The Los Alamos NUCLEAR TEST PROGRAM

Field Test Operations

LOS ALAMOS NATIONAL LABORATORY LOS ALAMOS, NEW MEXICO

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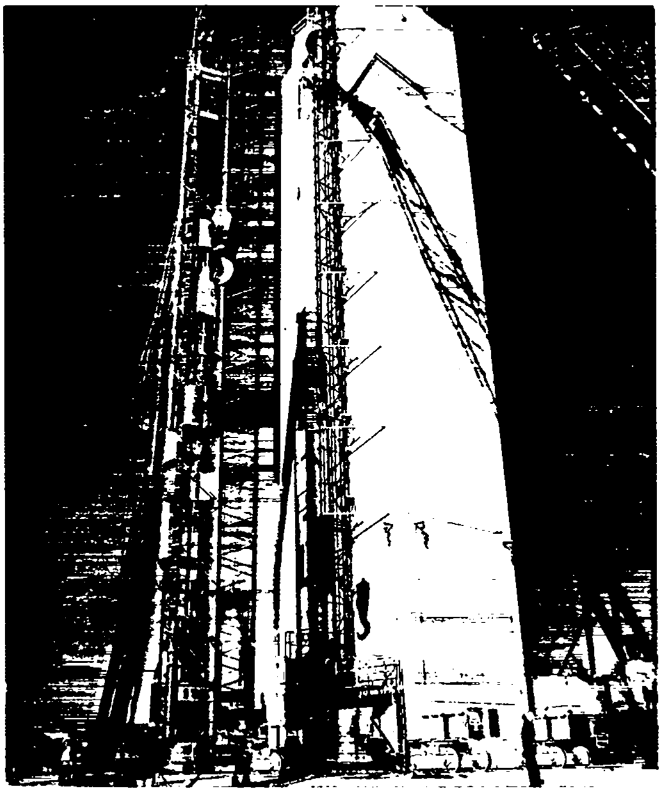
Contents

Introduction

Los Alamos National Laboratory, together with Lawrence Livermore National Laboratory and Sandia National Laboratories, plays a vital role in support of the national policy of nuclear deterrence. It designs, develops, fabricates, and tests nuclear explosives for the Department of Energy (DOE). These critically important tasks—accomplished with the assistance of a number of other DOE contractors—are part of the process that enables the DOE to meet its statutory responsibility.

Underground testing of nuclear explosives, which this brochure describes, is fundamental to weapon development. Los Alamos National Laboratory conducts field tests of nuclear explosives with the same sense of mission that sustained its successful wartime development and test of the world's first manmade nuclear explosive in 1945.

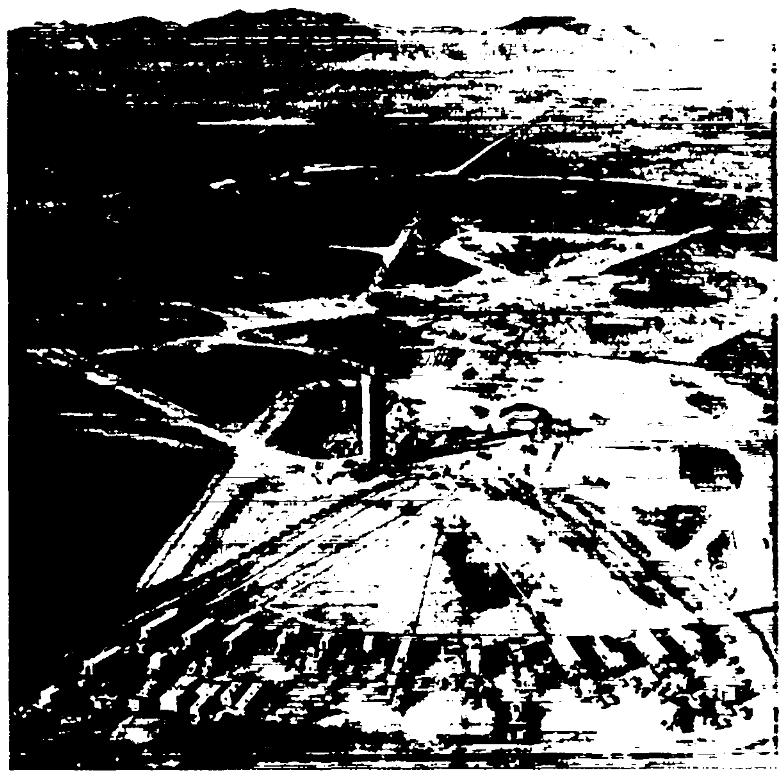


A typical rack and service tower used for underground nuclear tests.

Why Test Nuclear Explosives?

Nuclear testing is necessary to ensure the credibility of America's deterrent. By revealing significant problems that calculations and laboratory tests are unable to detect, field tests are a final reliability check: They ensure that the weapons in our defense arsenal will work if needed; that safety and security features designed into weapons are adequate; and that U.S. weapons will survive a nuclear attack by an adversary. Finally, field tests ensure that the United States and its allies can meet the changing technological threats posed by the arsenals of unfriendly nations.

To remain scientifically sound, the weapon physics program of applied research cannot be separated from experimental validation, which includes carefully chosen and planned underground nuclear experiments. At the same time, field tests offer scientists a unique opportunity to investigate some basic physics problems—research that may be difficult or impossible to do elsewhere. The complex behavior of nuclear explosions cannot completely be simulated by computer programs nor adequately explored by laboratory experiments. Theoretical calculations and laboratory investigation always precede field tests, but the ultimate truth—the answers to the questions, Are our theories valid? and Will a weapon perform as expected?—is revealed at the test site.



Aerial view of a ground-zero complex.

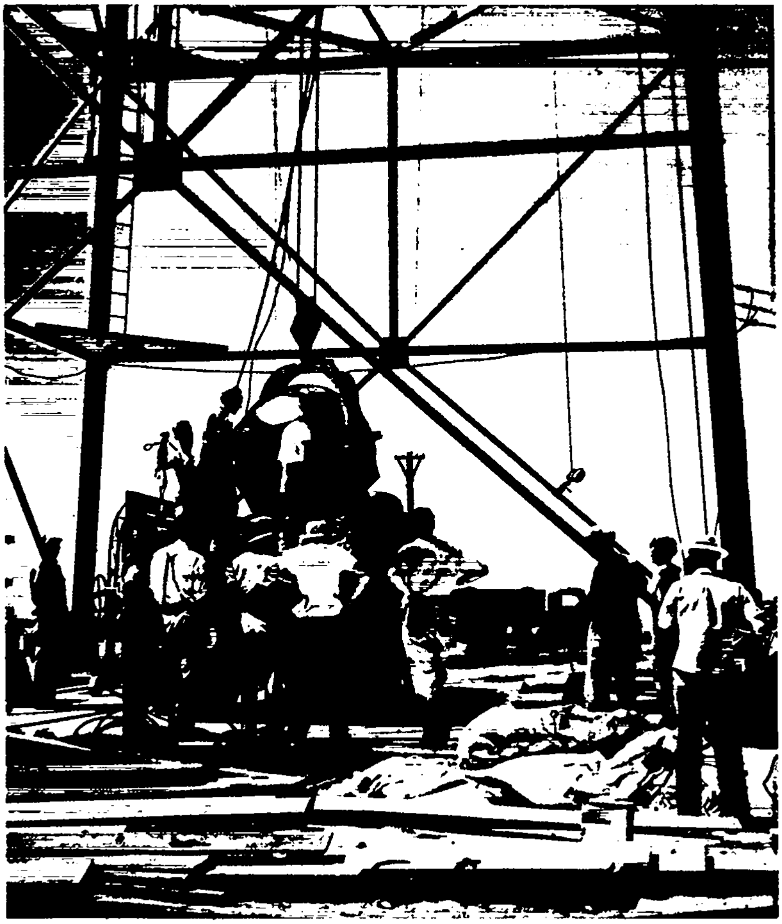
A Brief History of U.S. Field Testing

The world's first nuclear weapon test on July 16, 1945, conducted by the United States, occurred under the pressures of wartime conditions at Trinity Site in southern New Mexico. This event, followed by nuclear explosions over Japan three weeks later, hastened the end of World War II and began the era of nuclear weapon development and testing.

In the early years of testing, the United States detonated nuclear explosives in the atmosphere, on the ground, under the ground, and under water. Concerned about the spread of radioactive products during atmospheric tests, scientists first experimented with contained underground tests at the Nevada Test Site in 1957. On October 31, 1958, the United States and the Soviet Union agreed to a moratorium on nuclear testing.

Not quite three years later, on August 31, 1961, the Soviet Union announced its decision to resume nuclear weapon testing. The detonation of forty-five nuclear explosives shortly thereafter, within sixty-five days, made it apparent that the Soviets had used the moratorium to prepare for further atmospheric tests. President Kennedy ended U.S. compliance with his announcement of an underground nuclear test in September 1961, but the United States did not resume atmospheric testing until April 1962, seven months later.

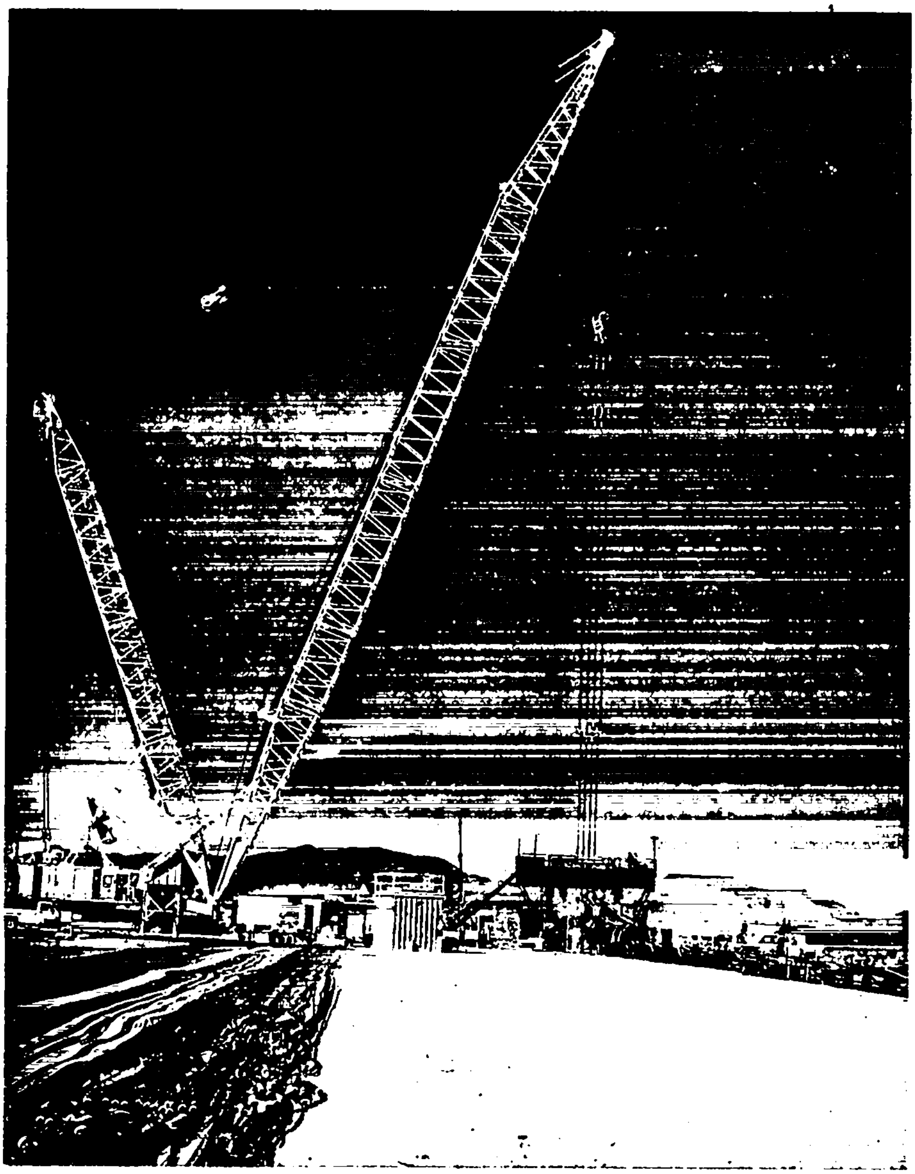
After the moratorium, the United States conducted most high-yield atmospheric tests in the Pacific, while lower-yield atmospheric and underground tests were fired in Nevada. Scientists improved methods of testing nuclear explosives underground, encouraged by the effective containment of radioactive debris this technique makes possible. They developed new diagnostic experiments for measuring fission and fusion reactions, shifting their focus from the primary effects of atmospheric tests—light, heat, and blast—to the measurement of radiation propagation, particle emissions, and shock interactions.



Scientists raise the world's first manmade nuclear explosive onto the tower from which the historic Trinity shot was fired (1945).

The Limited Test Ban Treaty, ratified by the United States, the United Kingdom, and the Soviet Union in 1963, halted atmospheric contamination from nuclear tests by prohibiting testing in all environments except under the ground. Since that time, the United States has conducted nearly all its nuclear tests at the Nevada Test Site. Since 1976, the United States has adhered to the provisions of the Threshold Test Ban Treaty, signed in 1974 but never ratified, which limits the yield of any nuclear weapon test to less than 150 kilotons.

Field Tests



A crane lowers a test rack into a hole.

Nuclear tests are of two general types. ***Performance*** tests are conducted to validate basic weapon physics theory or to evaluate the performance of a nuclear explosive. ***Effects*** tests evaluate the effects of radiation from a nuclear explosion on various critical components of missiles, warheads, and other military hardware. The United States conducts both nuclear performance tests and nuclear effects tests under the ground at the Nevada Test Site.

Nuclear performance tests are normally conducted in a vertical, drilled hole. Both Los Alamos and the Lawrence Livermore National Laboratory design, plan, and conduct performance tests. This brochure describes Los Alamos National Laboratory's role in this process.

In contrast, nuclear effects tests normally take place in a horizontal, mined tunnel. Effects tests are conducted by the Defense Nuclear Agency for the Department of Defense. However, either Los Alamos or Livermore supplies and fires the nuclear explosive for these tests and evaluates the explosion's characteristics and yield.

Since the era of nuclear testing began, scientists have referred to a nuclear explosive as a nuclear device. The term device originated during the years of wartime secrecy and today is ordinarily used to describe a nuclear explosive that has not been developed into a weapon. The terms device and explosive are used interchangeably in this brochure.

Safety Considerations

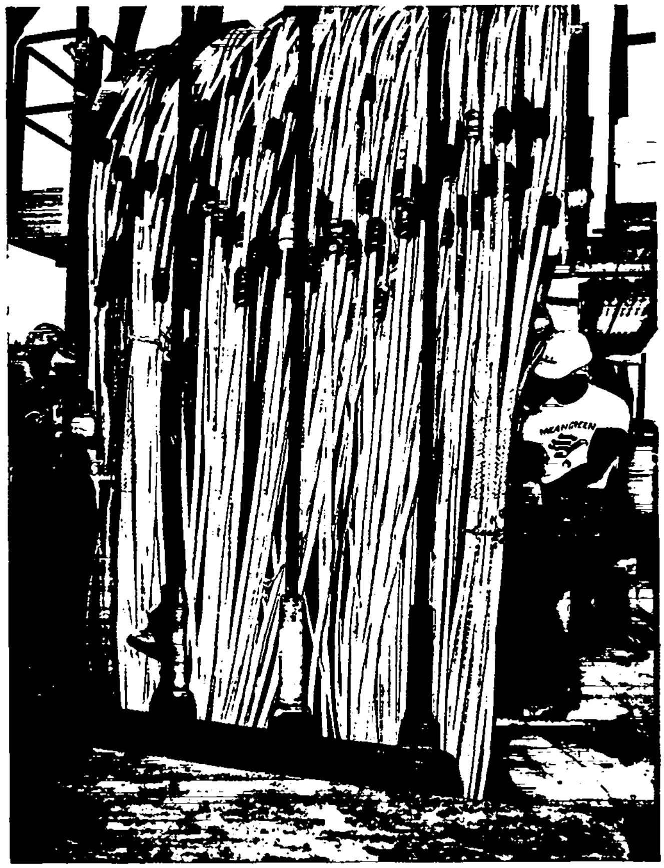
Of primary importance for any underground test is the containment of all radioactive debris and gases. The Los Alamos and Lawrence Livermore national laboratories take detailed safety precautions to prevent accidental venting.

To begin, geologists make an intensive survey to determine the best location for the test hole and to assess the properties of the surrounding earth and rock. The information they obtain, combined with predictions about the behavior of the explosive to be tested, determines how the test hole will be stemmed, or backfilled, to prevent leaks. Typically, blocks are installed to keep gases from flowing beside or through electrical cables, and the hole is stemmed with alternating layers of gravel, fine sand, concrete, and epoxy.

Geological information, the stemming plan, and other factors that could affect containment are presented to a Containment Evaluation Panel. This panel, composed of members from several agencies, assesses the plan for the manager of the DOE's Nevada Operations Office, who is responsible for the safe operation of all programs conducted at the Test Site.

The DOE must also approve all other operations involving a nuclear explosive. It grants approval only after formal Nuclear Explosive Safety Study groups consider in detail the plans for a test. Besides considering proposed security measures, these groups examine the assembly, storage, and transportation of the nuclear device; prearming procedures; emplacement of the device and stemming operations; and the system that will arm and fire the device.

The Laboratory and other DOE contractors follow all normal industrial safety procedures. Further, people who work with the nuclear explosive or its firing system receive special training and certification.



Gas blocks and cable separators keep radioactive gases from escaping uphole through cables or stemming materials.

The Approval Process

Testing that involves nuclear explosives is subject to a well-defined, specific approval process that culminates at the highest level of government. The Los Alamos nuclear test program is approved yearly by the president of the United States after extensive, detailed review by government departments and agencies. The decision to expend resources on a specific nuclear test is made by a panel of senior Los Alamos staff members, while permission to detonate a specific nuclear explosive is granted on an individual basis by DOE headquarters, normally about three weeks before a shot is scheduled. Before electing to exercise this authority on detonation day, the DOE test controller at the Test Site gives careful consideration to up-to-the-minute weather, security, and safety reports. A detailed account of these precautions begins on page 15.

A panel of experts, together with support personnel, monitors all operational aspects of a nuclear test.

Preparing for a Nuclear Test

How do Los Alamos scientists assess the performance of a nuclear explosive?

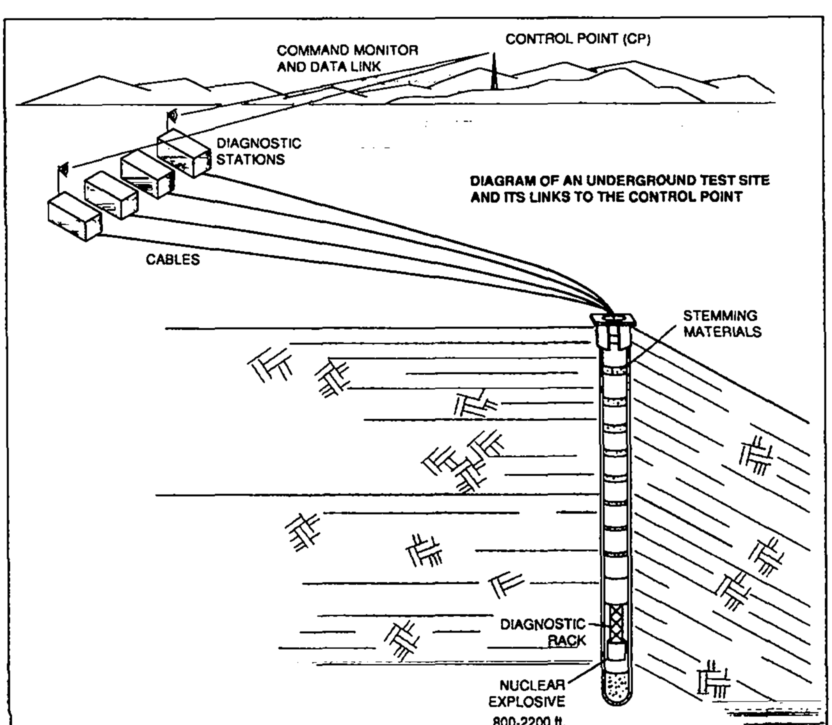
The process begins at Los Alamos with both theoretical and experimental tests. Theoretical physicists make extensive calculations, refining them until they can predict with reasonable assurance that the design of a particular nuclear device will result in useful information from an underground test. Teams of scientists, engineers, and technicians investigate hydrodynamic effects by conducting explosions of nonnuclear materials, and experimentalists design diagnostic experiments that will be mounted on the test rack. These experiments evaluate the performance of a nuclear explosive and explore new concepts in weapon physics. They provide information by measuring the radiation—gamma rays, x rays, and neutrons—emitted from fission and fusion reactions.

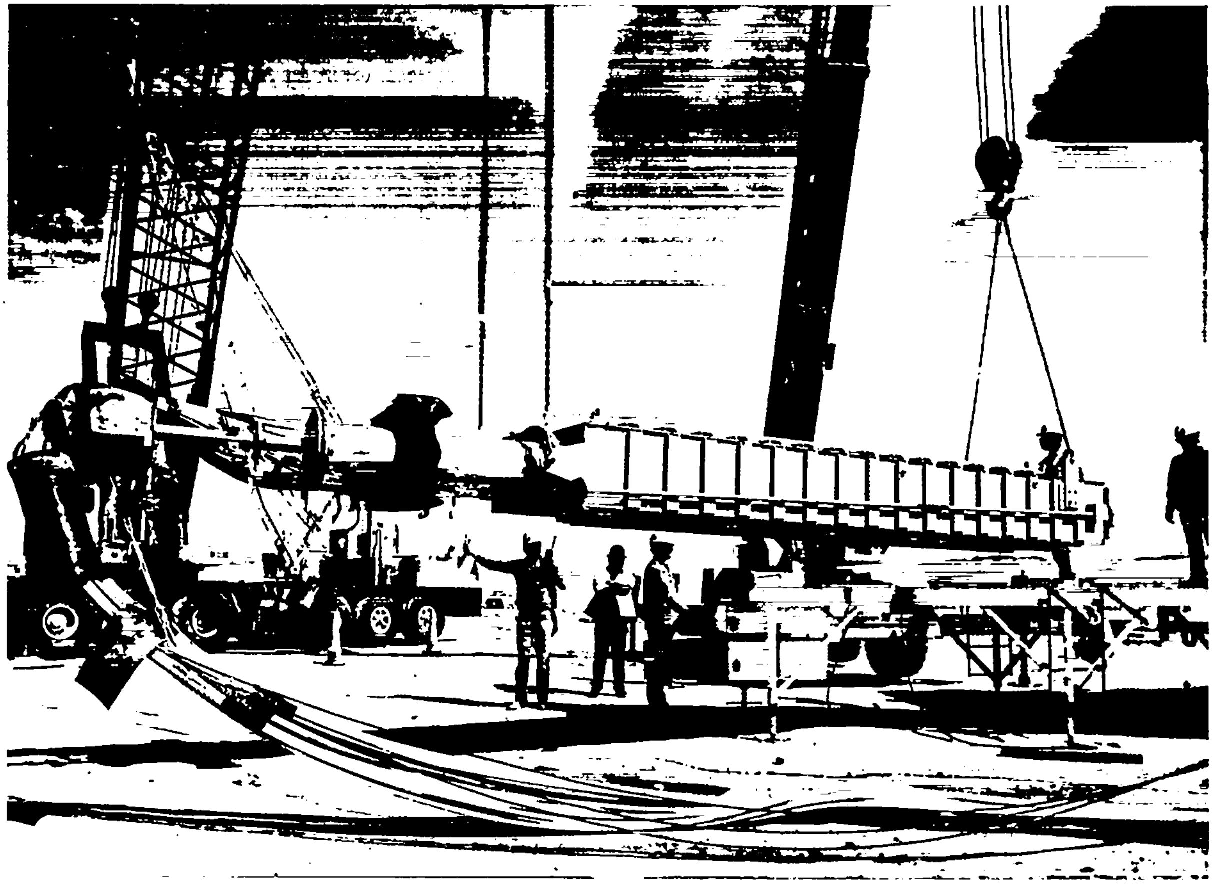
At the Nevada Test Site, the focus of nuclear performance tests is the rack, the structure that holds the nuclear explosive, diagnostic instruments, and downhole components of the timing and firing hardware. The rack is buried in a deep hole and covered with stemming materials to prevent leakage of radioactive debris and gases. Coaxial cables, blocked against gas flow, transmit information about the detonation from detectors on the rack to recorders housed in trailers several hundred feet from surface ground zero, the point on the ground directly above the underground explosion.

Scientists fire a nuclear device by microwave or optical fiber signals from the Control Point. Data from the diagnostic recording stations in the trailers are transmitted to the Control Point in a similar manner. At Los Alamos, scientists compare predicted with actual results and refine their calculations.

After a device has been fired, radiochemists send samples of radioactive debris—which is recovered from the underground cavity created by the explosion—to Los Alamos, where it is extensively analyzed.

In effect a highly specialized physics laboratory, the completed rack, when emplaced downhole and ready for detonation, represents the efforts of hundreds of people—among them physicists, construction workers, engineers, technicians, drillers, geologists, and safety experts—who coordinate their efforts to conduct a successful test.





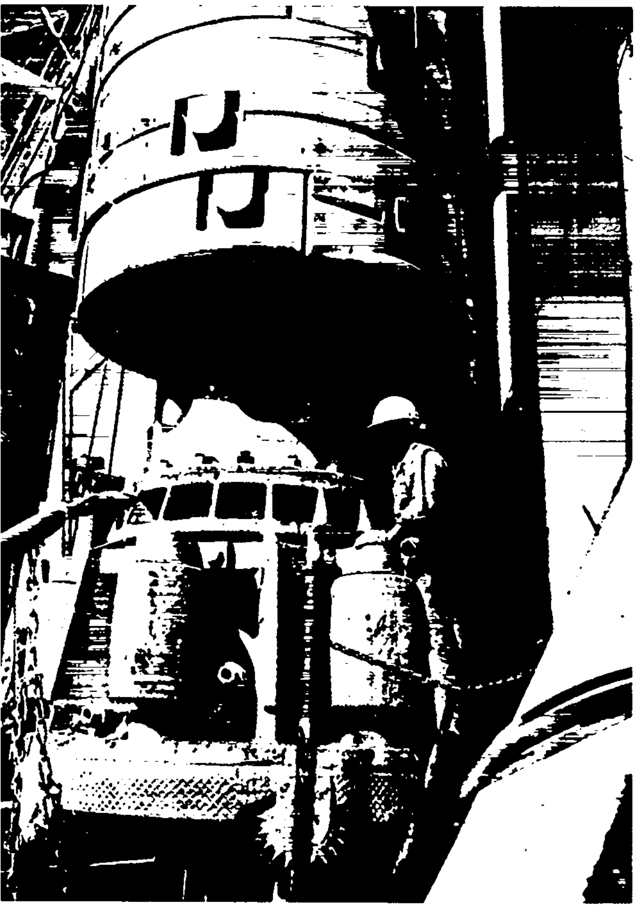
Diagnostic equipment arrives for installation on the rack.

Initial Preparations

After the decision to conduct a nuclear test has been made, the complex processes of theoretical design and engineering development begin. Various teams spend months completing preliminary tasks: they design diagnostic experiments, prepare the site at ground zero, build the rack, design the nuclear explosive, and select the timing and firing system. These activities culminate in the arrival of the rack and components of the nuclear device at the Test Site.

Diagnostics

At Los Alamos, physicists design experiments that will measure the nuclear explosive's performance. Results from these experiments enable scientists to refine their calculations and gain additional insight into how nuclear devices work.



'y designed drill bit bores the test hole.

Site Preparation

Drilling the Test Hole

Meanwhile, site preparation begins at the Nevada Test Site with the drilling of the test hole. Containment scientists calculate how deeply an explosive must be buried and prepare a detailed geological cross section of the hole. They may use computer simulations to help assess shock interactions if the physical properties of adjacent strata or nearby faults look unusual at the chosen location for ground zero.

Drilling time for an emplacement hole requires from three to twelve weeks of around-the-clock work, depending on the hole's location, depth, and diameter. Typical depths range from 600 to 2200 feet; typical diameters range from 74 to 120 inches.

Laying Cable

Next, construction crews lay the electrical cables that will run from trailers housing recording instruments to detectors on the rack, a total length of 1000 to 3500 feet.

Numerous cables connect instruments on the rack with above-ground recording stations.

Crews install trailers on shock-mounted frames a short distance from surface ground zero.

Installing Temporary Buildings and Recording Stations

Last, crews prepare the area around surface ground zero. They set up temporary support buildings and the trailers that house the diagnostic recording stations.

Rack Construction

At Los Alamos, crews fabricate, assemble, and adjust the rack. Each rack is designed to ensure unimpeded access from the target of interest to its diagnostic detectors.

When a rack is completed, it is trucked from Los Alamos to the Test Site.

Device Design

Nuclear explosives are normally designed at Los Alamos, where many parts are also fabricated. Other DOE contractors build the remaining components.

The Timing and Firing System

Concurrently, timing and firing engineers select the system that will arm and fire the nuclear explosive and provide timing signals to the diagnostic stations.

A rack arrives from Los Alamos.

Final Preparations

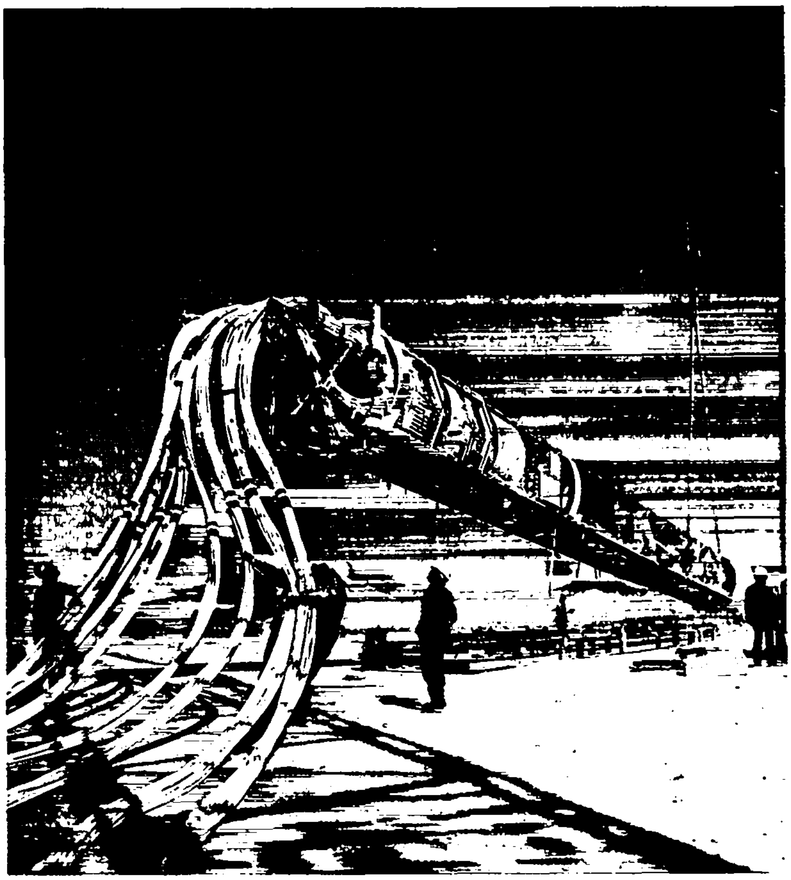
The arrival of the rack at its test area initiates the final series of preparations that culminate in a test event. Over the next several weeks, crews install the diagnostic instruments and the timing and firing system and, finally, insert the nuclear explosive into the rack. Once the explosive is inserted, the rack and associated cables are lowered into place, and the hole is stemmed.

Suspension of the Rack

After connecting the rack to coaxial cables and optical fibers, crews suspend it in a service tower until all final preparations for insertion of the nuclear explosive have been made.

Installation of Rack Hardware

Teams of physicists, technicians, engineers, and craftspeople align line-of-sight pipes and install the detectors associated with each diagnostic experiment. To prevent interference or crosstalk (unwanted signals) between experiments, they isolate detectors, cables, and line-of-sight pipes with large quantities of shielding materials.



Cranes lift a rack to orient it vertically for installation in a service tower.

Preparation of Diagnostic Recording Stations

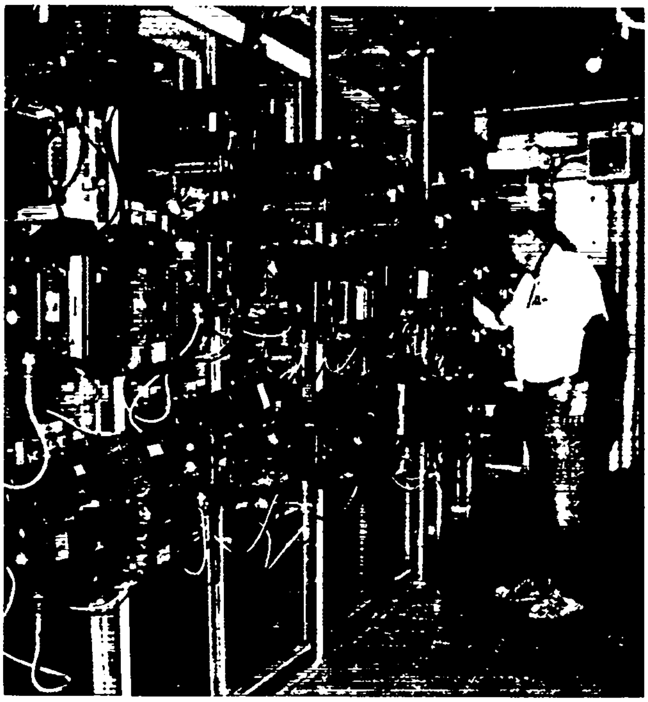
At the diagnostic recording stations, very fast recording instruments (oscilloscopes, cameras, digital recorders, and ancillary equipment) are configured for the test event and extensively checked and tested.

Installation of Timing and Firing Systems

Engineers and technicians set up the Timing Station and the Red Shack, where arming and firing signals are received and sent downhole. They conduct ten to twenty dry runs to ensure that the arming and firing signals are correct and that the instruments in the recording stations and the diagnostic systems operate properly.

Final Assembly of the Nuclear Device

Nuclear explosive fabrication experts assemble the various parts of the device in a remote area of the Test Site. They follow strict safety and security measures throughout this entire operation.



In the recording stations, banks of cameras photograph diagnostic information displayed on oscilloscopes.

Insertion of the Nuclear Device

A convoy of armed guards and armored vehicles delivers the nuclear device to surface ground zero, which is cleared of all but a few essential people. After it is positioned, technicians align the device with line-of-sight pipes and bolt it securely to the rack.

Engineers, following detailed checklists, connect the timing and firing system to the device and give all hardware a final visual check.

Once the nuclear device leaves its assembly area, the time needed to complete final preparations is kept to the essential minimum.

Into the Hole

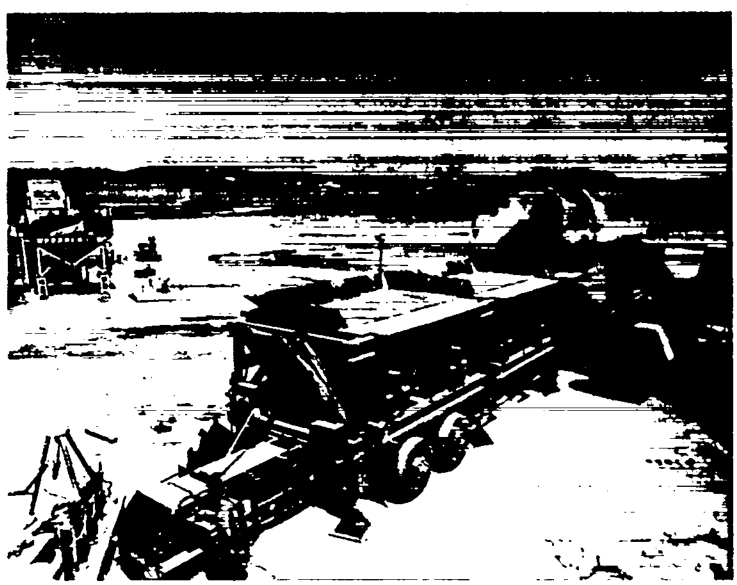
Using wire-rope harnesses and a large-capacity crane, crews lower the rack to the bottom of the hole.

Stemming

Stemming operations occur next, a process that may take up to two weeks. Test holes are filled with layers of fine, powderlike fill about ten feet thick that alternate with layers of pea-sized gravel about forty feet thick. Epoxy plugs are poured around cable "fanouts" and gas blocks, forming an impervious medium. Fanouts separate the cables so that each will be completely sealed in the epoxy.

During this period the timing and firing system, the diagnostic experiments, and recording systems are repeatedly checked and tested.

With the completion of stemming operations, the nuclear device is ready to be detonated.



Stemming materials are measured and weighed with special equipment in a carefully controlled operation.

A Typical Detonation

Detonation day ("D-day") represents the culmination of months of teamwork by several hundred people. Not all are present for a test event; most have completed their assignments earlier and are at work preparing for a subsequent event.

A nuclear test is conducted by remote control from the Control Point, a command post several miles from ground zero. From here, after final briefings are held, signals that begin the firing process are sent by microwave or optical fibers to the Red Shack.

The Countdown
D-Day Minus One

Safety is the paramount consideration in any test involving a nuclear explosive. The day before a scheduled detonation, the Test Controller's Advisory Panel, known as the "shot panel," meets in the Test Operations Center at the Control Point to advise the DOE test controller on matters of safety, security, and related subjects. The proceedings are recorded verbatim by a court reporter.

Members of the shot panel include a senior advisor from Los Alamos, senior members of the National Oceanographic and Atmospheric Administration and the Environmental Protection Agency, and a physician trained in radiation medicine.

The Control Point is the operations center for a nuclear test.

D-Day. Zero time minus several hours

Once again, a readiness briefing reviewing updated weather, projected fallout, and operational information is held. If all conditions are favorable, the DOE test controller gives the Los Alamos test director permission to connect the nuclear explosive to the electrical cables in the Red Shack. The shot panel continues to monitor weather and other conditions, both on and off the Test Site.

To prevent unauthorized detonation of a device, an arm-enable code, which will be used to "unlock" the arming system remotely, is chosen and set by two Los Alamos engineers just before they make final cable connections in the Red Shack.

D-Day. Zero time minus about twenty minutes

After final confirmation that all conditions remain acceptable, the DOE test controller gives the Los Alamos test director permission to fire. Control signals that first unlock the arming system and then complete the arming process are relayed to the Red Shack.

Timing, firing, and control signals are sent from the Control Room.

Contrary to popular belief, manually pushing a button does not set off the detonation. Signals are sent to the Red Shack by an automatic sequencer that typically cycles through its program in ten to fifteen minutes. The sequencer sends the control signals that complete the arming process and activate the recording equipment in the diagnostic stations.

This suitcase contains the arm-enable code that unlocks the firing system in the Red Shack.

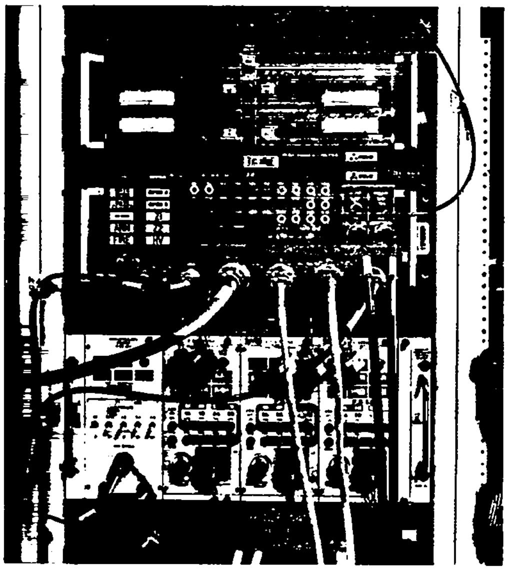
A "fire" signal is sent, and the device is detonated.

Often the only visible sign of a detonation is puffs of dust, caused by shock waves traveling along the ground's surface, that may rise from the immediate area and from any nearby craters. The diagnostic recording stations in the test area will jump and sway. In a few seconds, people at the Control Point may feel a ground roll or two, similar to an earthquake; in the case of high-yield shots, people off-site may also notice some movement.

The most spectacular visible phenomenon associated with an underground nuclear detonation may be the later collapse or subsidence of the ground immediately surrounding surface ground zero, but this collapse does not always occur.

Once conditions are safe, a reentry team, traveling in convoy, enters the test area. This team makes sure that no radioactivity is present above ground and establishes a controlled area so that other parts of the Test Site may be reopened for normal work.

The reentry team is followed by a recovery team, which retrieves films and other data from the recorders in the diagnostic stations. Later in the day, physicists and designers, eager to learn what information has been recorded, meet to take a preliminary look at results and to compare notes.



D-Day. Zero time

D-Day. Zero time plus one-half to twenty-four hours or more

Recovery Operations

Craters mark the site of underground tests.

Equipment in the Red Shack relays information to and from the nuclear device.

Radiochemical Analysis

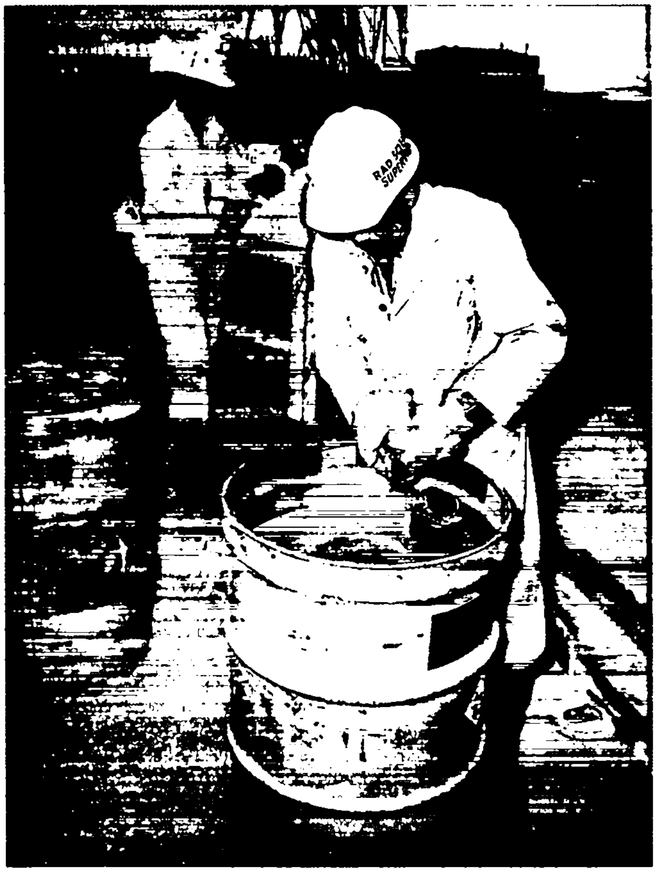
For a complete picture of the nuclear device's performance, results of all the prompt diagnostic experiments are correlated with the radiochemical analysis of shot debris.

As soon as it is safe, drillers set up a postshot drill rig to recover samples. Once the angled hole is drilled through radioactive debris in the bottom of the collapsed cavity, radiochemists and drilling engineers conduct tests to determine the areas richest in radioactive elements.

Working around the clock because the radioactivity in the cavity decays rapidly, radiochemists and radiation safety technicians carefully collect and package samples and ship them to Los Alamos for analysis.

Conclusion

The test is over, but the work is only starting for the many people who will sort out the mass of accumulated information. The months, even years, of planning, designing, building, and fielding a nuclear performance test by the hundreds of people involved will increase our understanding of nuclear explosive design as well as of basic hydrodynamic physics, strengthening our ability to implement the nation's defense policy of nuclear deterrence.



Technicians package postshot debris samples for radiochemical analysis at Los Alamos.

The People: A Nuclear Test Is a Team Effort

Teams meet frequently to plan the details of a test event.

The magnitude of the planning effort for a nuclear test surprises most people. Physical preparations may take a year or more; before that, physicists and weapon designers spend many months doing theoretical research, studying the literature, conducting experiments with nonnuclear materials, and making calculations. A nuclear test involves the combined effort of hundreds of people employed by Los Alamos National Laboratory and other defense contractors—an effort equivalent to about two hundred years of individual work.

Preliminary studies are done at Los Alamos, but once the design and parameters of a test have been established, the action moves to the Nevada Test Site. Weapon physicists make numerous trips to Nevada from the Laboratory's location in northern New Mexico to ready the experiments they have planned for the test.

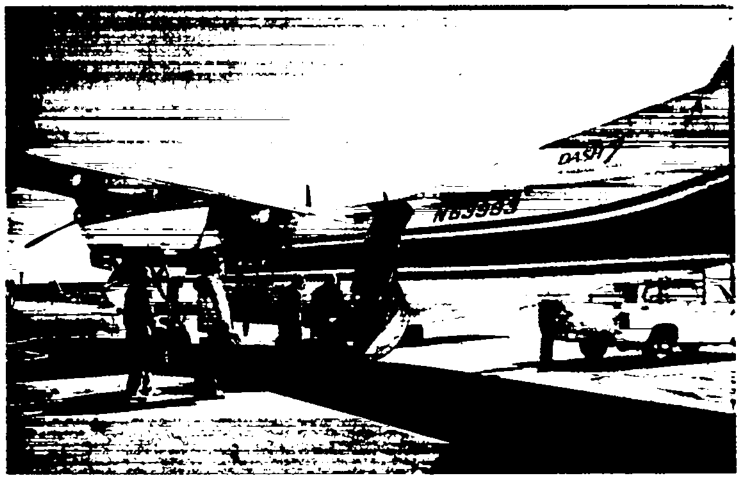
Essentially all technical divisions of the Laboratory make significant contributions to the Los Alamos underground nuclear test program. In addition, Department of Energy contractors support the Laboratory's effort in a number of vitally important ways.

The Test Site itself is managed by the Nevada Operations Office of the DOE, headquartered in Las Vegas, whose principal mission is to carry out the DOE's nuclear testing program. This office maintains the Nevada Test Site for its users, which include Los Alamos, Lawrence Livermore National Laboratory, Sandia National Laboratories, the Defense Nuclear Agency, and others. Day-to-day operation of the Test Site is the responsibility of the DOE's on-site Nevada Test Site Organization. The Nevada Operations Office has ultimate responsibility for the safety of all activities conducted at the Test Site.

Reynolds Electrical and Engineering Co., Inc., is the DOE's prime contractor at the Test Site. In addition to operation, construction, drilling, mining, and maintenance services, it provides on-site radiation safety and industrial health services. The technical facets of field testing are supported by EG&G, which designs and builds the detectors, recorders, and related instruments used for routine measurements. EG&G technicians and engineers also set up and monitor the timing and firing systems, the command and control communications, and the instruments in the diagnostic recording stations under the direction of the Laboratory.

Holmes and Narver does architectural engineering of facilities at the Test Site, while Fenix and Scisson designs the drilling plan for each vertical test hole and Wackenhut Services, Inc., provides physical security services.

The people who contribute to the underground nuclear test program are part of a unique group. Dependent as they are on teamwork to carry out demanding jobs that require special skills, usually working under the pressure of deadlines, and relying on each other's expertise to complete a mission important to the defense of the United States, they demonstrate a sense of purpose and a camaraderie that inspires their efforts and their commitment to their work.



Scientists preparing for a field test spend many hours traveling between Los Alamos and the Nevada Test Site.

The Place: The Nevada Test Site

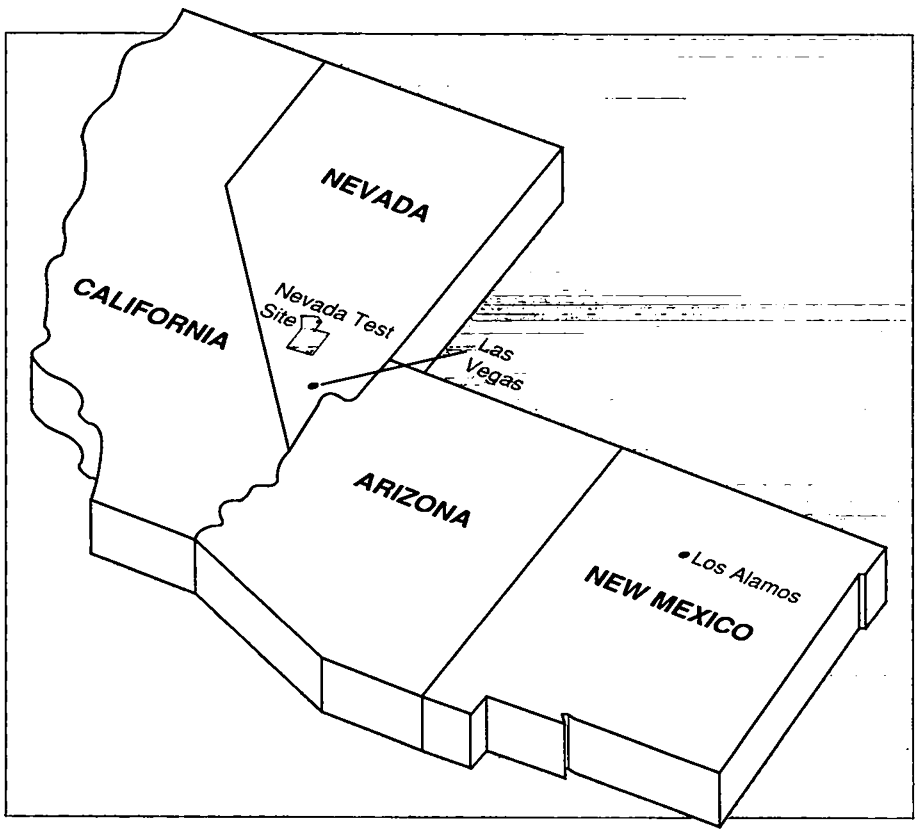
The test in January 1951 of a one-kiloton device, dropped from an Air Force plane over Frenchman Flat, inaugurated operations at the Nevada Test Site. News coverage of other atmospheric tests soon made Frenchman Flat and Yucca Flat, a larger valley to the north, known worldwide.

The Nevada Test Site provides an on-continent proving ground for testing nuclear explosives. Established in December 1950 to reduce the expense and logistic problems of testing in the Pacific, the Test Site is today the location of all the nation's underground nuclear tests.

Only twelve air miles from the nearest border of Death Valley, the Test Site covers an area of high desert larger than the state of Rhode Island—1350 square miles. Its rugged basin-and-range terrain is dominated by two high mesas, Rainier and Pahute, whose highest point reaches 7679 feet. Precipitation of only four to twelve inches a year and temperatures that range between 110°F and -14°F combine to produce hot, dry summers punctuated by afternoon thundershowers and cold, dry winters. Except for a few small springs, the Test Site has no permanent surface water.

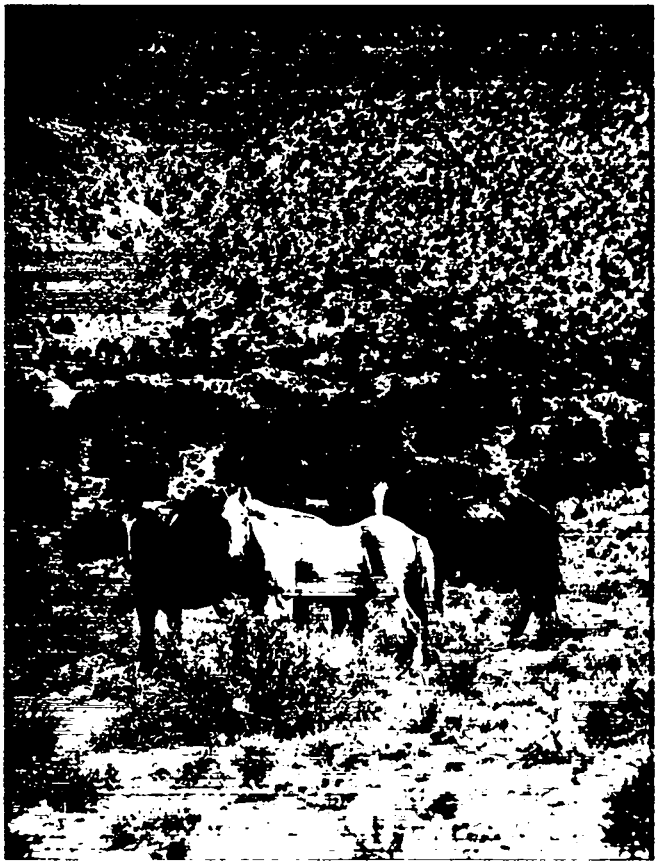
Vegetation at the Test Site appears sparse and rather monotonous; visitors see mostly creosote bush, blackbrush, and, above 5000 feet, sagebrush. Piñon and juniper trees dot the high mesas. But because the Test Site lies on the transition between the Mohave and Great Basin deserts, it supports a surprising diversity of plant species. Many are inconspicuous until spring, when their flowers paint the desert floor.

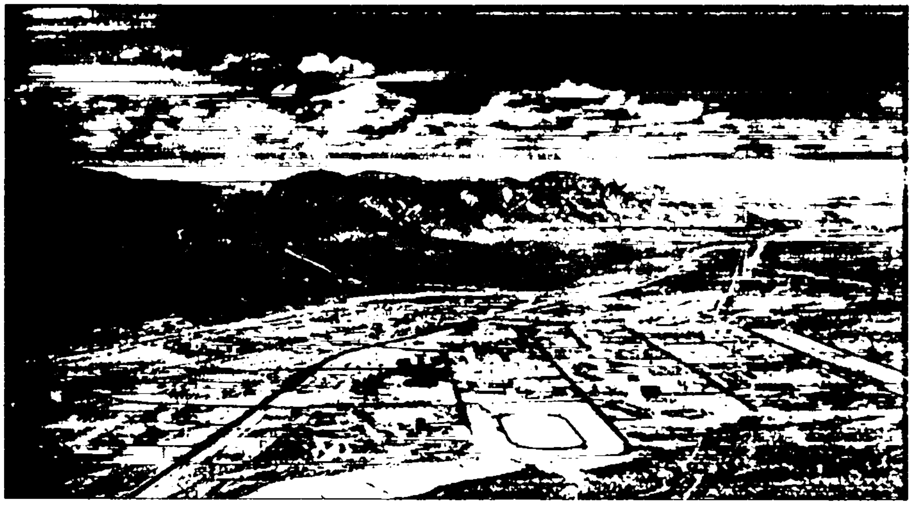
The Nevada Test Site encompasses varied terrain.



Invertebrates—mostly insects—comprise the majority of animals at the Test Site both in numbers of species and relative abundance. Of the mammals, visitors are most likely to see members of the rodent family; the Test Site also supports fourteen species of lizards and seventeen species of snakes. Wild horses and domestic cattle range over parts of the area.

Once home only to roving bands of Indians and later to prospectors, miners, and a few ranchers, the Test Site is now the work place of over five thousand people, most of whom commute from Las Vegas one hundred miles to the southeast. Offices of the DOE, the three national weapon laboratories, and DOE contractors cluster at Mercury, a "company town" that also boasts temporary housing for several hundred people, a nearby airstrip, a restaurant, a cafeteria, a post office, a movie house, a bowling alley, and a swimming pool.





Top: The Test Site supports a surprising variety of plants and animals. Wild horses thrive at higher elevations.

Located just inside the main gate, Mercury is the Test Site's administrative headquarters.

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