Chapter 2

# The Nuclear Testing Program

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## INTRODUCTION

In the past four decades, nuclear weapons have evolved into highly sophisticated and specialized devices. Throughout this evolution, the nuclear testing program has played a major role in developing new weapon systems and determining the effects of nuclear explosions.

## THE HISTORY OF NUCLEAR TESTING

On July 16, 1945 the world's first nuclear bomb (code named "Trinity") was detonated atop a 100-foot steel tower at the Alamogordo Bombing Range, 55 miles northwest of Alamogordo, New Mexico.[1] The explosion had a yield of 21 kilotons (kts), the explosive energy equal to approximately 21,000 tons of TNT.[2] The following month, American planes dropped two atomic bombs ("Little Boy," 13 kilotons; "Fat Man," 23 kilotons) on the Japanese cities of Hiroshima and Nagasaki, ending World War II and beginning the age of nuclear weapons.[3]

Within weeks after the bombing of Hiroshima and Nagasaki, plans were underway to study the effects of nuclear weapons and explore further design possibilities. A subcommittee of the Joint Chiefs of Staff was created, on November 10, 1945, to arrange the first series of nuclear test explosions. President Truman approved the plan on January 10, 1946. The Bikini Atoll was selected as the test site and the Bikinians were relocated to the nearby uninhabited Rongerik Atoll. Two tests ("Able" and "Baker*') were detonated on Bikini in June and July of 1946 as part of "Operation Crossroads," a series designed to study the effects of nuclear weapons on ships, equipment, and material.[4] The Bikini Atoll, however, was found to be too small to accommodate support facilities for the next test series and so "Operation Sandstone" was conducted on the nearby Enewetak Atoll. The tests of Operation Sandstone (" X-ray," " Yoke," and "Zebra' were proof tests for new bomb designs.

As plans developed to expand the nuclear arsenal, the expense, security, and logistical problems of testing in the Pacific became burdensome. Attention turned toward establishing a test site within the continental United States. The Nevada Test Site was chosen in December 1950 by President Truman as a continental proving ground for testing nuclear weapons. A month later, the first test-code named "Able' '-was conducted using a device dropped from a B-50 bomber over Frenchman Flat as part of a five-test series called "Operation Ranger. ' The five tests were completed within 11 days at what was then called the ''Nevada Proving Ground. "

Although the Nevada Test Site was fully operational by 1951, the Pacific continued to be used as a test site for developing thermonuclear weapons (also called hydrogen or fusion bombs), On October 31, 1952, the United States exploded the first hydrogen (fusion) device on Enewetak Atoll.[5] The test, code named "Mike,' had an explosive yield of 10,400 kilotons-over 200 times the largest previous test.

1 The Alamogordo Bombing Range is now the White Sands Missile Range.

2 A kiloton (kt) was originally defined as the explosive equivalent of 1,000 tons of TNT. This definition, however, was found to be imprecise for two reasons. First, there is some variation in the experimental and theoretical values of the explosive energy released by TNT (although the majority of values lie in the range from 900 to 1,100 calories per gram). Second, the term kiloton could refer to a short kiloton ($2 \times 10^6$ pounds), a metric kiloton ($2.205 \times 10^6$ pounds), or a long kiloton ($2.24 \times 10^6$ pounds). It was agreed, therefore, during the Manhattan Project that the term "kiloton' would refer to the release of $10^{12}$ (1,000,000,000,000) calories of explosive energy.

3 John Malik, ''The Yields of the Hiroshima and Nagasaki Nuclear Explosions, ' Los Alamos National Laboratory report LA-8819, 1985.

4 The target consisted of a fleet of over 90 vessels assembled in the Bikini Lagoon including three captured German and Japanese ships; surplus U.S. cruisers, destroyers, and submarines; and amphibious craft.

5 The first test of an actual hydrogen *bomb* (rather than a *device* located on the surface) was ''Cherokee which was dropped from a plane over Bikini Atoll on May 20, 1956. Extensive preparations were made for the test that included the construction of artificial islands 10 house measuring equipment The elaborate experiments required that the bomb be dropped in a precise location in space. To accomplish this, the Strategic Air Command held a competition for bombing accuracy. Although the winner hit the correct point in every practice run, during the test the bomb was dropped 4 miles off-target.

The test was followed 2 weeks later by the 500 kiloton explosion "King," the largest fission weapon ever tested.

At the Nevada Test Site, low-yield fission devices continued to be tested. Tests were conducted with nuclear bombs dropped from planes, shot from cannons, placed on top of towers, and suspended from balloons. The tests were designed both to develop new weapons and to learn the effects of nuclear explosions on civilian and military structures. Some tests were conducted in conjunction with military exercises to prepare soldiers for what was then termed "the atomic battlefield. "

In the Pacific, the next tests of thermonuclear (hydrogen) bombs were conducted under "Operation Castle,' a series of six tests detonated on the Bikini Atoll in 1954. The first test, "Bravo," was expected to have a yield of about 6,000 kilotons. The actual yield, however, was 15,000 kilotons-over twice what was expected.[6] The radioactive fallout covered an area larger than anticipated and because of a faulty weather prediction, the fallout pattern was more easterly than expected. A Japanese fishing boat, which had accidentally wandered into the restricted zone without being detected by the Task Force, was showered with fallout. When the fishing boat docked in Japan, 23 crew members had radiation sickness. The radio operator died of infectious hepatitis, probably because of the large number of required blood transfusions.[7] The faulty fallout prediction also led to the overexposure of the inhabitants of two of the Marshall Islands 100 miles to the East. In a similar though less severe accident, radioactive rain from a Soviet thermonuclear test fell on Japan.* These accidents began to focus worldwide attention on the increased level of nuclear testing and the dangers of radioactive fallout. Public opposition to atmospheric testing would continue to mount as knowledge of the effects of radiation increased and it became apparent that no region of the world was untouched.[9]

Attempts to negotiate a ban on nuclear testing began at the United Nations Disarmament Conference in May 1955. For the next several years efforts to obtain a test ban were blocked as agreements in nuclear testing were linked to progress in other arms control agreements and as differences over verification requirements remained unresolved. In 1958, President Eisenhower and Soviet Premier Khrushchev declared, through unilateral public statements, a moratorium on nuclear testing and began negotiations on a comprehensive test ban. The United States adopted the moratorium after conducting 13 tests in seven days at the end of October 1958. Negotiations broke down first over the right to perform onsite inspections, and then over the number of such inspections. In December 1959, President Eisenhower announced that the United States would no longer consider itself bound by the "voluntary moratorium" but would give advance notice if it decided to resume testing. Meanwhile (during the moratorium), the French began testing their newly acquired nuclear capability. The Soviet Union, which had announced that it would observe the moratorium as long as the western powers would not test, resumed testing in September 1961 with a series of the largest tests ever conducted. The United States resumed testing two weeks later (figure 2-1).[10]

Public opposition to nuclear testing continued to mount. Recognizing that the U.S. could continue its development program solely through underground testing and that the ratification of a comprehensive test ban could not be achieved, President Kennedy proposed a limited ban on tests in the atmosphere, the oceans, and space. The Soviets, who through their own experience were convinced that their test program could continue underground, accepted the proposal. With both sides agreeing that such a treaty could be readily verified, the Limited Test Ban Treaty (LTBT) was signed in 1963, banning all aboveground or underwater testing.

In addition to military applications, the engineering potential of nuclear weapons was recognized by the mid-1950's. The Plowshare Program was formed in 1957 to explore the possibility of using nuclear explosions for peaceful purposes.[11] Among the

[6] Bravo was the largest test ever detonated by the United States.

[7] See "The Voyage of the Lucky Dragon, " Ralph E. Lapp, 1957, Harper& Brothers Publishers, New York.

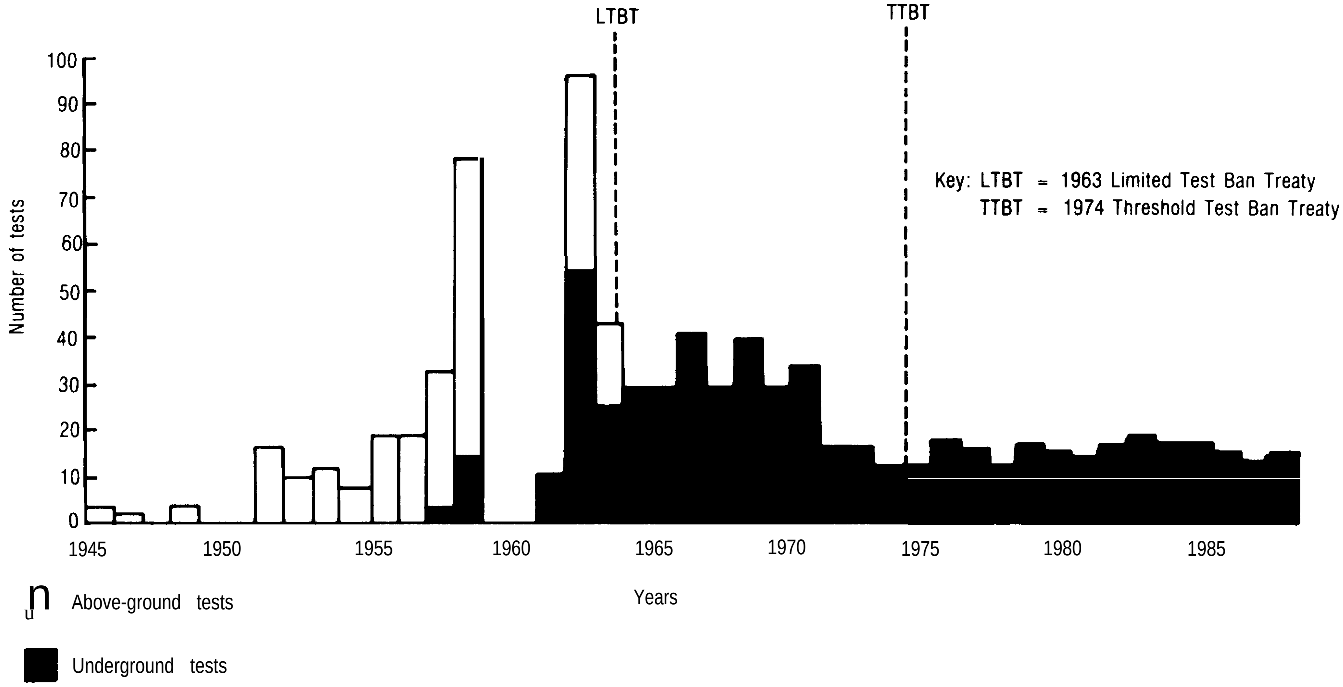
[8] "Arms Control and Disarmament Agreements, " United States Arms Control and Disarmament Agency, Washington, DC, 1982 Edition, p. 34.

[9] Since the large thermonuclear tests, all people have strontium-90 (a sister element of calcium) in their bones, and cesium-137 (a sister element Of potassium) in their muscle. Also, the amount of iodine-131 in milk in the United States correlates with the frequency of atmospheric testing.

[10] See "Ares Control and Disarmament Agreements, ' United States Arms Control and Disarmament Agency, 1982 edition.

[11] The name is from ". . . . they shall beat their swords into plowshares," Isaiah 2:4.

**Figure 2-1—U.S. Nuclear Testing**




**SOURCE: Data from the Swedish Defense Research Institute.**

applications considered were the excavation of canals and harbors, the creation of underground storage cavities for fuel and waste, the fracturing of rock to promote oil and gas flow, and the use of nuclear explosions to cap oil gushers and extinguish fires. It was reported that even more exotic applications, such as melting glaciers for irrigation, were being considered by the Soviet Union.

The first test under the Plowshare Program, ''Gnome,' was conducted 4 years later to create an underground cavity in a large salt deposit. The next Plowshare experiment, Sedan in 1962, used a 104 kiloton explosion to excavate 12 million tons of earth. In 1965, the concept of 'nuclear excavation' was refined and proposed as a means of building a second canal through Panama.[12] Three nuclear excavations were tested under the Plowshare program ("Cabriolet," Jan. 26, 1968; "Buggy," Mar. 12, 1968; and "Schooner," Dec. 12, 1968). Schooner, however, released radioactivity off site and, as a consequence, no future crater test was approved. Consideration of the radiological and logistical aspects of the project also contributed to its demise, Estimates of the engineering requirements indicated that approximately 250 separate nuclear explosions with a total yield of 120 megatons would be required to excavate the canal through Panama. Furthermore, fallout predictions indicated that 16,000 square kilometers of territory would need to be evacuated for the duration of the operation and several months thereafter.[13] Because it was also clear that no level of radioactivity would be publicly acceptable, the program was terminated in the early 1970s.

In 1974, President Richard Nixon signed the Threshold Test Ban Treaty (TTBT) restricting all nuclear test explosions to a defined test site and to yields no greater than 150 kilotons. As a result, all U.S. underground nuclear tests since 1974 have been conducted at the Nevada Test Site. As part of the earlier 1963 Limited Test Ban Treaty, the United States established a series of safeguards. One of them, "Safeguard C," requires the United States to maintain the capability to resume atmospheric testing in case the treaty is abrogated. The Department of Energy (DOE) and the Defense Nuclear Agency continue today to maintain a facility for the

[12] The 1956 war over the Suez Canal created the first specific proposals for using nuclear explosions to create an alternative canal.

[13] Bruce A. Bolt, "Nuclear Explosions and Earthquakes, The Parted Veil" San Francisco, CA: W.H. Freeman& Co., 1976, pp. 192-1%.

Photo credit: David Graham, 1988

Sedan Crater

atmospheric testing of nuclear weapons at the Johnston Atoll in the Pacific Ocean.

## LIMITS ON NUCLEAR TESTING

The testing of nuclear weapons by the United States is currently restricted by three major treaties that were developed for both environmental and arms control reasons. The three treaties are:

1. the 1963 Limited Nuclear Test Ban Treaty, which bans nuclear explosions in the atmosphere, outer space, and underwater, and restricts the release of radiation into the atmosphere,

2. the 1974 Threshold Test Ban Treaty, which restricts the testing of underground nuclear weapons by the United States and the Soviet Union to yields no greater than 150 kilotons, and

3. the 1976 Peaceful Nuclear Explosions Treaty (PNET), which is a complement to the Threshold Test Ban Treaty (TTBT). It restricts individual peaceful nuclear explosions (PNEs) by the United States and the Soviet Union to yields no greater than 150 kilotons, and group explosions (consisting of a number of individual explosions detonated simultaneously) to aggregate yields no greater than 1,500 kilotons.

Although both the 1974 TTBT and the 1976 PNET remain unratified, both the United States and the Soviet Union have expressed their intent to abide by the yield limit. Because neither country has indicated an intention not to ratify the treaties, both parties are obligated to refrain from any acts that would defeat their objective and purpose.[14] Consequently, all nuclear test explosions compliant with treaty obligations must be conducted underground, at specific test sites (unless a PNE), and with yields no greater than 150 kilotons. The test must also be contained to the extent that no radioactive debris is detected outside the territorial limits of the country that conducted the test.[15] Provisions do exist, however, for one or two slight, unintentional breaches per year of the 150 kiloton limit due to the technical uncertainties associated with predicting the exact yields of nuclear weapons tests.[16]

[14] Art. 18, 1969 Vienna Convention on the Law of Treaties.

[15] Art. I, 1(b), 1963 Limited Test Ban Treaty.

[16] Statement of understanding included with the transmittal documents accompanying the Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty when submitted to the Senate for advice and consent to ratification on July 29, 1979.

## OTHER LOCATIONS OF NUCLEAR TESTS

U.S. nuclear test explosions were also conducted in areas other than the Pacific and the Nevada Test Site.

Three tests with yields of 1 to 2 kilotons were conducted over the South Atlantic as ''Operation Argus.' ' The tests ("Argus I," Aug. 27, 1958; "Argus H," Aug. 30, 1958; and "Argus III," Sept. 6, 1958) were detonated at an altitude of **300** miles to assess the effects of high-altitude nuclear detonations on communications equipment and missile performance.

Five tests, all involving chemical explosions but with no nuclear yield, were conducted at the Nevada Bombing Range to study plutonium dispersal. The tests, "Project 57 NO l," April 24, 1957; "Double Tracks," May 15, 1963; "Clean Slate I," May 25, 1963; "Clean Slate II," May 31, 1963; and "Clean Slate III,' June 9, 1963; were safety tests to establish storage and transportation requirements.

Two tests were conducted in the Tatum Salt Dome near Hattiesburg, Mississippi, as part of the Vela Uniform experiments to improve seismic methods of detecting underground nuclear explosions. The first test 'Salmon,' October 22, 1964, was a 5.3 kiloton explosion that formed an underground cavity. The subsequent test "Sterling," December 3, 1966, was 0.38 kt explosion detonated in the cavity formed by Salmon. The purpose of the Salmon/Sterling experiment was to assess the use of a cavity in reducing the size of seismic signals produced by an underground nuclear test.[17]

Three joint government-industry tests were conducted as part of the Plowshare Program to develop peaceful uses of nuclear explosions. The experiments were designed to improve natural gas extraction by fracturing rock formations. The first test, ''Gasbuggy,' was a 29 kiloton explosion detonated on December 10, 1967, near Bloomfield, New Mexico. The next two were in Colorado: "Rulison" was a 40 kiloton explosion, detonated near Grand Valley on September 10, 1969; and "Rio Blanco" was a salvo shot of three explosions, each with a yield of 33 kt, detonated near Rifle on May 17, 1973.

Three tests were conducted on Amchitka Island, Alaska. The first (October 29, 1965), "Long Shot" was an 80 kiloton explosion that was part of the Vela Uniform project. The second test, "Milrow," October 2, 1969, was about a one megaton explosion to ''calibrate' the island and assure that it would contain a subsequent test of the Spartan Anti-Ballistic Missile warhead. The third test, "Cannikin," November 6, 1971, was the Spartan warhead test with a reported yield of "less than five megatons. This test, by far the highest-yield underground test ever conducted by the United States, was too large to be safely conducted in Nevada.[18]

Three individual tests were also conducted in various parts of the western United States. "Gnome' was a 3 kiloton test conducted on December 10, 1961 near Carlsbad, New Mexico, to create a large underground cavity in salt as part of a multipurpose experiment. One application was the possible use of the cavity for the storage of oil and gas. "Shoal" was a 12 kiloton test conducted on October 26, 1963 near Fallen, Nevada as part of the Vela Uniform project. ''Faultless" was a test with a yield of between 200 and 1,000 kiloton that was exploded on January 19, 1968, at a remote area near Hot Creek Valley, Nevada. Faultless was a ground-motion calibration test to evaluate a Central Nevada Supplemental Test Area. The area was proposed as a alternative location for high-yield tests to decrease the ground shaking in Las Vegas.

## THE NEVADA TEST SITE

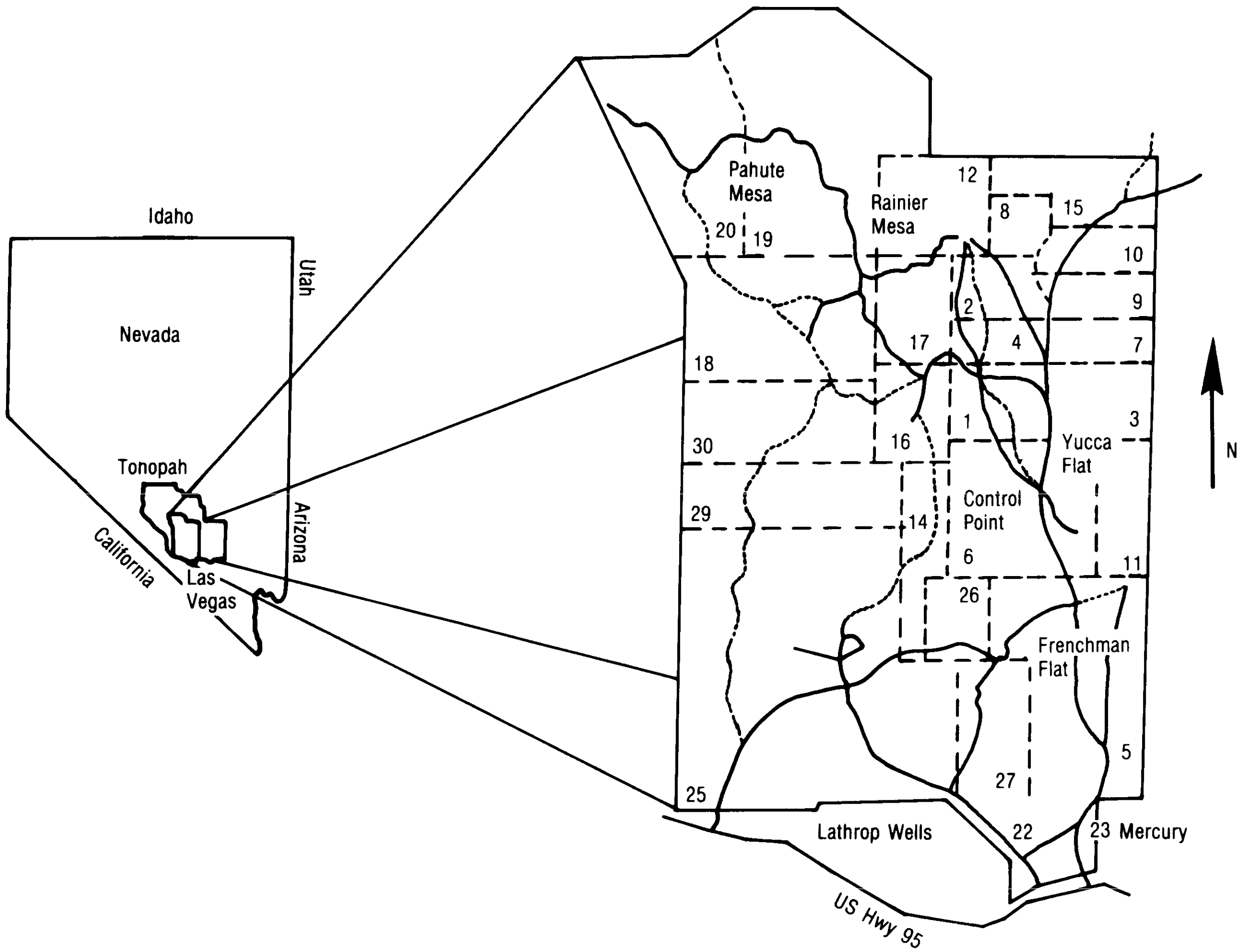
The Nevada Test Site is located 65 miles northwest of Las Vegas. It covers 1,350 square miles, art area slightly larger than Rhode Island (figure 2-2). The test site is surrounded on three sides by an additional 4,000 to 5,000 square miles belonging to Nellis Air Force Base and the Tonopah Test Range. The test site has an administrative center, a control point, and areas where various testing activities are conducted.

At the southern end of the test site is Mercury, the administrative headquarters and supply base for

17 For a complete discussion of the issues related to Seismic Verification see, U.S. Congress, Office of Technology Assessment, *Seismic Verification of Nuclear Testing Treaties*, OTA-ISC-361, Washington, DC: U.S. Government Printing Office, May 1988.

18 The predictions of ground motion suggested that an unacceptable amount (in terms of claims and dollars) of damage would occur to structures if the test was conducted in Nevada.

**Figure 2-2--Nevada Test Site**




SOURCE: Modified from Department of Energy.

DOE contractors and other agencies involved in Nevada Operations. Mercury contains a limited amount of housing for test site personnel and other ground support facilities.

Near the center of the test site, overlooking Frenchman Flat to the South and Yucca Flat to the North, is the Control Point (CP). The CP is the command headquarters for testing activities and is the location from which all tests are detonated and monitored.

Frenchman Flat is the location of the first nuclear test at the test site. A total of 14 atmospheric tests occurred on Frenchman Flat between 1951 and 1962. Most of these tests were designed to determine the effects of nuclear explosions on structures and military objects. The area was chosen for its flat terrain which permitted good photography of detonations and fireballs. Also, 10 tests were conducted underground at Frenchman Flat between 1965 and 1971. Frenchman Flat is no longer used as a location for testing. The presence of carbonate material makes the area less suitable for underground testing than other locations on the test site.[19]

Yucca Flat is where most underground tests occur today. These tests are conducted in vertical drill holes up to 10 feet in diameter and from 600 ft to more than 1 mile deep. It is a valley 10 by 20 miles extending north from the CP. Tests up to about 300 kilotons in yield have been detonated beneath Yucca

[19] During an explosion, carbonate material can form carbon dioxide which, under pressure, can cause venting.

Photo credit: David Graham, 1988

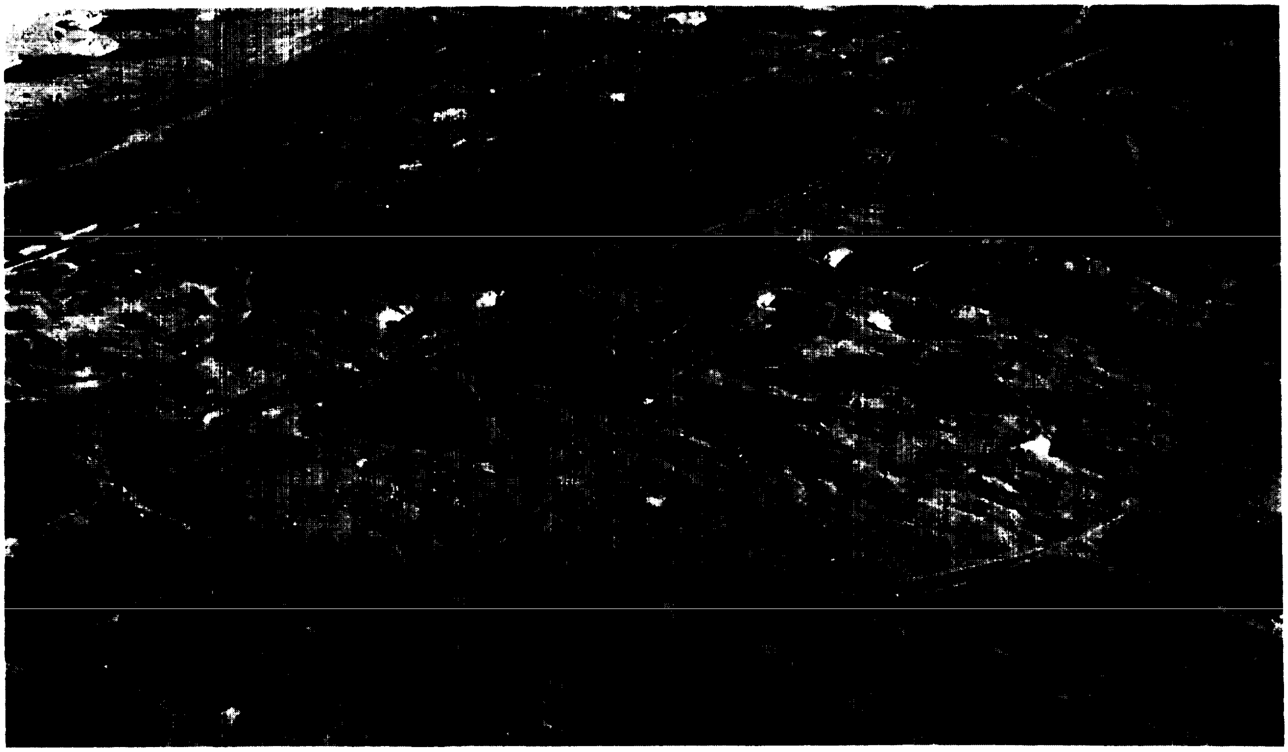
Test Debris on Frenchman Flat

Flat, although Pahute Mesa is now generally reserved for high-yield tests.

Tests up to 1,000 kilotons in yield have occurred beneath Pahute Mesa, a 170 square mile area in the extreme north-western part of the test site. The deep water table of Pahute Mesa permits underground testing in dry holes at depths as great as 2,100 feet. The distant location is useful for high-yield tests because it minimizes the chance that ground motion will cause damage offsite.

Both Livermore National Laboratory and Los Alamos National Laboratory have specific areas of the test site reserved for their use. Los Alamos uses areas 1, 3, 4 (east), 5, and 7 in Yucca Flat and area 19 on Pahute Mesa; Livermore uses areas 2, 4 (west), 8, 9, and 10 in Yucca Flat, and area 20 on Pahute Mesa (figure 2-2). While Los Alamos generally uses Pahute Mesa only to relieve schedule conflicts on Yucca Flat, Livermore normally uses it for large test explosions where the depth of burial would require the test to be below the water table on Yucca Flat.

The Nevada Test Site employs over 11,000 people, with about 5,0(K) of them working on the site proper. The annual budget is approximately $1 billion divided among testing nuclear weapons (81%) and the development of a storage facility for radioactive waste (19%). The major contractors are Reynolds Electrical &Engineering Co., Inc. (REECo),



Pho credit epa tme Energy

Aerial View of Yucca Flat

Edgerton, Germeshausen & Greer (EG&G), Fenix & Scisson, Inc., and Holmes& Narver, Inc. REECo has 5,000 employees at the test site for construction, maintenance, and operational support, which includes large diameter drilling and tunneling, on-site radiation monitoring, and operation of base camps. EG&G has 2,200 employees, who design, fabricate, and operate the diagnostic and scientific equipment. Fenix & Scisson, Inc. handles the design, research, inspection, and procurement for the drilling and mining activities. Holmes & Narver, Inc. has responsibility for architectural design, engineering design, and inspection. In addition to contractors, several government agencies provide support to the testing program: the Environmental Protection Agency (EPA) has responsibility for radiation monitoring outside the Nevada Test Site; the National Oceanic and Atmospheric Administration (NOAA) provides weather analyses and predictions; and the United States Geological Survey (USGS) provides geological, geophysical, and hydrological assessments of test locations.

## TYPES OF NUCLEAR TESTS

Presently, an average of more than 12 tests per year are conducted at the Nevada Test Site. Each test is either at the bottom of a vertical drill hole or at the end of a horizontal tunnel. The vertical drill hole tests are the most common (representing over 90% of all tests conducted) and occur either on Yucca Flat or, if they are large-yield tests, on Pahute Mesa. Most vertical drill hole tests are for the purpose of developing new weapon systems. Horizontal tunnel tests are more costly and time-consuming. They only occur once or twice a year and are located in tunnels mined in the Rainier and Aqueduct Mesas. Tunnel tests are generally for evaluating the effects (radiation, ground shock, etc.) of various weapons on military hardware and systems. In addition, the United Kingdom also tests at a rate of about once a year at the Nevada Test Site.

It takes 6 to 8 weeks to drill a hole depending on depth and location. The holes used by Livermore and Los Alamos differ slightly. Los Alamos typically uses holes with diameters that range from about 4

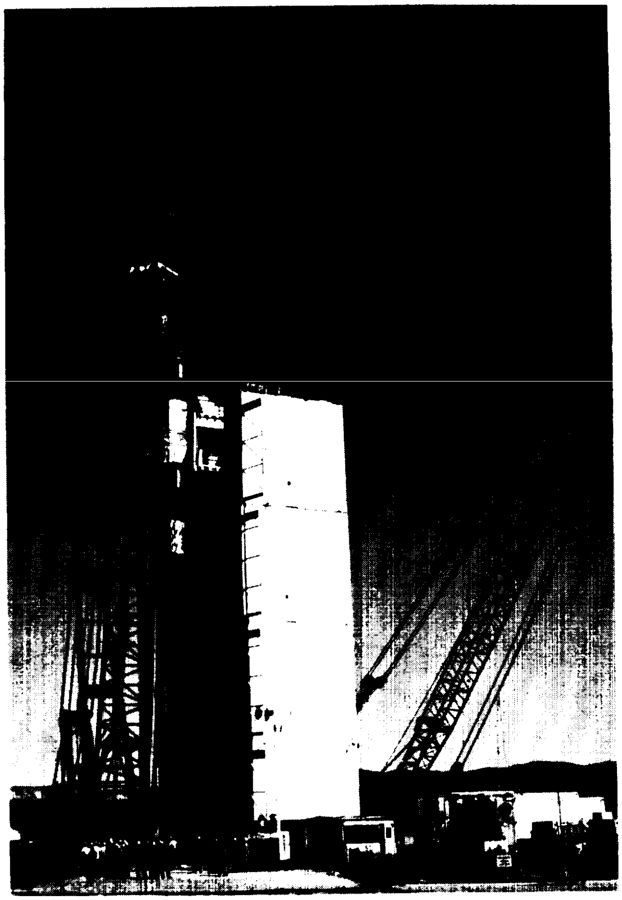


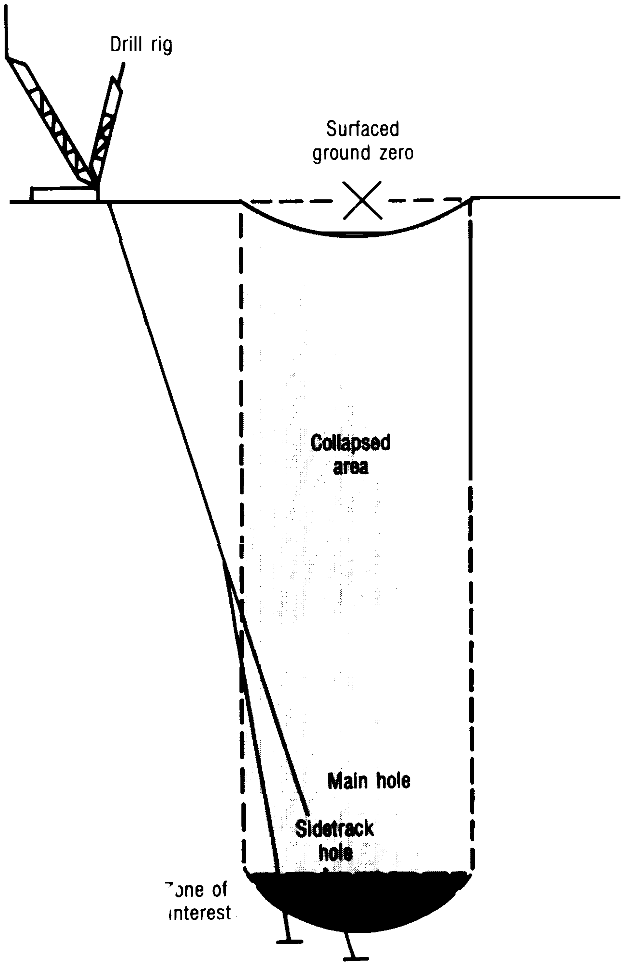
Photo credit: Department of Energy

Emplacement Tower for Vertical Drill Hole Test

1/2 up to *7 ft;* while Livermore typically uses 8-ft diameter holes and an occasional 10-ft diameter hole.[20] Livermore usually places its experimental devices above the water table to avoid the additional time and expense required to case holes below the water table.

When the device is detonated at the bottom of a vertical drill hole, data from the test are transmitted through electrical and fiber-optic cables to trailers containing recording equipment. Performance information is also determined from samples of radioactive material that are recovered by drilling back into the solidified melt created by the explosion (figure 2-3). On rare occasions, vertical drill holes have been used for effects tests. One such test, "Huron King," used an initially open, vertical "line-of-sight" pipe that extended upwards to a large

**Figure 2-3-Drill-Back operation**




SOURCE: Modified from Michael W. Butler, *Pastshot Drilling Handbook,* Lawrence Livermore National Laboratory, Jan. 19, 1984.

enclosed chamber located at the surface. The chamber contained a satellite inside a vacuum to simulate the conditions of space. The radiation from the explosion was directed up the hole at the satellite. The explosion was contained by a series of mechanical pipe closures that blocked the pipe immediately after the initial burst of radiation. The purpose of the test was to determine how satellites might be affected by the radiation produced by a nuclear explosion.

Tunnel tests occur within horizontal tunnels that are drilled into the volcanic rock of Rainier or Aqueduct Mesa. From 1970 through 1988, there

[20] Livermore has considered the use of 12 ft diameter holes, but has not yet used one.

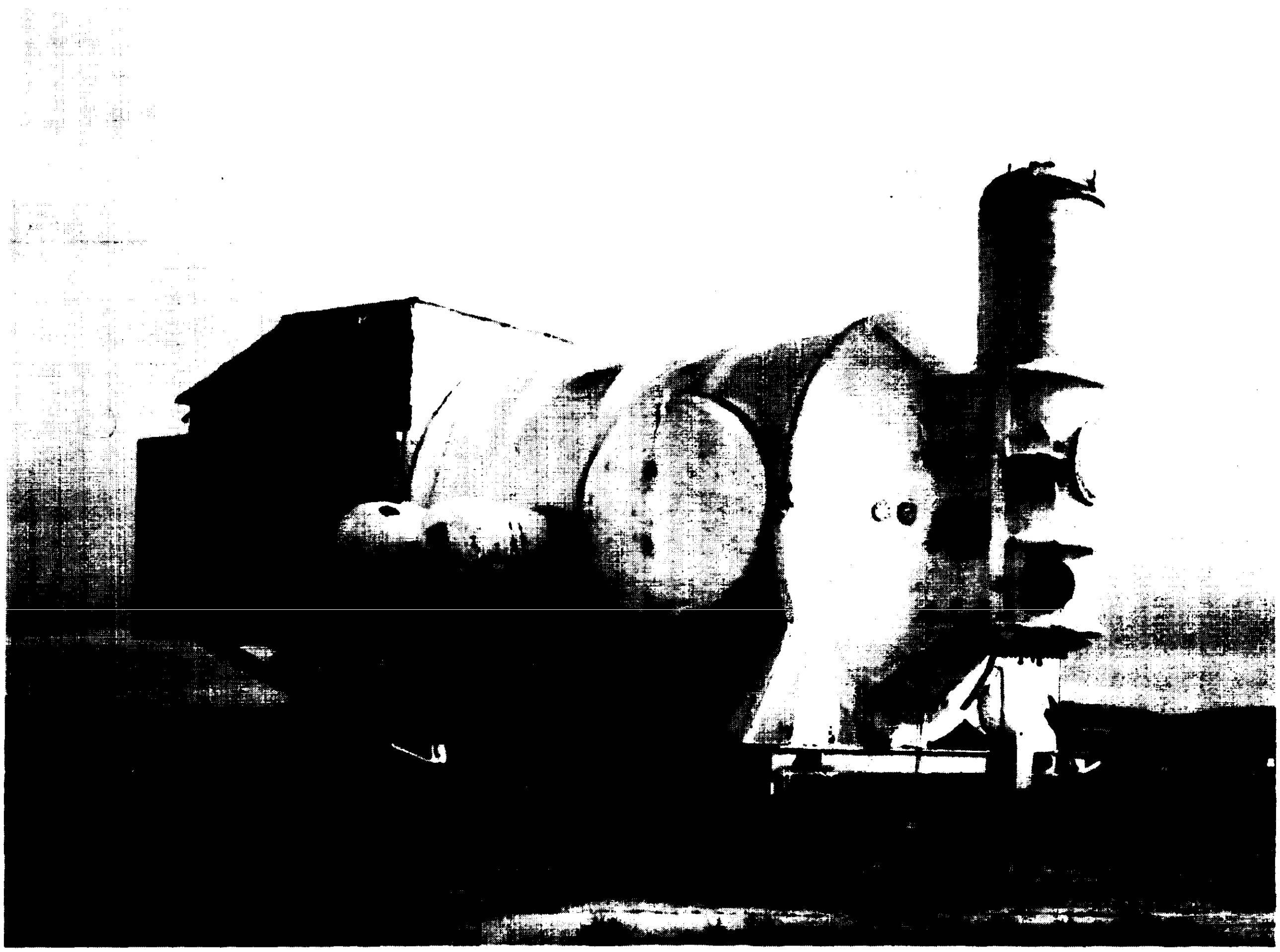


Photo credit: David Graham, 1988

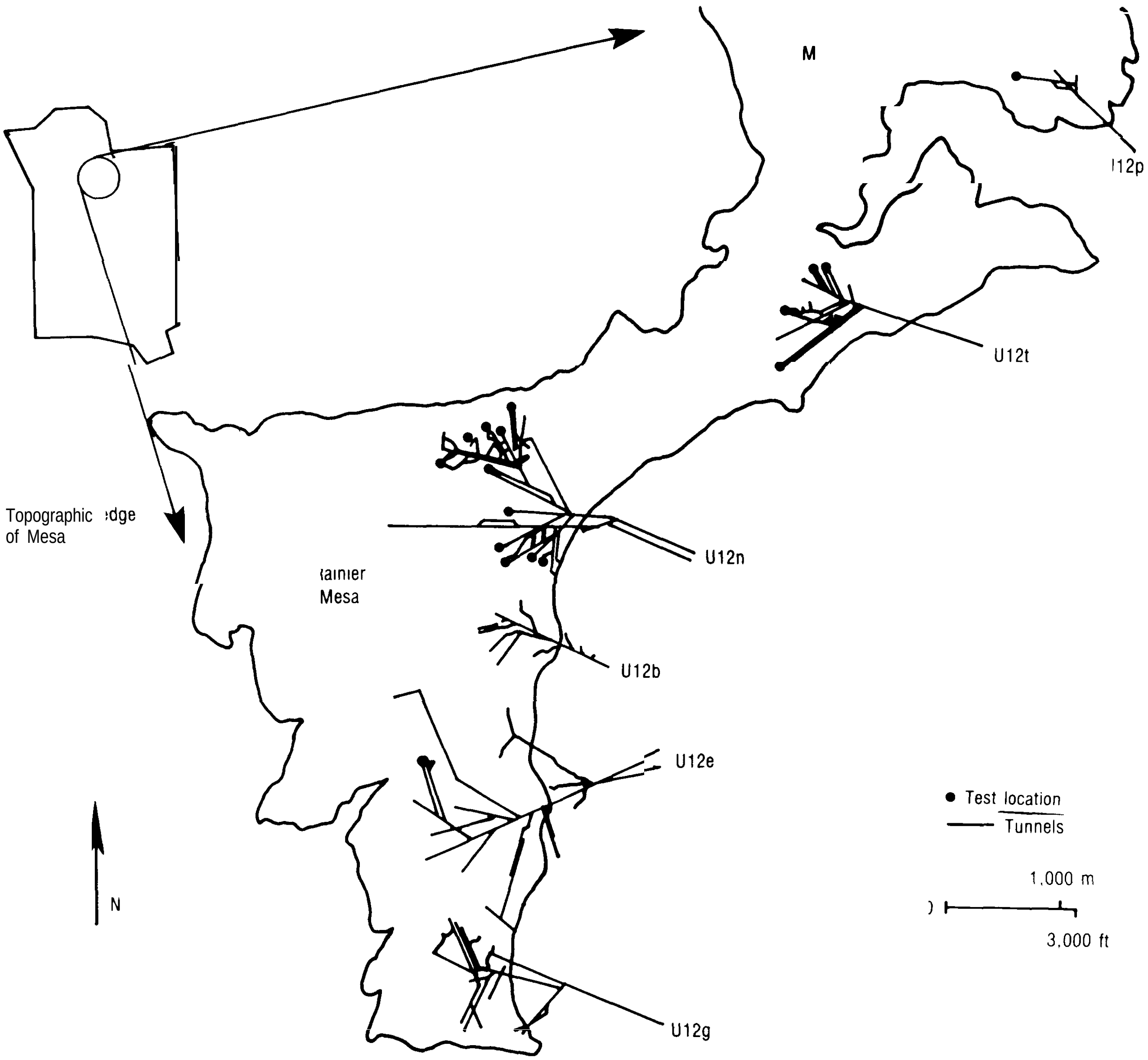
Huron King Test

have been 31 tunnel tests conducted in Rainier and Aqueduct Mesas (figure 2-4). It may require 12 months of mining, using three shifts a day, to remove the 1 million cubic feet of rock that may be needed to prepare for a tunnel test.

Effects tests performed within mined tunnels are designed to determine the effects of nuclear explosion-produced radiation on missile nose cones, warheads, satellites, communications equipment, and other military hardware. The tunnels are large enough so that satellites can be tested at full scale in vacuum chambers that simulate outer space. The tests are used to determine how weapons systems will withstand radiation that might be produced by a nearby explosion during a nuclear war. Nuclear effects tests were the first type of experiments performed during trials in the Pacific and were an extensive part of the testing program in the 1950s. At that time, many tests occurred above ground and included the study of effects on structures and civil defense systems.

Effects tests within cavities provide a means of simulating surface explosions underground. A large hemispherical cavity is excavated and an explosion is detonated on or near the floor of the cavity. The tests are designed to assess the capability of above-ground explosions to transmit energy into the ground. This information is used to evaluate the capability of nuclear weapons to destroy such targets as missile silos or underground command centers.

**Figure 2-4--Locations of Tunnel Tests In Rainier and Aqueduct Mesas**




SOURCE: Modified from Defense Nuclear Agency

## ANNOUNCEMENT OF NUCLEAR TESTS

The existence of each nuclear test conducted prior to the signing of the LTBT on August 5, 1963, has been declassified. Many tests conducted since the signing of the LTBT, however, have not been announced. Information concerning those tests is classified. The yields of announced tests are presently reported only in the general categories of either less than 20 kilotons, or 20 to 150 kilotons. The DOE's announcement policy is that a test will be pre-announced in the afternoon 2 days before the test if it is determined that the maximum credible yield is such that it could result in perceptible ground motion in Las Vegas. The test will be post announced if there is a prompt release of radioactive material or if any late-time release results in

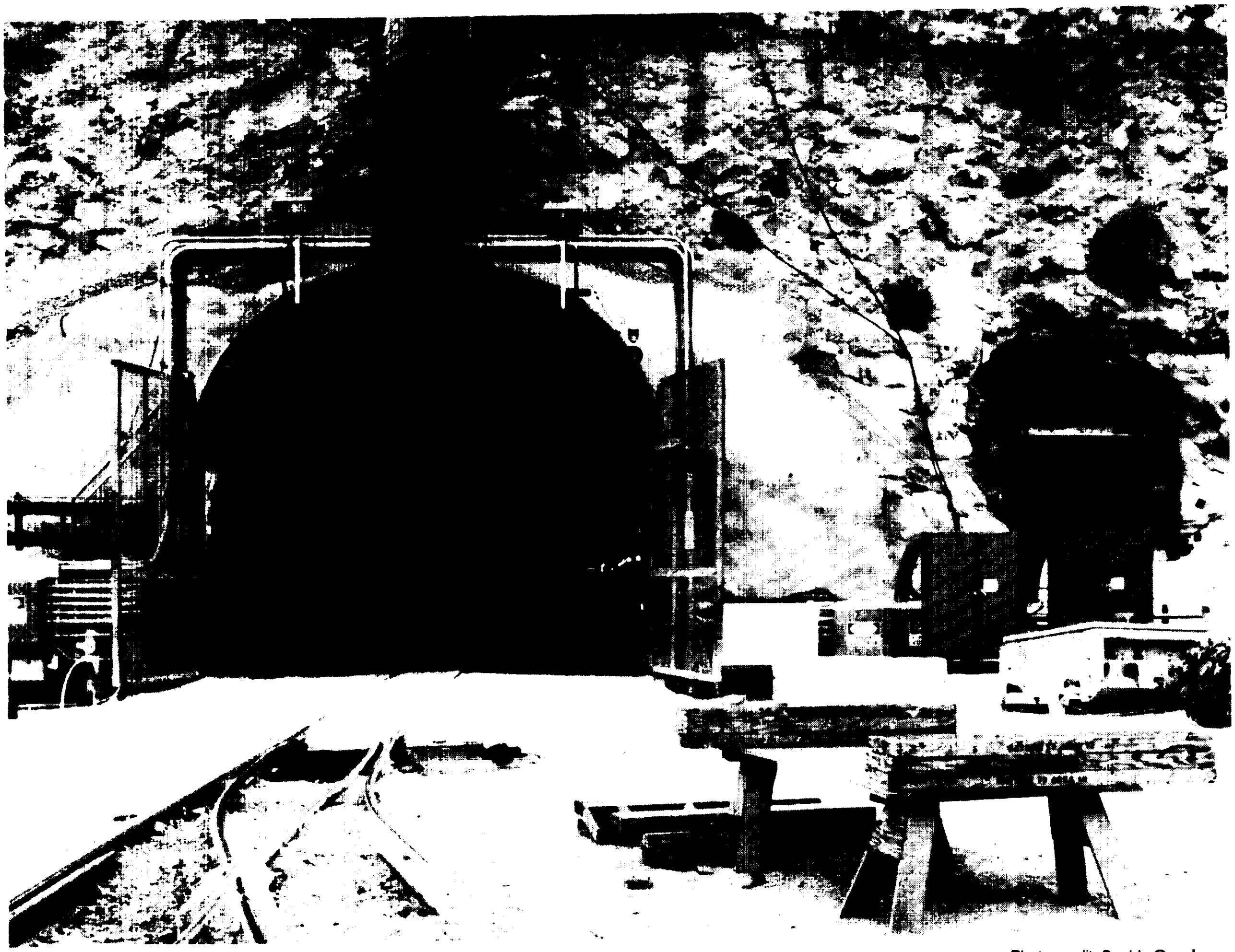


Photo credit: David Graham, 1968

Tunnel Entrance

radioactive material being detected off the test site. In the case of late-time release, however, the test will be announced *only if radioactive material is detected off-site.*

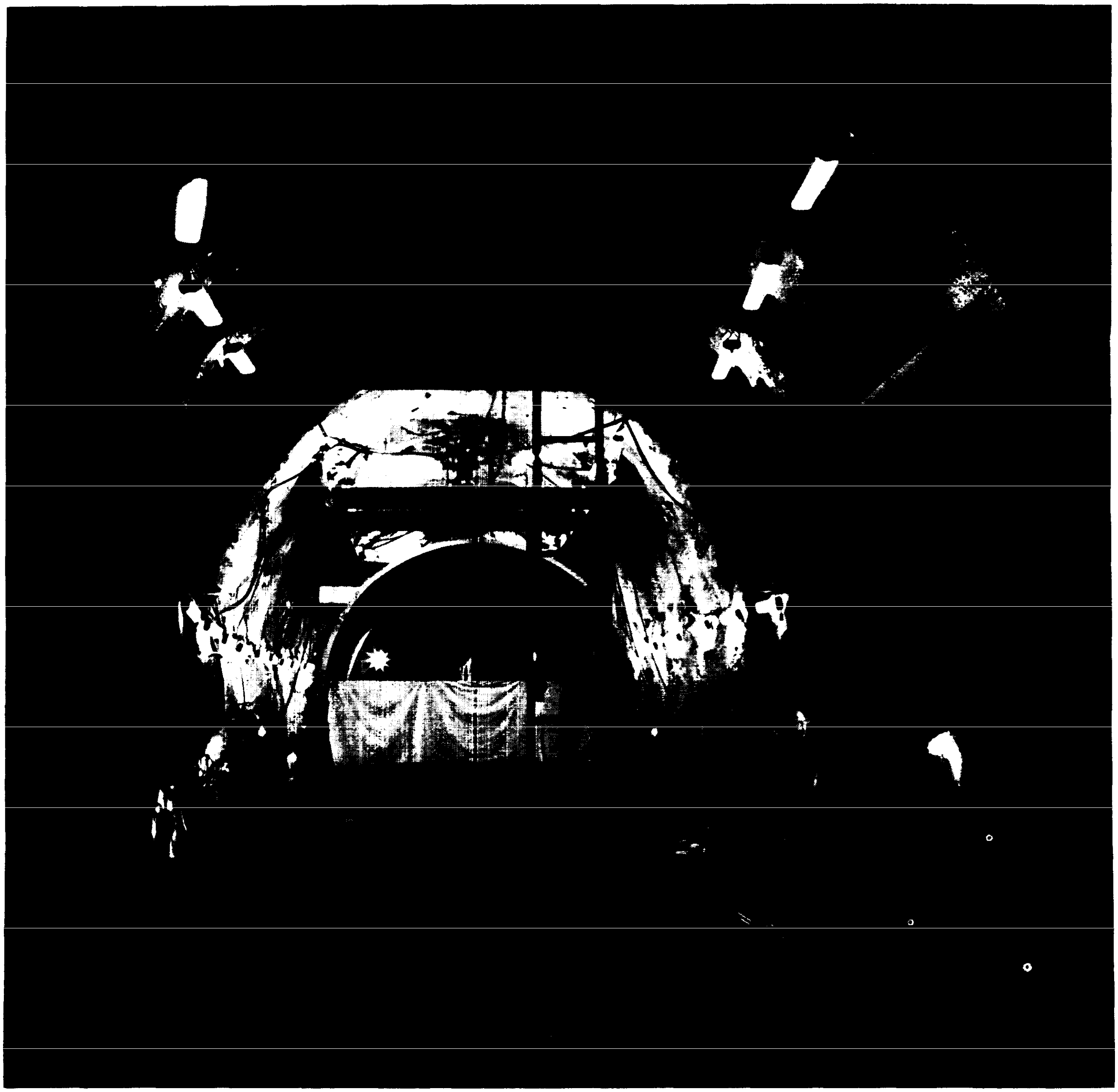
Starting with Trinity, names have been assigned to all nuclear tests. The actual nuclear weapon or device and its description are classified. Consequently, test planners assign innocuous code words or nicknames so that they may refer to planned tests. Early tests used the military phonetic alphabet (Able, Baker, Charlie, etc.). As more tests took place, other names were needed. They include names of rivers, mountains, famous scientists, small mammals, counties and towns, fish, birds, vehicles, cocktails, automobiles, trees, cheeses, wines, fabrics, tools, nautical terms, colors, and so forth.

## DETONATION AUTHORITY AND PROCEDURE

The testing of nuclear weapons occurs under the authority of the Atomic Energy Act of 1946 (as amended in 1954), which states:

"The development, use, and control of Atomic Energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security. '

The act authorizes the U.S. Atomic Energy Commission (now Department of Energy), to "con-



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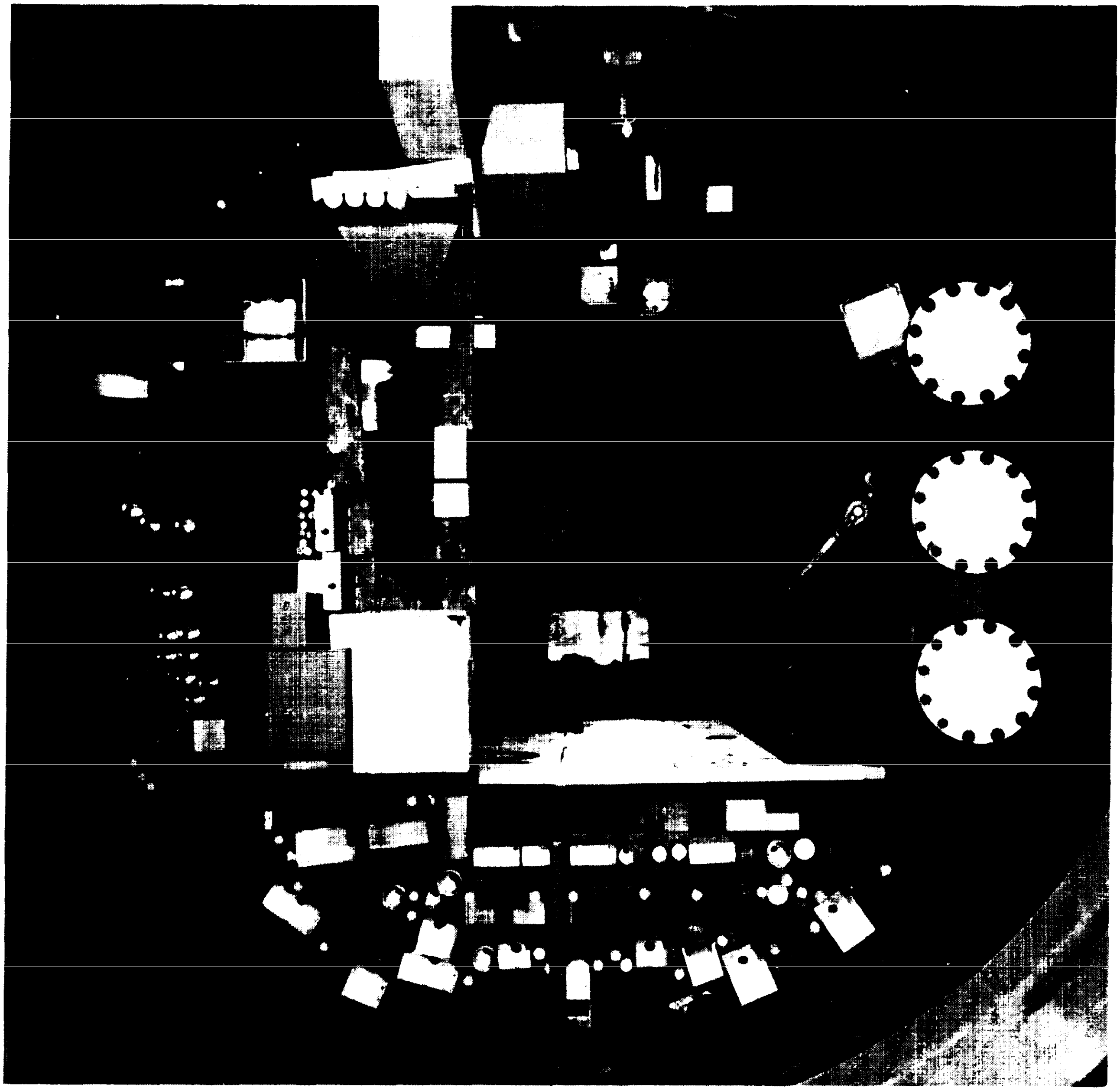

Photo credit: Defense Nuclear Agency

End of Tunnel

comments in its recommendation letter to the President. The Nevada Operations Office plans the individual tests with the responsible laboratory.

Both Livermore and Los Alamos maintain stockpiles of holes in various areas of the test site.[21] When a specific test is proposed, the lab will check its inventory to see if a suitable hole is available or if a new one must be drilled.

Once a hole is selected, the sponsoring laboratory designs a plan to fill-in (or "stem") the hole to contain the radioactive material produced by the explosion. The USGS and Earth scientists from several organizations analyze the geology surround-

[21] Each laboratory operates its own drilling crews continuously to maximize the economy of the drilling operation.

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22See Ch. 3, "Containment Evaluation Panel.

23The nuclear safety study prepared by DOE Safety Division contains safety considerations not related to containment, such as the possibility of premature or inadvertent detonation.

24In the case of tests sponsored by the Defense Nuclear Agency (DNA), the Scientific Advisor is from Sandia National Laboratory.

from the sponsoring Laboratory.[24] The three members are all knowledgeable about the weapons-testing program and consist of:

1. an EPA senior scientist with expertise in radiation monitoring,
2. a weather service senior scientist knowledgeable in meteorology, and
3. a medical doctor with expertise in radiation medicine.

Once the test has been approved for execution by the Test Controller's panel, the Test Controller has sole responsibility to determine when or whether the test will be conducted. The Test Controller and Advisory Panel members conduct the following series of technical meetings to review the test:[25]

D-7 *Safety Planning Meeting: The "D-7* Safety Planning Meeting" is held approximately 1 week before the test. This meeting is an informal review of the test procedure, the containment plan, the expected yield, the maximum credible yield, the potential for surface collapse, the potential ground shock, the expected long-range weather conditions, the location of radiation monitors, the location of all personnel, the security concerns (including the possibility of protesters intruding on the test site), the countdown, the pre-announcement policy, and any other operational or safety aspects related to the test.

*D-1 Safety Planning Meeting: The* day before the test, the D-1 Safety Planning Meeting is held. This is an informal briefing that reviews and updates all the information discussed at the D-7 meeting.

*D-1 Containment Briefing: The* D-1 Containment Briefing is a formal meeting. The laboratory reviews again the containment plan and discusses whether all of the stemming and other containment requirements were met. The meeting determines the extent to which the proposed containment plan was carried out in the field.[26] The laboratory and contractors provide written statements on their concurrence of the stemming plan.

*D-1 Readiness Briefing: The* D-1 Readiness Briefing is a formal meeting to review potential weather conditions and the predicted radiation fallout pattern for the case of an accidental venting.

The night before the test, the weather service sends out observers to release weather balloons and begin measuring wind direction and speed to a height of 1,400 ft above the ground. The area around the test (usually all areas north of the Control Point complex) is closed to all nonessential personnel. The Environmental Protection Agency deploys monitoring personnel off-site to monitor fallout and coordinate protective measures, should they be necessary.

*D-Day Readiness Briefing: The* morning of the test, the Test Controller holds the "D-Day Readiness Briefing. ' At this meeting, updates of weather conditions and forecasts are presented. In addition, the weather service reviews the wind and stability measurements to make final revisions to the fallout pattern in the event of an accidental venting. The fallout pattern is used to project exposure rates throughout the potential affected area. The exposure rates are calculated using the standard radiological models of whole-body exposure and infant thyroid dose from a family using milk cows in the fallout region. The status of on-site ground-based and airborne radiation monitoring is reviewed. The location of EPA monitoring personnel is adjusted to the projected fallout pattern, and the location of all personnel on the test site is confined. At the end of the meeting, the Scientific Advisor who is chairman of the Test Controller's Advisory Panel makes a recommendation to the Test Controller to proceed or delay.

If the decision is made to proceed, the Test Controller gives permission for the nuclear device to be armed. The operation of all radiation monitors, readiness of aircraft, location of EPA personnel, etc., are confined. If the status remains favorable and the weather conditions are acceptable, the Test Controller gives permission to start the countdown and to fire. If nothing abnormal occurs, the countdown proceeds to detonation. If a delay occurs, the appropriate preparatory meetings are repeated.

[24] In the case of tests sponsored by the Defense Nuclear Agency (DNA), the Scientific Advisor is from Sandia National Laboratory.

[25] Although the test has been planned to be contained, test preparations include provisions for an accidental release of radioactive material. Such provisions include the deployment of an emergency response team for each test.

[26] For example, readings from temperature sensors placed in the stemming plugs are examined to determine whether the plugs have hardened.

Photo credit: Department of Energy

Test Control Center