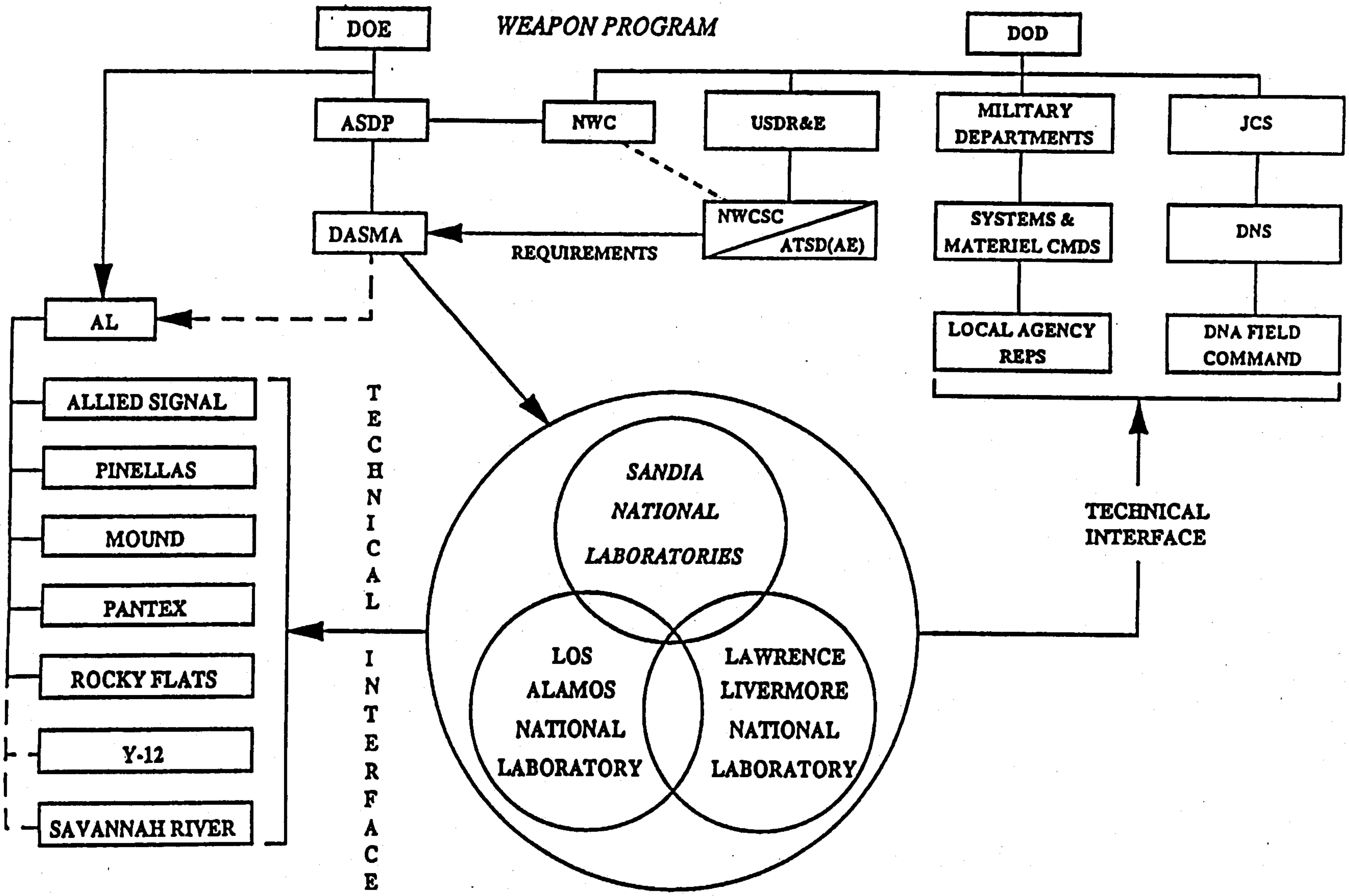
SANDIA-DOE/DOD INTERFACES



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Principle Elements of a Nuclear Weapon System

Physics Pkg.	Warhead Electrical System	Interface	Delivery System
Fissile Material	Fire Set	Carrying Package	Hand (ADM)
High Explosive	Power Source	Arming Logic	Truck (ADM)
Detonators	Neutron Source	Fuzes	Artillery
		RV Case	Aircraft/Bomb
		Parachute	Rockets
		Etc.	Missile
			Torpedo

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION IX

- WEAPON SYSTEMS
- REQUIREMENTS
- NUCLEAR WEAPONS SYSTEMS FOR ENDURING STOCKPILE
- AIRCRAFT INTERFACE

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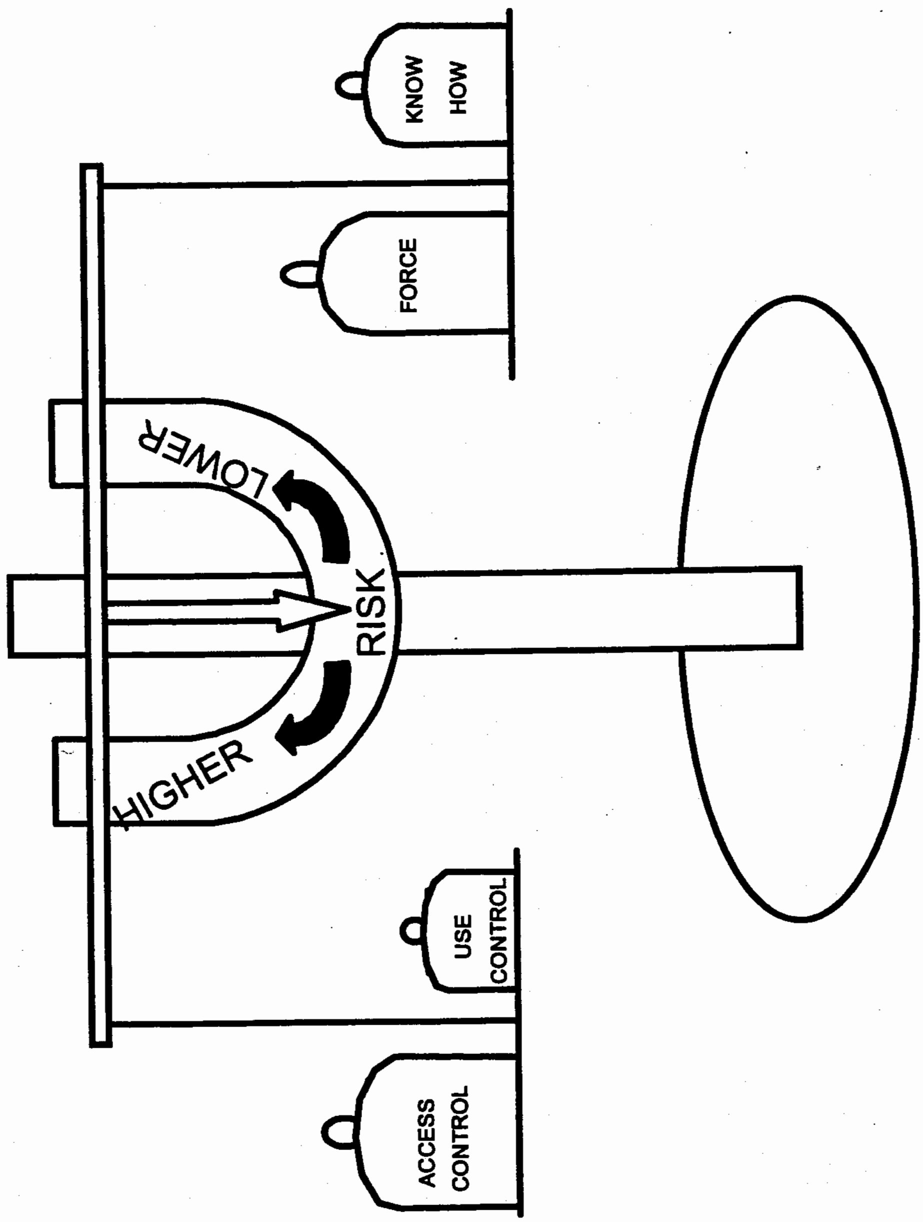
KNOW HOW
FORCE
LOWER
RISK
HIGHER
USE CONTROL
ACCESS CONTROL

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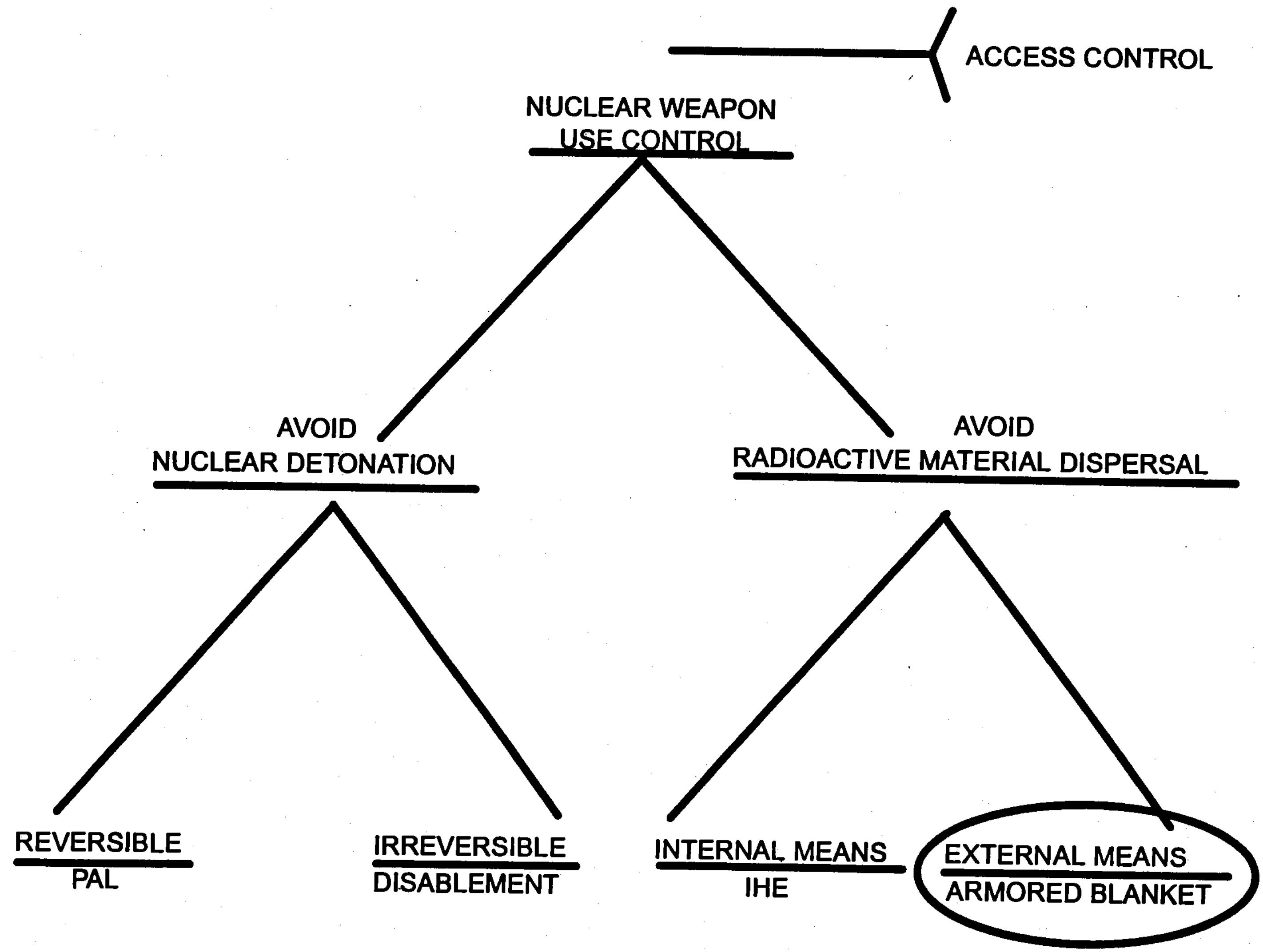

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CURRENT WEAPON/AIRCRAFT NUCLEAR CAPABILITIES

	USAF					
	B-1B	B-52H	B-2	F-16C,D	F-111E,F	F-15E
B61-3				X	X	X
B61-4				X	X	X
B61-7	X	X	X*			
B61-10				X	X	X
B83-0	X	X	X*			
B83-1	X	X	X*			
B53-1		X				
W80-1		X				

*Planned

DoD b(1)

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The pressure on the Nuclear Warhead Community has been to reduce the warhead size and weight yet maintain high yields and flexibility

- The weapons system drive to achieve greater range and increase operational flexibility or survivability is directly tied to weight and volume of the nuclear warhead
- A rule of thumb for missiles and aircraft is for every 1 lb weight saved in payload it saves 10 lbs in systems weight
- Strategic aircraft are sensitive to the weight/volume and therefore number carried, the flexibility and target coverage
- Tactical aircraft with external stores are even more sensitive to weight and volume because of the increase drag associated with increase diameter (present area)

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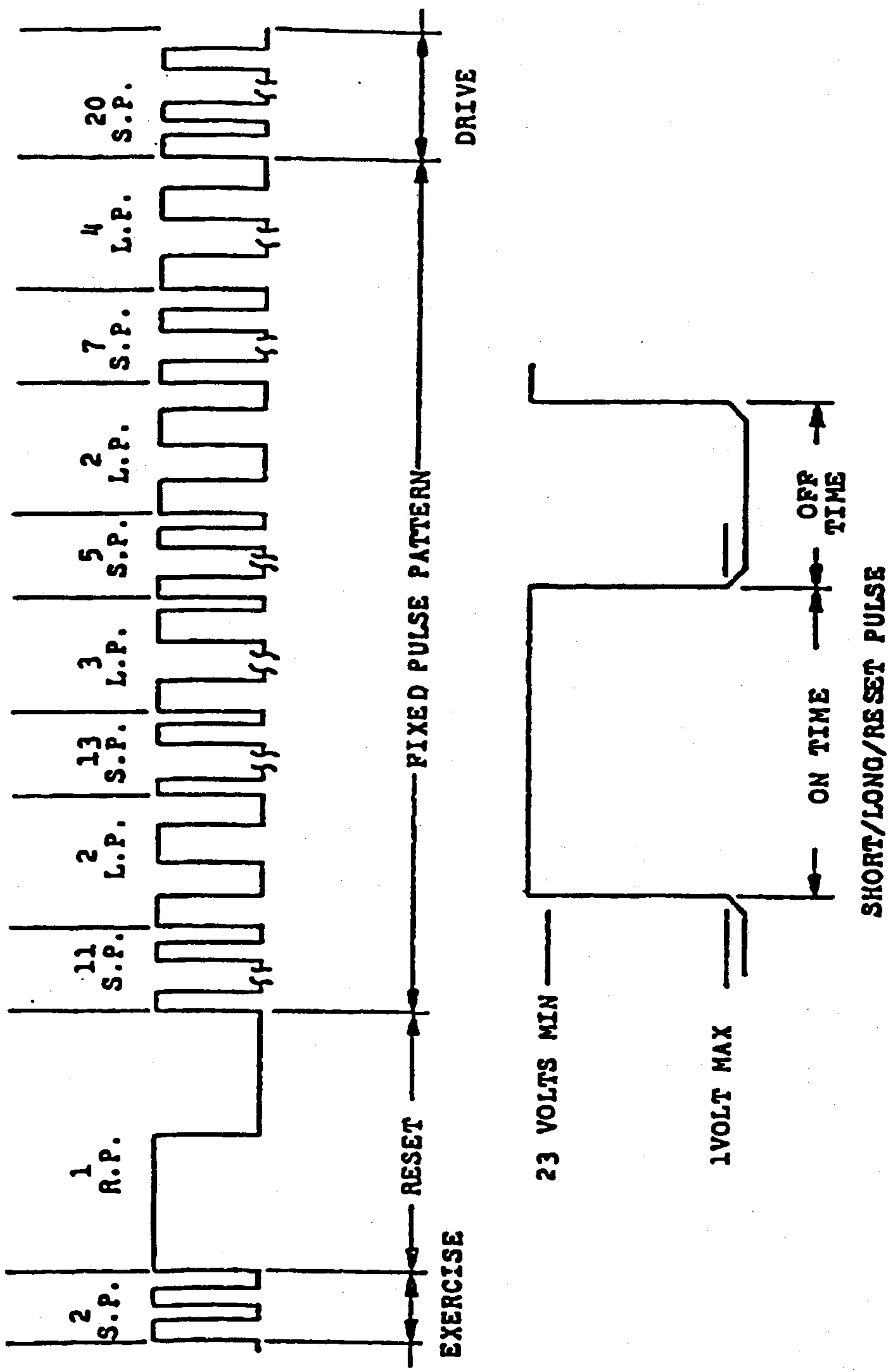

NOTE: The ON pulse (3.1.2.h) shall be above 23 V min. for at least the min. ON TIME and may be above the 23 V min. for the max. ON TIME. The ON pulse shall not be above 1 V max. for greater than the max. ON TIME. The OFF pulse shall be less than 1 V for at least the min. OFF TIME.

Figure 2. Unique Signal Format

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SURVEY OF WEAPONS DEVELOPMENT AND TECHNOLOGY

WR708

SESSION X

- Nuclear Weapons Dismantlement

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Dismantlement Topics

- Process
- Magnitude
- DOE/Labs Organiztion
- Technology Applications
- Laboratories Increased Presence at Pantex
- Lab-to-Lab Interchanges with Russians

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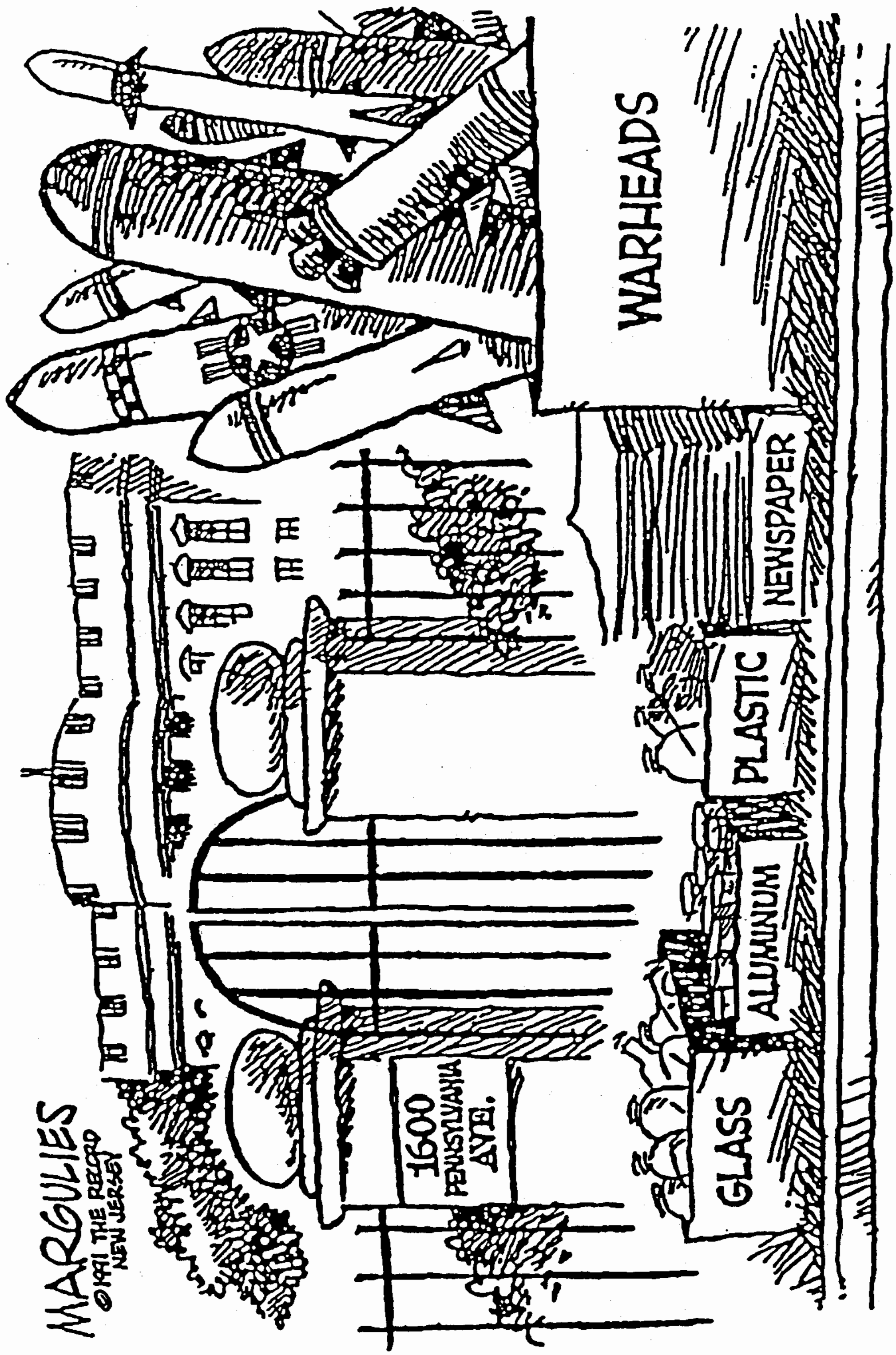

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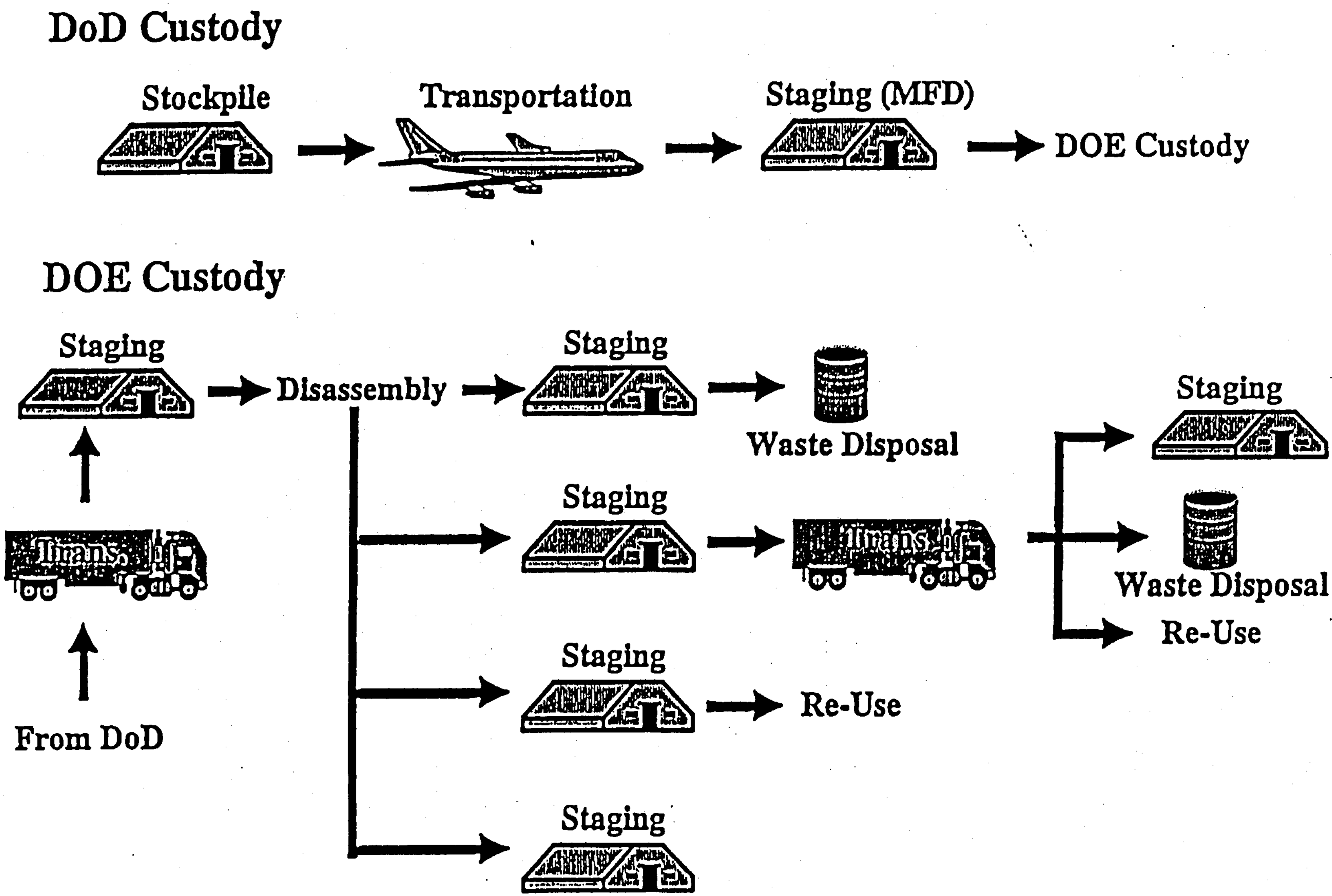
Nuclear Stockpile Dismantlement Process



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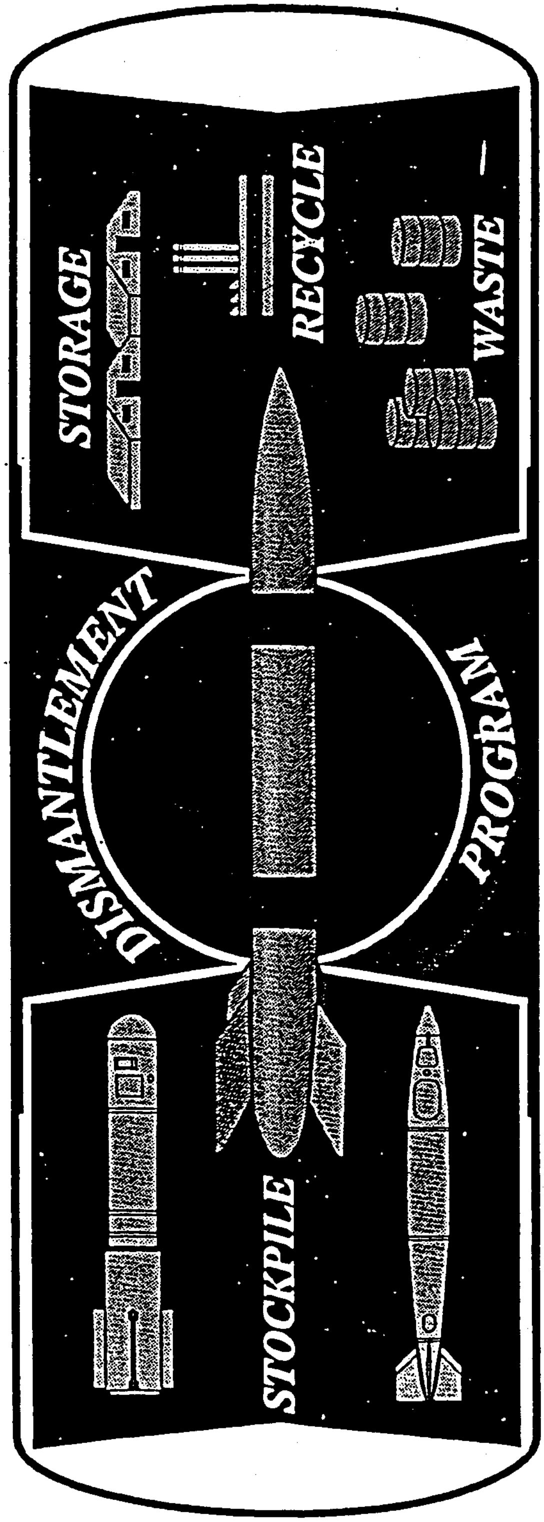
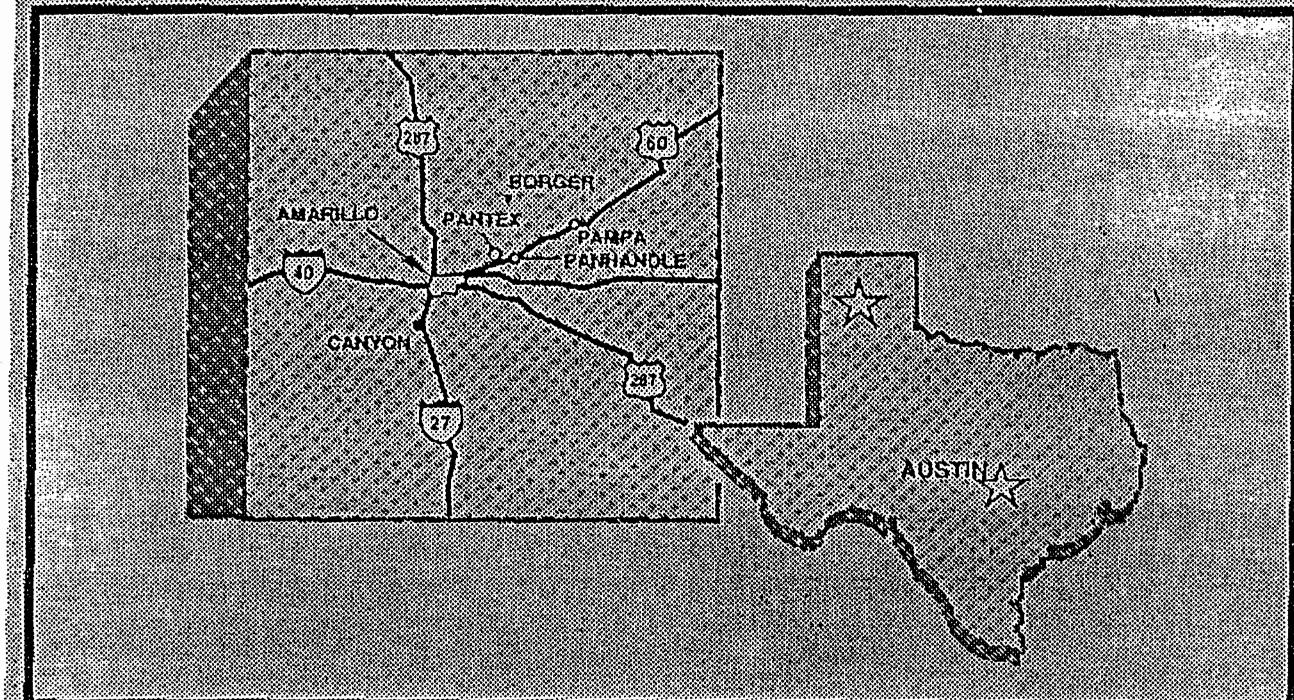

STORAGE
RECYCLE
WASTE
DISMANTLEMENT
PROGRAM
STOCKPILE

[redacted] UNCLASSIFIED

PANTEX PLANT LOCATION



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Pantex Organization Responsibilities

- Government owned facility
- DOE Amarillo Area Office (reports to AL)
  - Administers operating contract
- Mason & Hanger - Silas Mason Co., Inc.
  - Management and operating (M&O) contractor
- Battelle Memorial Institute
  - Subcontractor for Environment, Safety, and Health (ES&H)
- Sandia National Laboratories
  - Operates Weapons Evaluation Test Laboratory (WETL)

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Pantex Plant Statistics

- $190M operating budget
- 2945 employees
  - 2600 M&H
  - 250 Battelle
  - 78 AAO
  - 17 Sandia
- 16,000 acres
- 2.5M sq. ft. buildings (425 units)

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Size of Dismantlement

- Pantex capability approximately 2000 per year
- Backlog of weapons
- Retirements continue
- Taper off to support retirements as they occur

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DoD 4(?)

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Stockpile (P&PD 93-2)

SRD Viewgraph

Shows

Stockple, Reserves, and Retiring

(Not included herein)

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Department of Energy
Executive Mangement Team for Dismantlement

- Formed by DASMA
- Covers all aspects of retirement, return, disassembly, waste characterization, and disposal
- Develop integrated departmental positions and strategies for dismantlement
  - Internal to DOE
  - With DoD
- Membership with DoD
  - DOE/AL, DOE/HQ, LANL, SNL, LLNL
  - Reports to DASMA weapons panel

Department of Energy
Executive Management for Dismantlement

DOE/AL	Deborah Monette	Chair
DOE/HQ	Karen Lombardo	Exec Sec
LANL	Mike Kelly	
LLNL	Jerry Dow	
SNL	Paul Longmire	

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Dismantlement Priorities

- Weapons Shipment Planning
  - Priority based on risk analysis
- Material Destination - Disposal
  - Identification
  - Characterization
  - Obey Laws
- Storage of SNM
  - Keep at Pantex until better solution found

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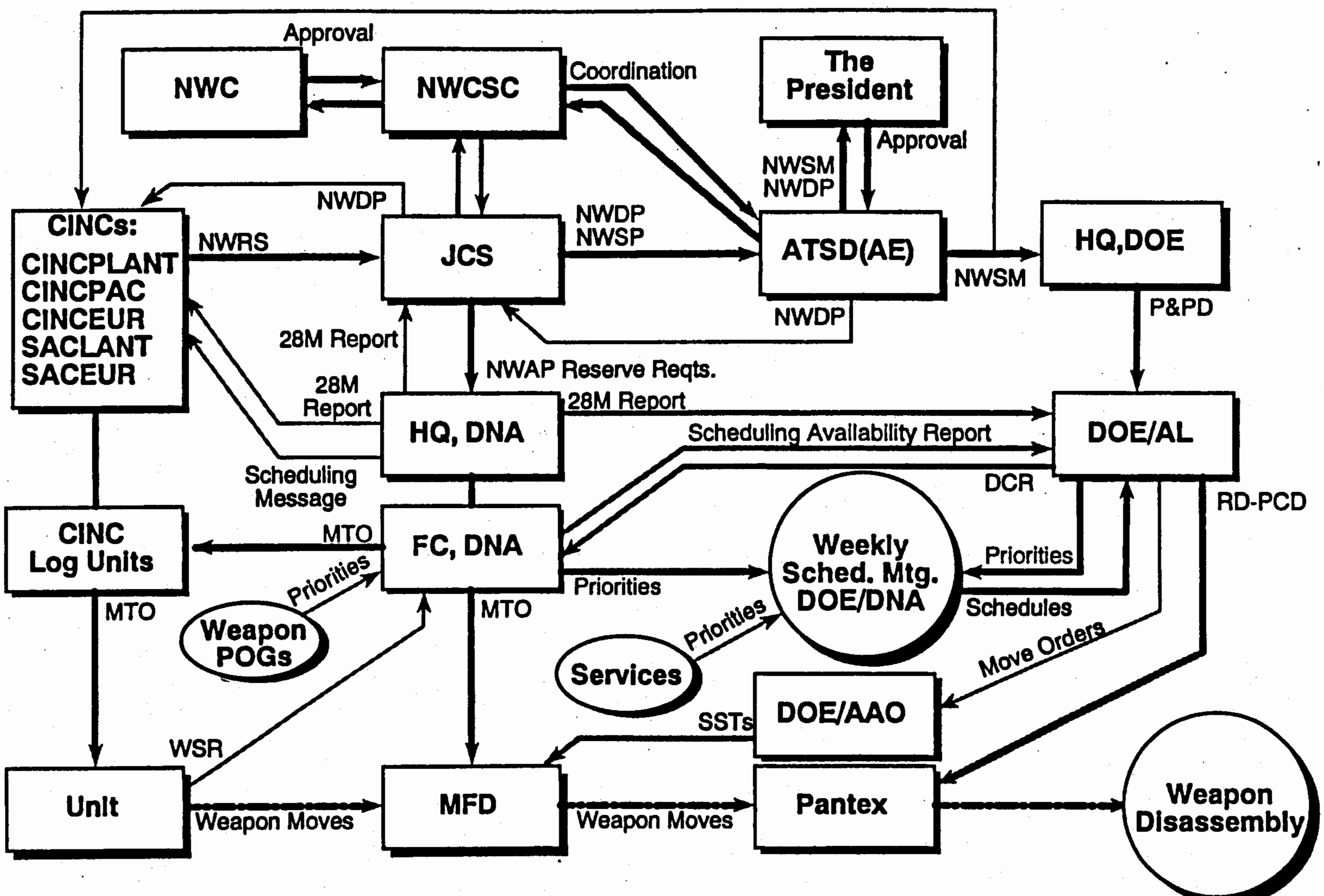
DISMANTLEMENT PRIORITIZATION PROCESS



Dismantlement Prioritization Working Group

- Joint DOE/DoD group chaired by Sandia
- Initial phase identified and ranked weapons based on weapon features
- Dismantlement process from initial retirements to disposal was defined
- Influences that determine priorities were identified
- DOE issues such as staging requirements and transportation assets were examined
- Software written to process data
- Group continues for information exchange and planning assistance

NEW LIST FOR FOIA AS OF JAN. 5, 2001

1. A DOCUMENT OF LOW-YIELD NUCLEAR EXPLOSION CALCULATIONS: THE 9/22/79 VELA SIGNAL (U) BY E.M. JONES, R.W. WHITAKER, H. G. HORAK AND J. W. KODIS, LA- 9062, SAC200122580000, ISSUED ON MAY 1982
2. A DOCUMENT OF SYSTEMS RESEARCH REPORT ON A METHOD FOR AUTOMATED RECOGNITION OF SATELLITE RADIOMETRIC WAVEFORMS (U) BY CHARLES V. JAKOWATZ, JR., PAUL A. THOMPSON, SANDIA NATIONAL LABORATORIES, RS 0310/85/268, SAC200122590000, ISSUED ON NOVEMBER 1, 1985
3. A DOCUMENT OF J-14 FILE COPY, ISSUED MAY 5,1998, SAA200118530000, 98SA20A000254
4. A DOCUMENT OF ANALYSIS SUMMARY, P-14A-173, SAA2001186????, ISSUED 4/28/98
5. A CLASSIFIED RECORD CONTROL NO. 4-31446, DATED 3/16/65, TYPE "B" RADIATION EXPOSURE BY JAMES V. GLENN COMMITTEE CHAIRMAN AND H. JACK BLACKWELL, AREA MANAGER, SAC200144210000, DATED ON APRIL 20, 1965
6. MONTHLY FIRE REPORT FOR JANUARY, 1999, SAC200142920000, 256196
7. MONTHLY FIRE REPORT FOR DECEMBER 1999, 256197
8. MONTHLY FIRE REPORT FOR NOVEMBER 1998
9. MONTHLY FIRE REPORT FOR OCTOBER 1997
10. MONTHLY FIRE REPORT FOR FEBRUARY 1996
11. MONTHLY FIRE REPORT FOR JANUARY 1996
12. MONTHLY FIRE REPORT FOR DECEMBER 1995
13. MONTHLY FIRE REPORT FOR NOVEMBER 1995, 256405
14. October 31 Estimates from Mr. Oppenheimer to Gen. Groves regarding Implosion Method, SAC200141730000, 84-019 32-4, November 18, 1943
15. DOCUMENT #1, JOINT DOD/DOE TRIDENT MK4/MK5 REENTRY BODY ALTERNATE WARHEAD PHASE 2 FEASIBILITY STUDY REPORT (U), BY DAVID A. PONTON, JAMES V. TYLER, DONALD D. TIPTON, DOUGLAS R. HENSON, KARL B. RUEB AND BARRY W. HARMAH, SAB20017421B001, 99SA20B000347, DATED JANUARY 1994
16. DOCUMENT #2, HPRF PHASE 2 STUDY GENERAL MEETING 94-3 (#10) MINUTES, BY KEITH M. BAIRD, HPRF STUDY DIRECTOR, SAB20017422B001, DATED OCTOBER 28, 1994
17. DOCUMENT #3, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY GENERAL MEETING 94-2 (#9), BY KEITH M. BAIRD, NWIC-MM-94-2, SAB20017423B001, DATED JULY 15, 1994
18. DOCUMENT #4, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY GENERAL MEETING 94-1 (#8), BY KEITH M. BAIRD,NWIC-MM-94-1, SAB20017424B001, DATED MARCH 10, 1994
19. DOCUMENT #5, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY MEETING #4 MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-93-1, SAB20017425B001, APRIL 19, 1993
20. DOCUMENT #6, JOINT DOD/DOE PHASE 2 FEASIBILITY STUDY OF A HIGH POWER RADIO FREQUENCY WEAPON, FINAL REPORT (U), BY JOHN R. CURRY, DATED FEBRUARY 20, 1996
21. DOCUMENT #7, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY MEETING #3 MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-92-15, SAB20017427B001, DECEMBER 11 1992
22. DOCUMENT #8, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY GENERAL MEETING 94-4 (#11) MINUTES, BY KEITH M. BAIRD, SAB20017428B001, DATED JANUARY 4, 1995
23. DOCUMENT #9, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY GENERAL MEETING 95-1 (#12), BY KEITH M. BAIRD, SAB20017429B001, DATED JANUARY 31 TO FEBRUARY 1, 1995
24. DOCUMENT #10, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY KICKOFF MEETING MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-92-10,SAB20017430B001, DATED OCTOBER 8, 1992

25. DOCUMENT #11, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY MEETING #2 MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-92-12, SAB20017431B001, DATED NOVEMBER 18, 1992
26. DOCUMENT #12, HIGH POWER RADIO FREQUENCY PHASE 2 STUDY, MEETING #6 MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, NWIC-MM-93-1, SAB20017432B001, DATED SEPTEMBER 16, 1993
27. DOCUMENT #13, HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY, MEETING #5 MINUTES (U), BY CAPTAIN WILLIAM A. LAMB, OAS-MM-93-4, SAB20017433B001, DATED JUNE 17, 1993
28. DOCUMENT # 14, AIR FORCE STOCKPILE-TO-TARGET SEQUENCE FOR THE HIGH POWER RADIO FREQUENCY WARHEAD (U), PHASE 2 STUDY, BY KENNETH J. VILLAREAL, DRAFT 4, SAB20017434B001, DATED OCTOBER 3, 1994
29. DOCUMENT #15, SUMMARY OF ELECTROMAGNETIC TESTS FOR HIGH POWER RADIO FREQUENCY, PHASE 2 STUDY, BY J. E. SOLBERG, SAND94-3118, SAB20017435B001, DATED OCTOBER 1994
30. DOCUMENT #16, HIGH POWER RADIO FREQUENCY MILITARY CHARACTERISTICS, DRAFT 5, BY THE NUCLEAR WEAPONS INTEGRATION DIVISION, SAB20017436B001, DATED SEPTEMBER 8, 1994
31. DOCUMENT #17, HIGH POWER FREQUENCY, PHASE 2 STUDY GENERAL MEETING #7 MINUTES, BY KEITH M. BAIRD, NWIC-MM-93-2, SAB20017437B001, DATED DECEMBER 9, 1993