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Tonopah Test Range
Outpost of Sandia National Laboratories

Leland Johnson

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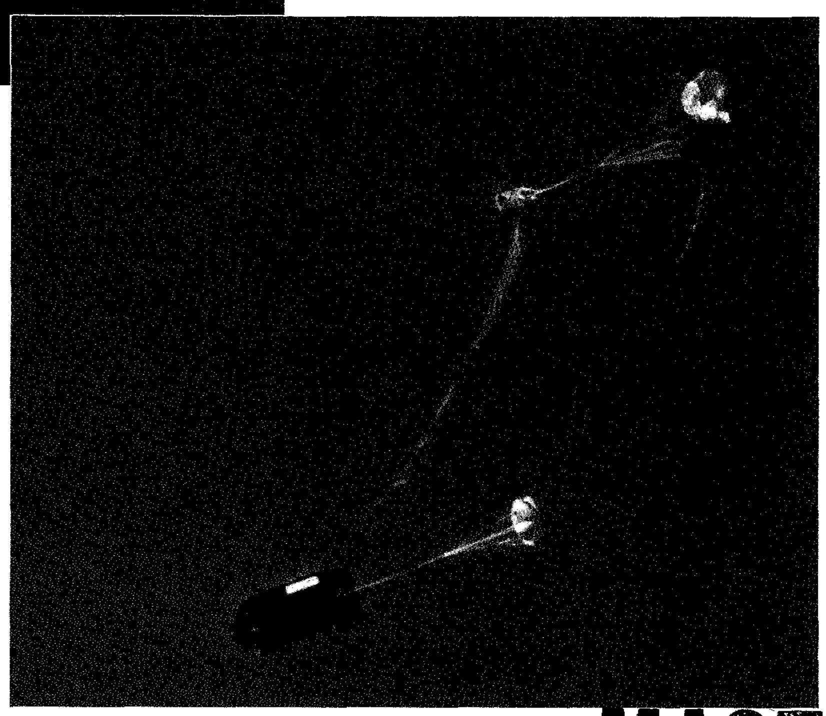

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Abstract

Tonopah Test Range is a unique historic site. Established in 1957 by Sandia Corporation, Tonopah Test Range in Nevada provided an isolated place for the Atomic Energy Commission to test ballistics and non-nuclear features of atomic weapons. It served this and allied purposes well for nearly forty years, contributing immeasurably to a peaceful conclusion to the long arms race remembered as the Cold War. This report is a brief review of historical highlights at Tonopah Test Range.

Sandia's Los Lunas, Salton Sea, Kauai, and Edgewood testing ranges also receive abridged mention. Although Sandia's test ranges are the subject, the central focus is on the people who managed and operated the range. Comments from historical figures are interspersed through the narrative to establish this perspective, and at the end a few observations concerning the range's future are provided.

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Preface

Tonopah Test Range is a unique historic site. Established in 1957 by Sandia Corporation, the forerunner of Sandia National Laboratories, Tonopah Test Range in Nevada provided an isolated place for the Atomic Energy Commission to test ballistics and non-nuclear features of atomic weapons. It served this and allied purposes well for nearly forty years, contributing immeasurably but substantially to a peaceful conclusion to the long arms race remembered as the Cold War. For this achievement alone, the range and the Sandians who operated and used it merit historical study.

This brief review of historical highlights at Tonopah Test Range solicits corrections and additional memoirs from Sandians serving the range from 1957 to the present. The Los Lunas, Salton Sea, Kauai, and Edgewood testing ranges also receive abridged mention. Although Sandia's test ranges are the subject, the central focus, to the extent records permit, is on the people who managed and operated the range. Based on available unclassified materials, this paper seeks to encourage efforts by Sandia's managers to archive and preserve the range's documentary records, thereby enhancing historical resources for future study.

In the case of Tonopah, one must assume the long historical perspective to comprehend either its past or its future. Comments from historical figures are interspersed through the narrative to establish this perspective, and at the end a few observations concerning the range's historical future are provided.

The author is grateful to Gary West, Kathleen McCaughey, Wayne Lathrop, and the staff of Tonopah Test Range for their hospitality, cooperation, and support of this preliminary study. Nancy Pruitt and Anna Nusbaum of Recorded Information Management provided leadership and guidance for the study, and Archives Coordinator Myra O'Canna assisted with interviews and collected the photographs needed as illustrations. Thanks are due as well to the Sandians serving at Tonopah, past and present, for sharing their memories and records.

Leland Johnson

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Tonopah Test Range

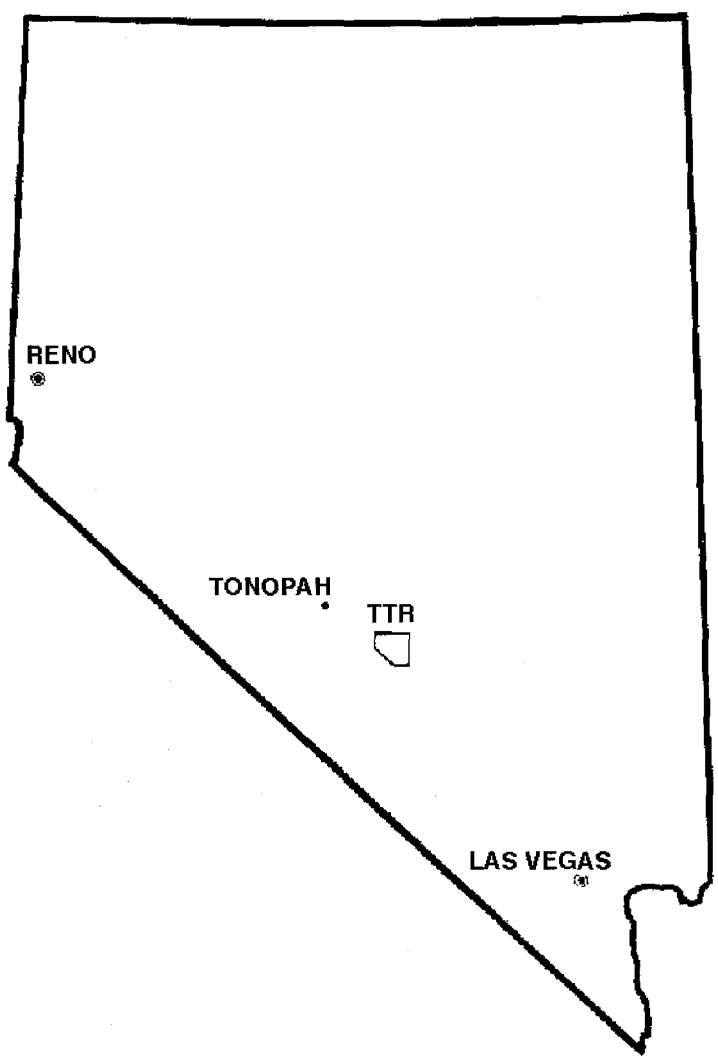
Begin to throng into my memory, of calling shapes and beck'ning shadows dire, and airy tongues that syllable men's names on sands and shores and desert wildernesses.

John Milton, 1634

"Fiercely beautiful" is the description commonly given to Tonopah Test Range by reporters privileged to visit it. Sandia's "crown jewel" and a "national resource" were other reactions from visitors awed by this technological mecca in the Nevada desert. Located in south-central Nevada midway between Reno and Las Vegas, the range occupies a desert valley more than a mile above mean sea level. Sandwiched between the Cactus and Kawich mountain ranges, the valley gets only five inches of rain and snow annually. As a result, it has sparse vegetation, chiefly grasses and a few joshua trees. Although antelope and wild horses graze the grass, wildlife is not abundant on the range. For flatlanders from wetter climates, the sharp-edged mountains east and west of the barren valley speckled by shiny yet dry lakes make awesome impressions indeed.

These remarkable environmental features proved appealing for reasons other than esthetics to Sandia's field testing managers during the 1950s. The desert valley's dryness afforded more than 300 days annually of weather clear enough for tracking aircraft and airborne weapons across the valley. It prevented the growth of dense vegetation that might obscure views of bomb impacts. The mountains lining the valley east and west clearly delineated a north-south flight path through the valley, assuring that secret testing could be conducted safely and securely.

Tonopah Test Range was so remote from population centers that commercial air traffic rarely interfered with testing, nor were highway traffic and encroaching urban sprawl of concern. Goldfield, a town of 300 residents, was a few miles west of the range, and Tonopah, a town of 3,000, was thirty-eight miles to the northwest. The range took its name from the town of Tonopah, and the name is a Shoshone or Paiute word translated as "little water" or perhaps "brushwater springs."



During the 19th century, a stagecoach line crossed through the valley and homesteaders established ranches near the base of the mountains bordering the valley where springs provided water supply. At the turn of the century, prospectors mined small caches of silver and turquoise in the valley. Although artifacts of these pioneer enterprises dot the range, no people had to be relocated by Sandia when it acquired the range in 1957. They had been removed when the Army Air Corps established the Las Vegas bombing range on the land and used it for aircraft crew training during World War II and later.

Remote, desolate, unpopulated, barren, dry, Tonopah Test Range was fiercely beautiful indeed to the Sandians who led the search during the 1950s for a weapons testing range with precisely these features.

Test All Things

Test all things; hold fast that which is good.
Paul of Tarsus, 65 AD

Weapons testing began in ancient times and complemented the development of technological civilizations. The title "engineer" was given in ancient times to the professionals who developed and tested engines of war capable of throwing boulders into enemy strongholds, or fireballs onto wooden enemy ships. The first engineers were, in fact, "weaponeers," a sobriquet enjoyed by the Sandians who helped bring the Cold War of the 20th century to a peaceful conclusion.

A cardinal tenet of engineering is that designs must be prototyped and tested in the field prior to use for any purpose, especially combat. "Knowledge must come through action; you can have no test which is fanciful, save by trial," declared Sophocles in 480 BC.

"Field test is one of the real roots of Sandia," said Howard Austin, one of Sandia's pioneer field testing managers. "In the early days," Austin remembered, "field test data were all we had to base designs on." Field testing became a primary mission of Sandia at its inception, and it was more a career discipline than an occasional sideline in support of weapons development. The field test engineer has been described as a special breed which demands exceptional degrees of independent decision making, of resourcefulness, and of ingenuity. In a sense, the professional lives and capabilities of field test technicians parallel those of construction engineers for the Army Corps of Engineers, or of Navy captains of ships at sea. All are challenging and normally quite mobile professions with substantial autonomy in the field.

The roots of Sandia's field testing organization extend back to World War II, when the United States tested its first atomic weapons to the extent feasible without breaching security. The 1945 Trinity test in New Mexico, a pivotal event in world history, was merely the most memorable of many related test events. Before firing the Trinity atomic device atop a 100-foot tower, the Los Alamos testing team detonated tons of high explosives atop a 20-foot tower. Meanwhile, the Army Air Force tested modified B-29s and mockup nuclear bombs, thereby checking aircraft crew performance, the delivery systems, and bomb ballistics. Called "pumpkins," the first prototype nuclear bombs were painted bright orange to enhance observations of their trajectories to targets. These were "drop-tested" from aircraft over land targets near the Wendover, Utah, Army Air Force base and over water targets at the Salton Sea, a Navy bombing range in southern California.

Weapons assembly and testing teams from Wendover and Los Alamos transferred in late 1945 to Sandia Base at Kirtland airfield near Albuquerque, where they formed the nucleus of the modern Sandia National Laboratories. Most of the original staff at Sandia were veterans of the Army's Manhattan Engineer District, or of the armed services. They knew, often from unfortunate personal experience, the consequences of bombs that were duds, of torpedoes that fizzled, of rifles that jammed. They were determined that the nation's ultimate weapons should be 100 percent reliable: that they would release from aircraft properly, fall directly toward the target, detonate at the precise elevation and timing, and cause maximum damage to targets, whether they be industrial centers, ships, transportation facilities, or enemy forces. Field testing of weapons prototypes therefore was imperative, for in the postwar years most design relied upon iterative cut-and-try testing. That is, after a weapon was designed and prototypes built, it was tested in the field as near to simulated combat conditions as possible, then returned to the laboratories for modifications or redesign and again tested to the maximum.

A few years after World War II, Sandia created Area III south of the original Sandia Base for full-scale environmental testing of weapons and their components. There, Sandia built centrifuges, sled tracks, and other facilities capable of testing weapons to destruction. But these facilities were unavailable in 1946, and Sandia could not accomplish the final acid tests of weapons, especially aircraft drop tests, at Albuquerque. To conduct these tests, a wide-open test range, free of commercial air traffic and urban development was required. Before acquiring Tonopah Test Range, Sandia used three other ranges: the Los Lunas, Salton Sea, and Yucca Flat test sites. Something of the history of these should be related before turning to the historic Tonopah site.

Los Lunas Test Range

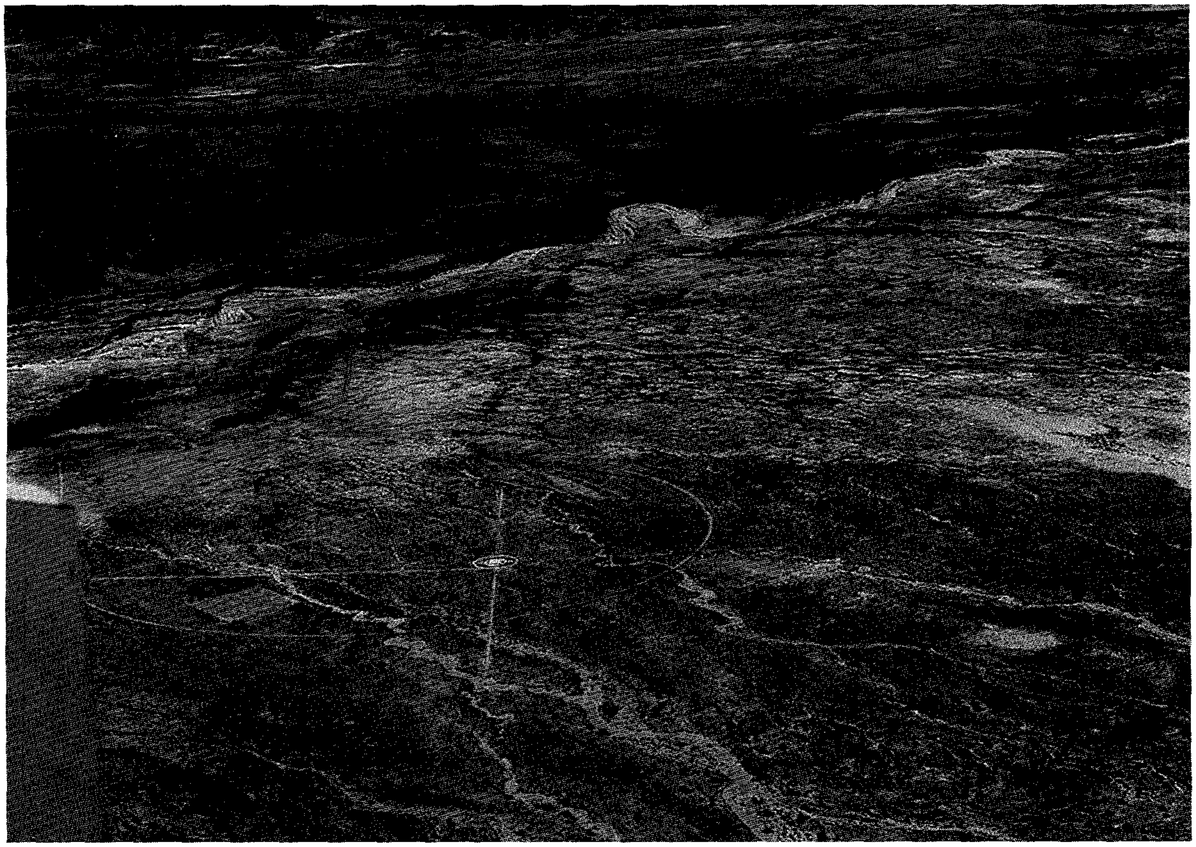
Glenn Fowler, Sandia's first field test director, had participated in the Massachusetts Institute of Technology's program of World War II for developing radar to track aircraft. Later, he had positioned the aircraft that collected aerial data on the 1945 Trinity test. He became chief of field testing for the Los Alamos Z-Division at Sandia in September 1945.

Fowler's first task was to identify a site for testing the non-nuclear parts of bombs designed at Sandia. In those days, the nuclear core or pit for the weapons was produced at Los Alamos and was separate from the bomb casing and the arming, fuzing, and firing systems designed at Sandia. The nuclear core was not inserted into the bomb casing until after both were aboard an aircraft bound for a target. Field testing then involved dropping the inert bomb casing minus the nuclear core, with materials weighing the same as the nuclear core placed inside the casing. Field tests of the nuclear pits were performed in the Pacific and after 1950 at the Nevada Test Site as well.

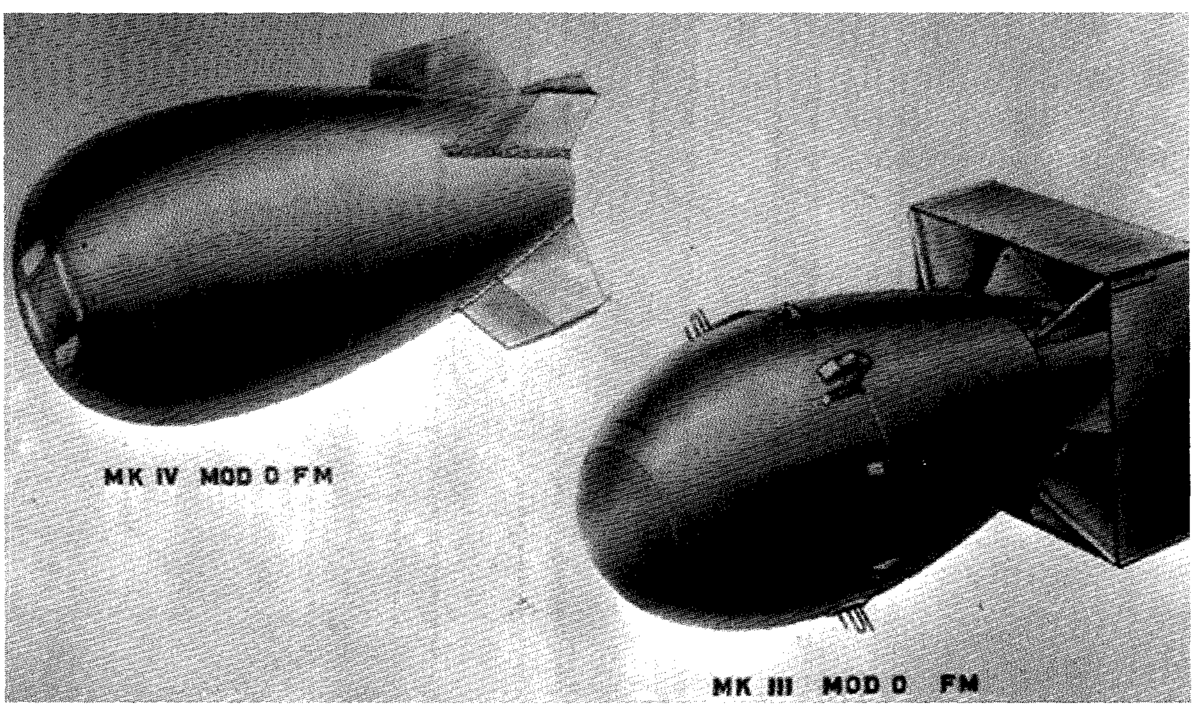
Fowler and Clinton DeSelm surveyed various sites for a test range from the air, then decided Kirtland airfield's practice bombing range near Los Lunas could also serve as Sandia's test range. On 1,320 acres leased from ranchers and the Isleta Pueblo, Sandia completed ground surveys in November and began test drops in December 1945. The first tests were of the Mark III, the first postwar nuclear bomb, which for testing was designated as Military training unit 107.

Other than target and camera-station markers, Sandia built no facilities at the Los Lunas range. The range had merely a single flight line and no roads at all; four-wheel drive vehicles provided transportation into the range. The range instrumentation included three K-24 cameras, one telemetry receiver, two Mitchell (Hollywood motion picture) cameras, and three transits for locating bomb impact points. For each scheduled test, the field testing crew loaded these instruments on trailers, then loaded an inert weapon aboard a B-29 at Kirtland airfield. While the plane struggled to reach an altitude of perhaps 30,000 feet, the crew had time to drive to Los Lunas and set up their instruments before the plane reached position for the drop.

Drop tests of the Mark IV bomb began in late 1946 at Los Lunas. These were large, ungainly bombs, little superior aerodynamically to falling boulders, except for stabilizer fins that pointed their front ends toward targets. The tests at Los Lunas therefore were properly described as ballistics tests. They sought information that would permit improving the control of bomb trajectory and accuracy.



Aerial view of target at Los Lunas Range in 1946.



Sketches of the Mark (model) III and IV nuclear bombs of the sort tested at Los Lunas and Salton Sea during the late 1940s.

When Sandia acquired a testing site at Salton Sea in 1946, use of the Los Lunas range declined. At 5,000 feet above mean sea level, Los Lunas did not meet the need for testing ballistics in the denser atmosphere near sea level. Sandia returned control of the Los Lunas range to the Air Force. In cooperation with the Air Force it occasionally participated in testing at Los Lunas until 1959, generally to check the mating of nuclear bombs with aircraft delivery systems.

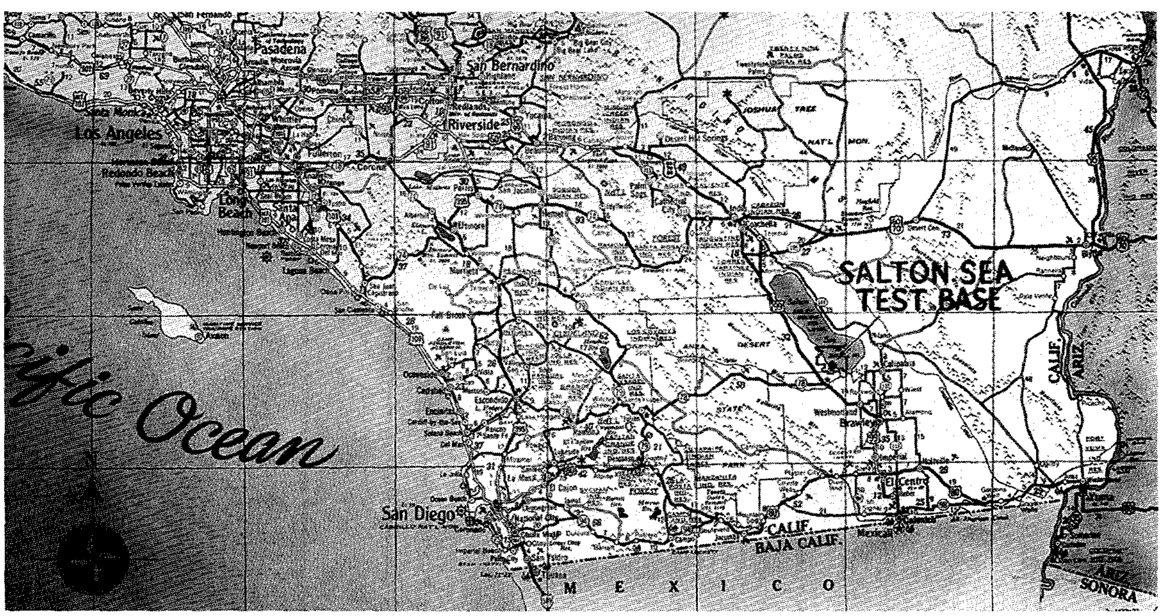
Oh The Desert

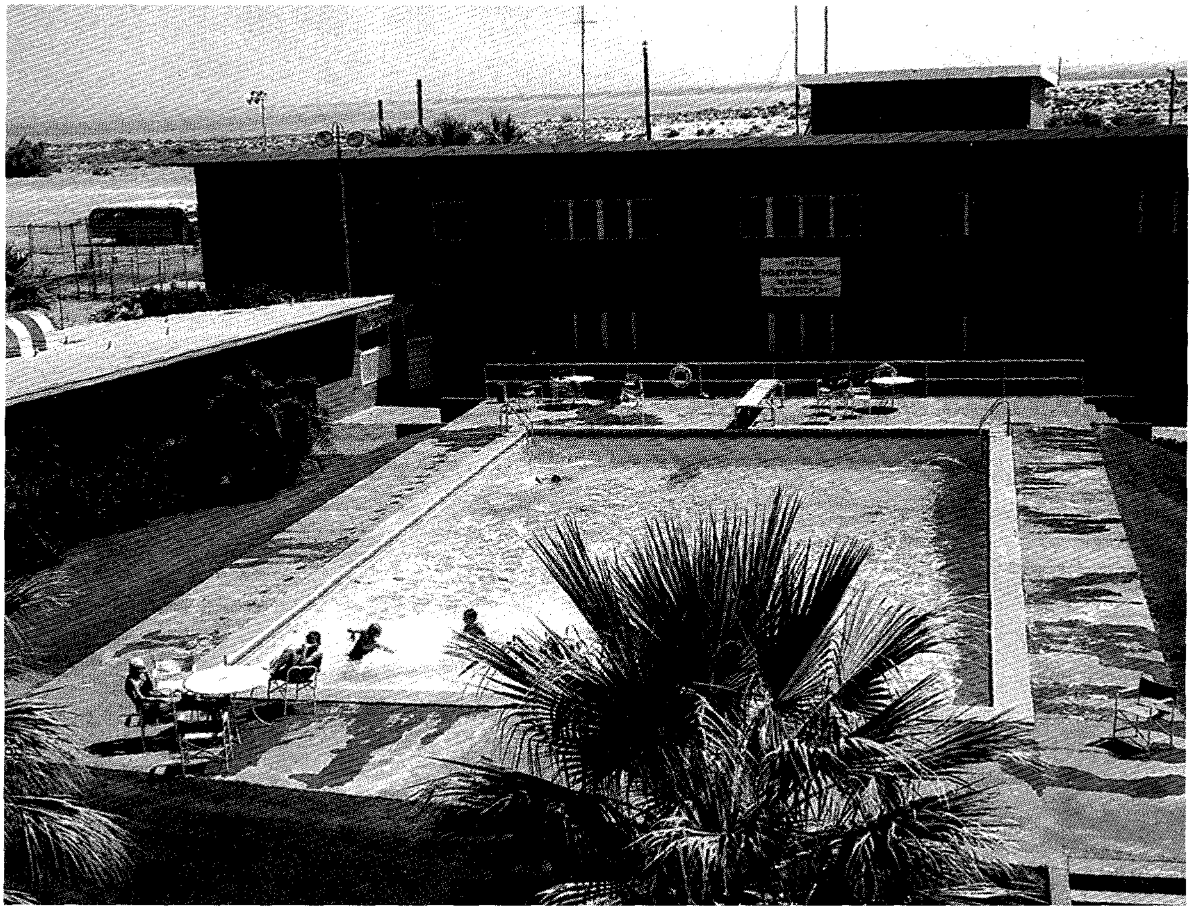
Oh! That the desert were my dwelling place.
Lord Byron, 1820

After examining the Palm Springs Army Airfield, El Centro Naval Air Station, and other sites, Glenn Fowler and colleagues in 1946 selected Salton Sea in southern California as the Sandia test range. It easily answered questions about ballistics in dense atmospheres, because it was 235 feet below sea level in the midst of sand dunes where summer temperatures exceeded 110 degrees. Hollywood producers had filmed "Desert Song" and "Wake Island" on Salton Sea's sandy shores. Early in World War II, General George Patton trained tank crews for the North African campaign in the Salton Sea vicinity, and on the sea the Navy built a range for aircraft torpedo bombing practice.

The Army Manhattan District acquired use of the Salton Sea base from the Navy in 1946, and Howard Austin took a Sandia team to the site to rebuild the old Navy targets, install camera pads, and plan roads and power and phone lines. Under the 1946 arrangement, the Army operated the 81-square-mile base, while Sandia managed technical and testing operations. When the Atomic Energy Commission (AEC) took charge of Manhattan District assets in 1947, it funded $3.5 million in improvements at Salton Sea. These included converting an existing aircraft control tower into a test control center, installing telemetry receivers on sand dunes northwest of the tower, and building four Askania stations, three Mitchell camera stations, two radar stations, a meteorological building, plus offices, shops, water-treatment plant, and housing. Housing included a trailer park, prefabricated homes, and the San Felipe Lodge. The lodge afforded temporary housing at the base together with a restaurant, tennis courts, and swimming pool to serve as the base's social and recreational center.

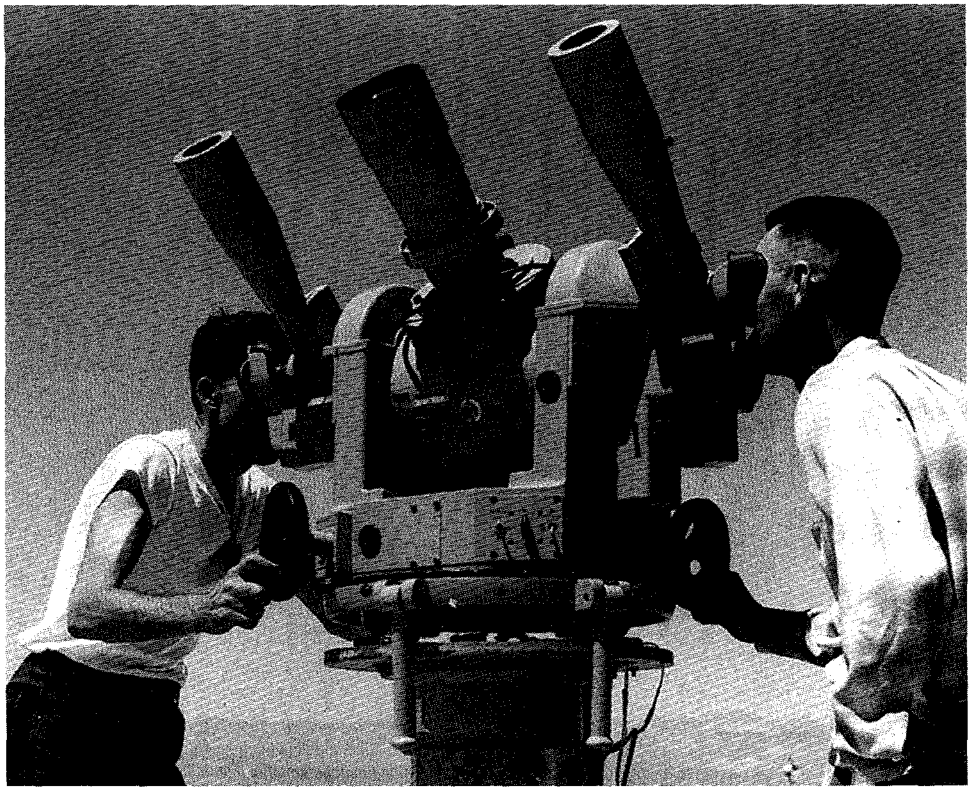
Salton Sea Instrument Laboratory and control center.





Swimming pool at the San Felipe Lodge, recreation center for Sandia's Salton Sea test base.

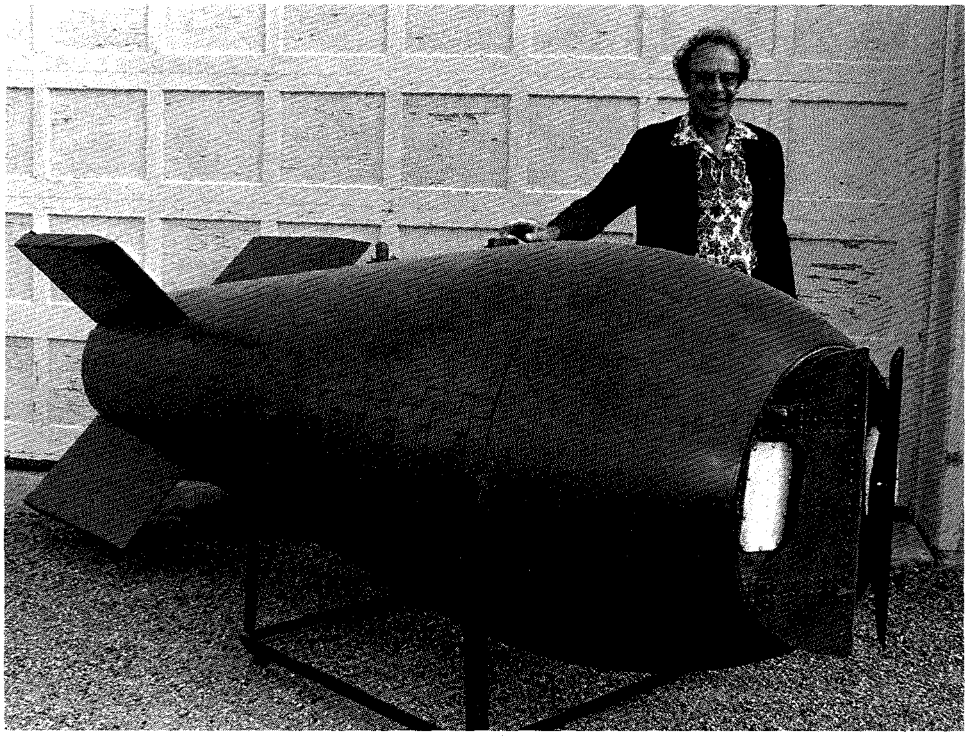
Ben Benjamin, an optical expert at Salton Sea, described the four optical systems adapted for use at Salton Sea to photograph the bombs during descent. Small cameras were mounted on the bombers and chase planes for aerial coverage of bomb releases and ballistics. A tracking telescope and high-speed camera placed on a modified Navy twin 40-mm antiaircraft turret turned to follow a bomb's descent while exposing thousands of film frames per second. A ballistics camera at a ground station made images of the aircraft and bomb through a slit in its shutter onto a large film plate, creating a sequence of images on a single plate. Finally, Askania phototheodolites, combining a motion picture camera with a surveyor's transit, photographed a bomb as it fell while recording its azimuth and elevation on each film frame. The Askanias were spoils of war, brought from Peenemunde where Wernher von Braun's rocket group used them to track Vengeance Weapons 1 and 2 fired at London near the end of World War II.



It required teamwork by two Sandians to operate Askania phototheodolites.

In addition to cameras and equipment for optical tracking, the Sandia team installed "automatic radios" in the bomb casings. These transmitted data on bomb environment and performance to telemetry receivers on the ground. During these precomputer days, the collected data went from Salton Sea back to the Sandia data analysis group at Albuquerque. This group keypunched the data onto cards for machine sorting to plot bomb trajectories and related events.

Sandia completed its first test drop at Salton Sea on March 12, 1947, and it conducted about 150 tests annually there during the following decade, with a peak effort of 223 tests in 1952. Most tests were high-altitude, subsonic drops of various ballistic shapes including both production units and experimental models of newer, more aerodynamic designs. When Glenn Fowler joked that every bomb shape had been tried at Salton Sea except the kitchen sink, some prankster kicked a kitchen sink out an open bomb-bay during the next test run.

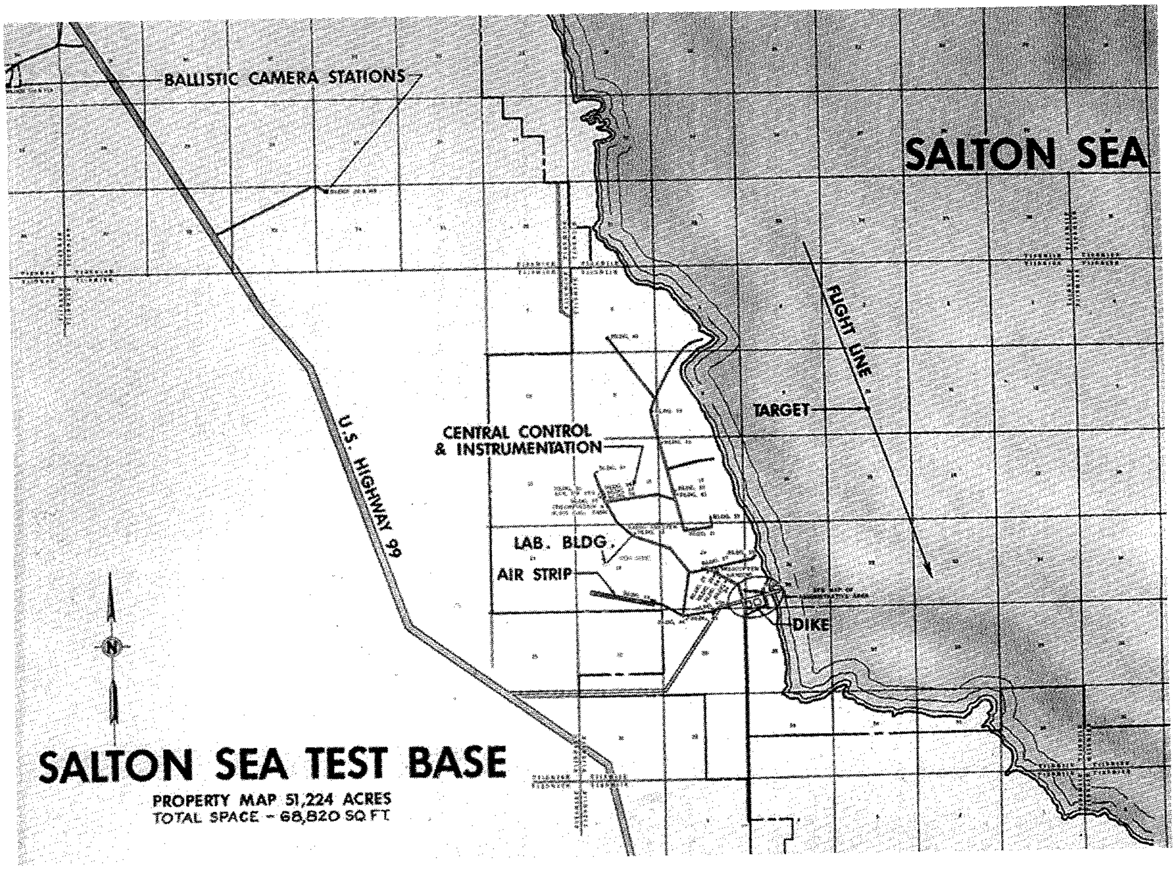


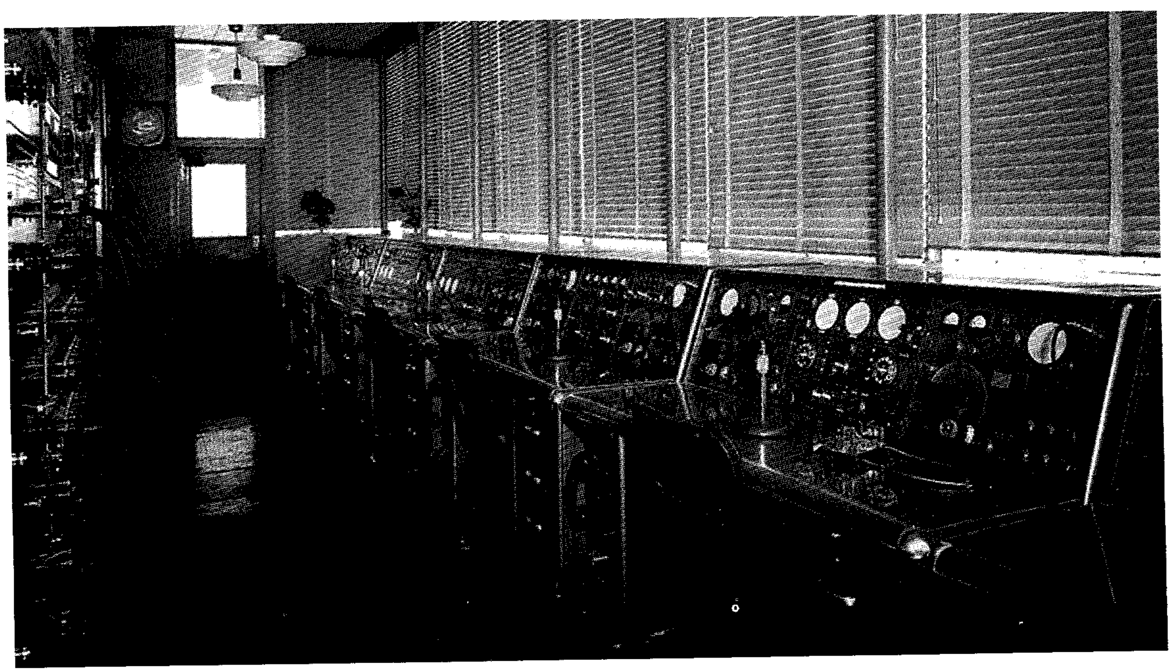
Corry McDonald at Sandia displays the more aerodynamic Mark 5 bomb tested at Salton Sea.

At first, the Atomic Energy Commission furnished the Salton Sea base's administrative and maintenance services, while Sandia managed only the technical operations. Sandia Corporation, created as a subsidiary of Western Electric in 1949, took full charge of the Salton Sea program in March 1950. Ted Sprink of Sandia became director of a Salton Sea Department for administrative support to testing. This included a few small boats, called the "Sandia Navy," to patrol the sea during testing and to maintain the targets.

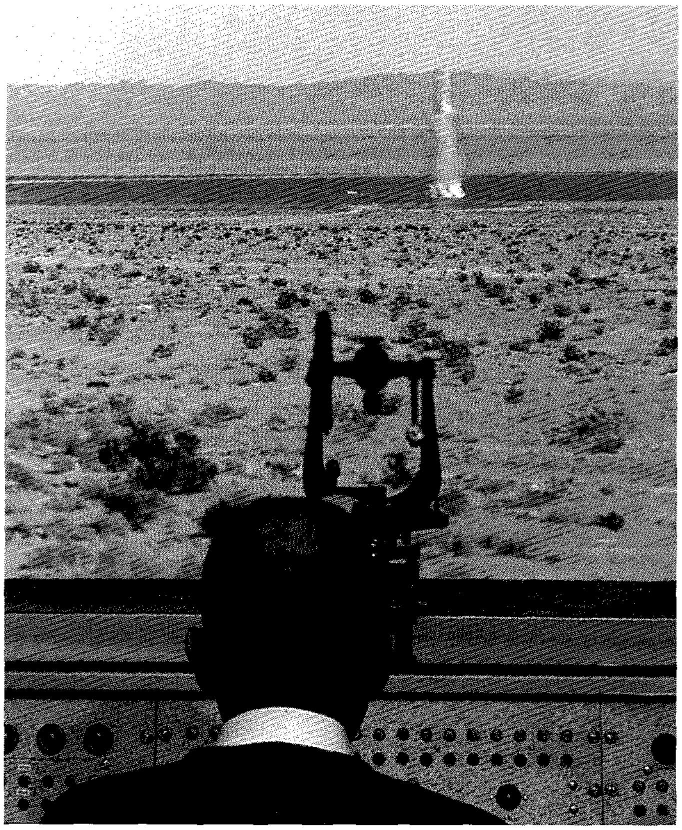
A third of the 100 Sandia employees at Salton Sea lived on the base, and the remainder commuted from the nearby Westmorland, Indio, and El Centro communities. When not conducting Atomic Energy Commission drop tests, the range crew supported target practice by bombers of the Strategic Air Command or the Special Weapons Center at Kirtland Air Force Base.

The range served additional purposes as well. For example, Herb Plagge and Sandia's meteorological section during the 1950s launched balloons from Salton Sea carrying radar and radiosonde transmitters to relay information about wind speed and directions in the troposphere. Their data on the jet stream and its potential effects on high-altitude aircraft went to New York University for analysis on the "electronic brain UNIVAC," one of the early computers.

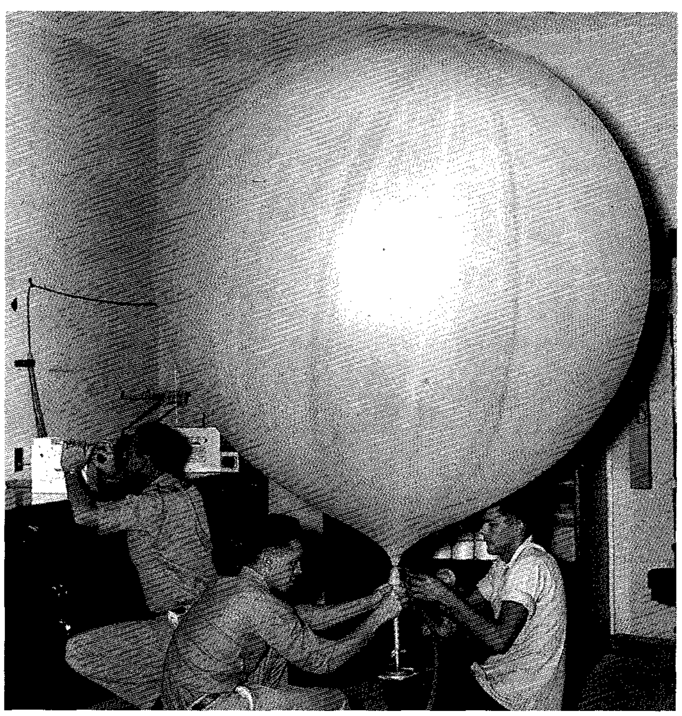




Consoles in the Salton Sea test control center.



Plume of a bomb impact in Salton Sea viewed from Sandia's control center.



Sandians fill balloons to check winds and weather at Salton Sea before test drops.

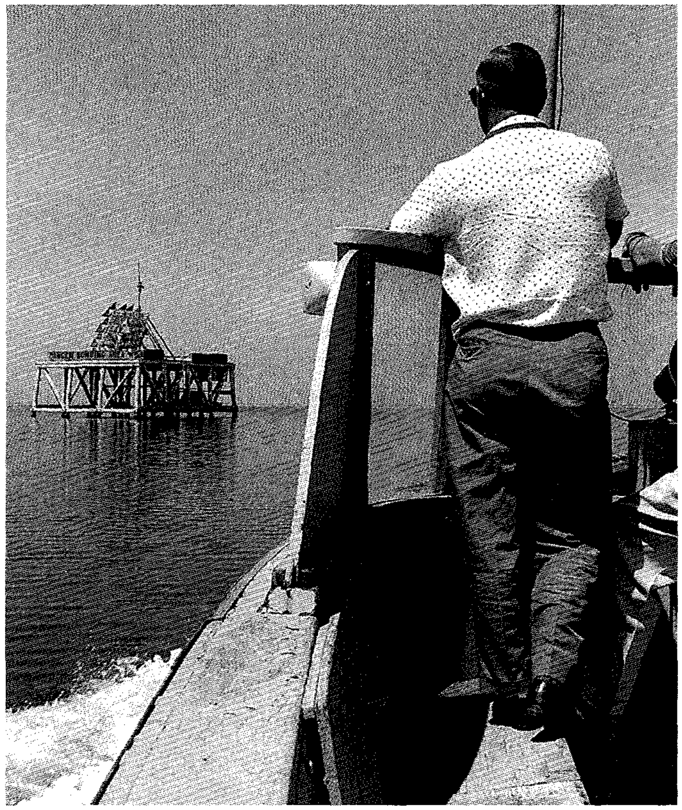
In 1956, the Salton Sea range crew observed the filming of a Hollywood epic, "Bailout at 43,000," starring John Payne. At the theater, this epic proved another bomb. More significant was a 1956 announcement by Sandia's mathematical group that they had in operation an analog computer capable of simulating the fall of a bomb from aircraft to target. After they fed data into the computer, it calculated the bomb trajectory and predicted its impact point. In time, they predicted, computers might eliminate the cut-and-try methods of designing and testing bombs, reducing field testing time from months to days.

As later was the case at Tonopah, Sandia operated the Salton Sea range chiefly for Atomic Energy Commission weapons programs. Tests for the Defense Department or other agencies were not allowed to interfere with the AEC program and were on a reimbursable basis. These reimbursables were forerunners of what later became known as Sandia's "Work for Others" programs.

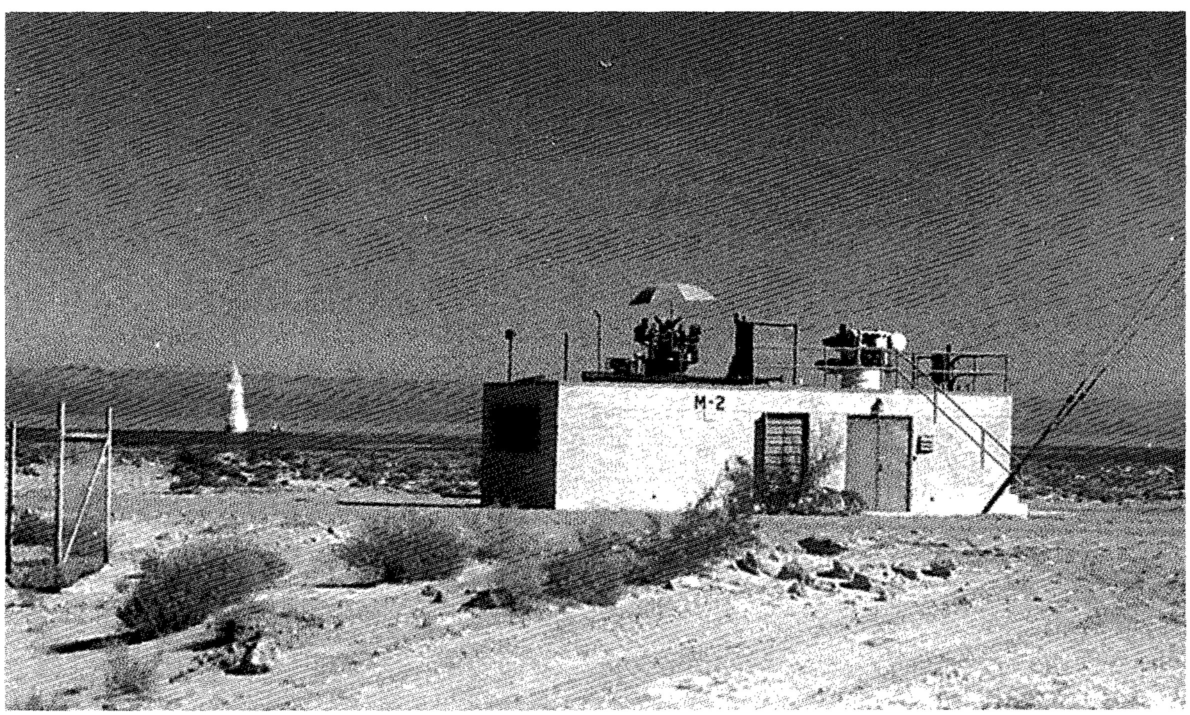
Much of the Salton Sea testing was developmental—a bomb drop to check its ballistics and performance. The pilot brought the aircraft to the range and the range director signaled when the test unit should be released. The test checked not how well the crew could hit targets, but how the bomb hardware performed, and there were spectacular misses. Once a hit was scored on the base's tennis court adjacent to the lodge. Back to the drawing board.

Other primary Atomic Energy Commission tests checked the weapons stockpile and the ability of the crew to stay on target. For quality assurance of the stockpile, a bomb was selected at random and taken from the stockpile. After removal of its nuclear core, Sandians replaced the core with a Joint Test Assembly (JTA) package that simulated the bomb's electrical functions and transmitted data on how it performed. Sandia then handed it to an aircraft crew for use as if during a combat mission. The crew flew to the Salton Sea and dropped the bomb on their own. The military service then evaluated the crew's accuracy while Sandia analyzed bomb performance. Any malfunctions were corrected, either by changing the manuals written at Sandia for bomber-crew guidance, or by correcting the technical problem in the bombs remaining in stockpile. The range crew sometimes referred to these as "JTA tests."

These developmental and stockpile tests for the Atomic Energy Commission provided the meat and potatoes for the Salton Sea range, as they did later for the Tonopah Range under the Department of Energy. All other testing provided the gravy, and the Salton Sea crew had full plates during the 1950s. They tracked NIKE missile launches for teams from the White Sands Missile Range which wanted to learn how the missiles performed at sea level elevations. When NASA dropped Mercury capsules fifty-two times into Salton Sea while developing parachutes to return John Glenn and other astronauts from space, the range crew tracked the capsules' descent into the water and assisted with their recovery.



Don Fifiled and Sandians inspect one of Salton Sea's wooden targets.



A Mitchell camera station at Salton Sea records the plume of a bomb impact.

A helicopter raises a NASA Mercury space capsule for test drops in Salton Sea. Sandia's crew provided photographic coverage of the drops and capsule-recovery assistance.

One of Salton Sea's mobile units, carrying Mitchell cameras and a Newtonian telescope.

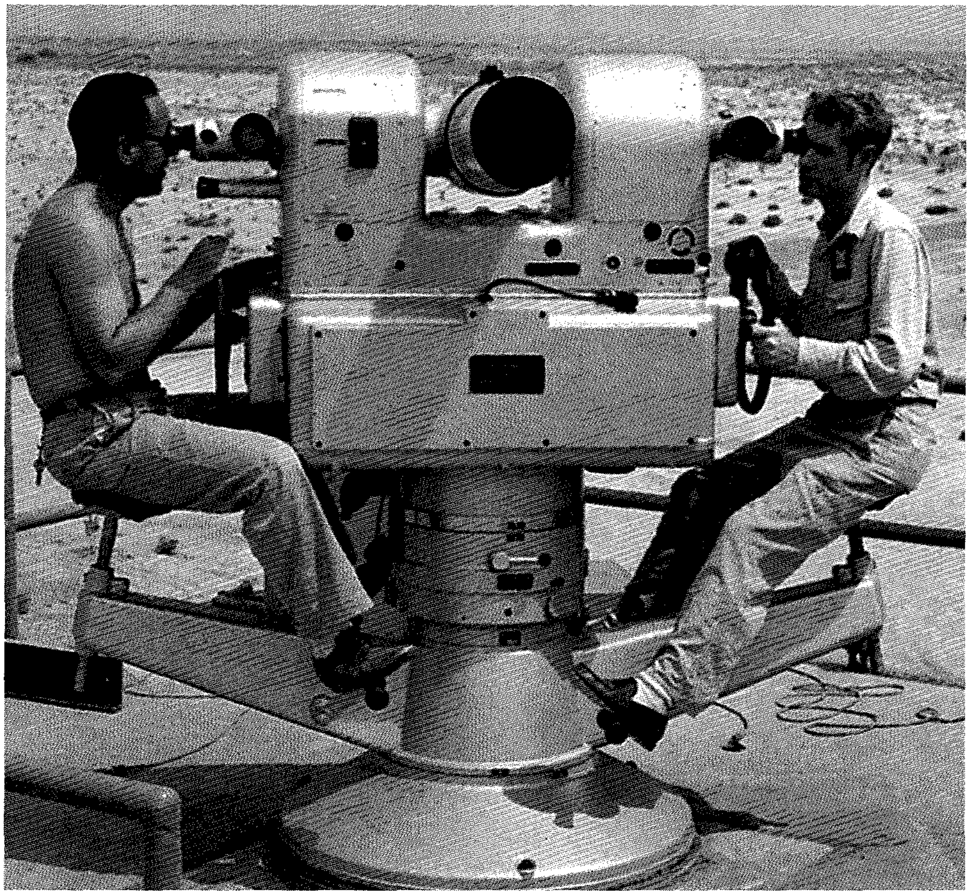
Parachute Development Testing. The F-111 PTV (Parachute Test Vehicle) testing parachutes for a crew escape capsule.

As the bombers progressed from B-29s to B-36s, B-47s, and B-52s, evolving from propeller-driven to jet-powered aircraft, the Salton Sea range crew found it increasingly difficult to track the faster and higher planes from existing stations. Sandia built artificial islands in the sea north and south of the target area to support instruments for full coverage of the drops. Then, the Salton Sea rose to overtop the islands. In 1954, a hastily constructed levee formed a wall on the seaward side of the test base to prevent its inundation. And as the islands sank into the sea, the Navy activated its gunnery range forty miles east of the test range, making the east-west flight approach to Salton Sea targets unusable. This forced the range crew to switch to a north-south flight axis that resulted in solar interference with optical measurements of the drops.

Newer, high-speed jet craft used more fuel, limiting their range from staging areas. Illustrating the problem this caused at Salton Sea, Sandia president James McRae told Brigadier General Alfred Dodd Starbird of an attempt to test a TX-28 bomb dropped from an F-107 plane out of Palmdale airfield. Although the F-107 flew 1400 miles an hour, when it reached Salton Sea it had only fuel enough for a single pass over the target without a practice run, and its bomb landed miles short of the target where it could have been tracked and photographed. "The test," McRae concluded gratuitously, "was not successful."

Other problems arose. Use of a land target built in 1951 on the Salton Sea shore was hampered by intersection of the flight approach line with commercial highways and air lanes. Stocked with sea bass, Salton Sea became popular with fishermen, forcing Sandia to mark and patrol the target area to protect the boaters. Moreover, population increased near the base and commercial air traffic and atmospheric haze from the Los Angeles metropolitan area began to interfere with testing.

Fowler, Howard Austin, and Richard Bice searched for a new test range, preferably one with ample land targets. While the firing systems on early nuclear bombs had used radar altimeters or barometric fuzes for detonating at prescribed elevations above ground surface, contact fuzes had become desirable during the 1950s to provide more flexible deployment choices.



An early Contraves phototheodolite used at Salton Sea.

Salvage divers recovering bomb debris from Salton Sea.

Yucca Flat

The facts will eventually test all our theories, and they form, after all, the only impartial jury to which we can appeal.
Louis Agassiz, 1866

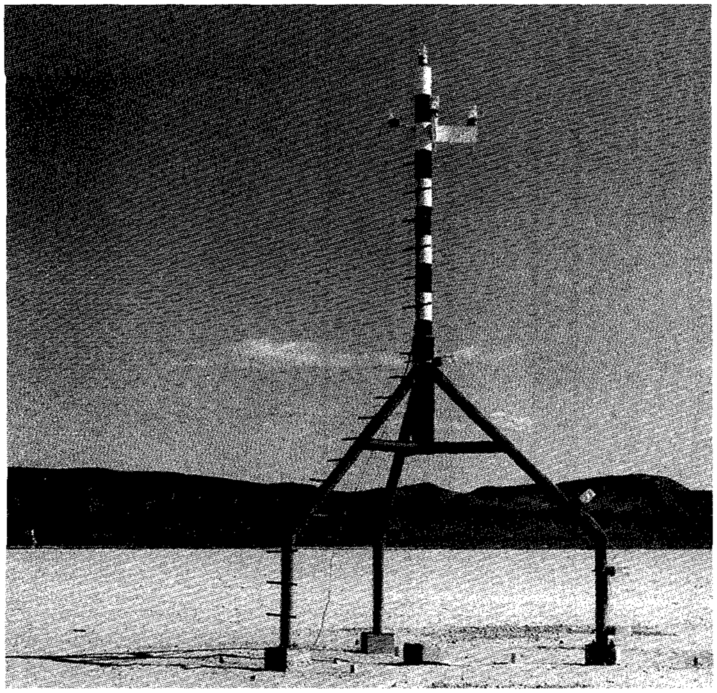
To test contact fuzing, a large area of nearly "tabletop flat" land was needed. Sandia found such a site in 1954 at Yucca Flat on the Nevada Test Site, where Sandia's testing group also supported the Atomic Energy Commission's atmospheric and underground testing of nuclear devices. Yucca Flat was one of those geologically interesting dry lakebeds found in southern Nevada. Runoff from rains and snows washed sediment from mountainsides into deep valleys, gradually filling depressions in the valleys with alkaline sediment. Hundreds of feet deep, the sediment formed a uniformly level surface, a perfect target for testing ground contact fuzes.

A 1955 aerial view of Yucca Flat, a dry lakebed at the Nevada Test Site used by Sandia as a temporary test range during 1950's.

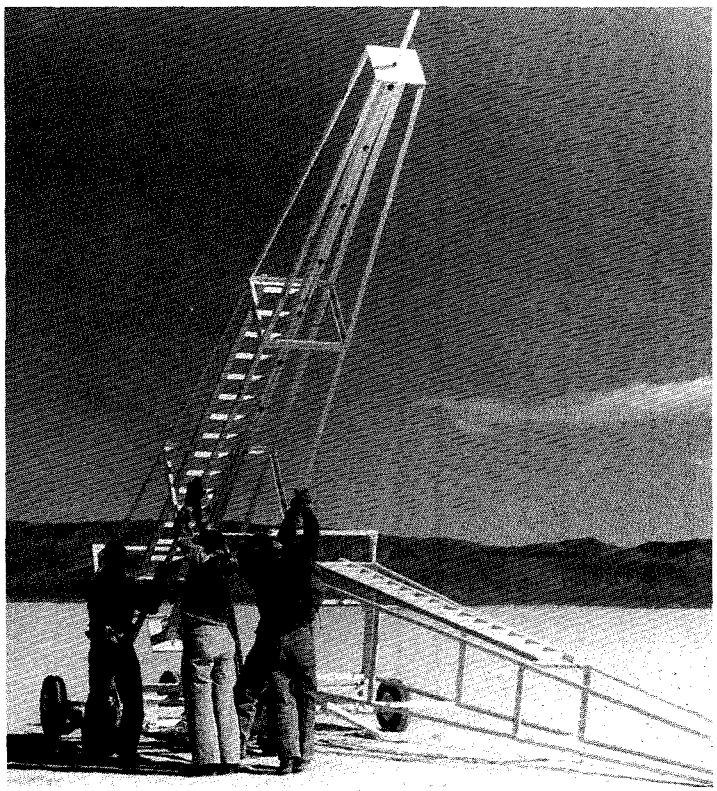
Howard Austin and Bobby G. Edwards headed range crews that began monthly treks with portable instruments from Salton Sea to Yucca Flat. To test contact fuzing, they placed camera stations in a 3,000-foot-diameter circle around a target on the Flat for night-time drops. They opened camera shutters just before bomb impact to record images of a flash bulb on the bomb that was set to fire when the contact fuze operated. After camera shutters closed, the crew set up stadia rod mounting small lights at the impact site and opened the camera shutters again. This created a double exposure on the photographic plates, allowing determination of the height above the ground at which the contact fuze operated. They learned the fuzes operated before the bomb hit ground because a falling bomb generates a bow or shock wave ahead of it sufficient to crush the contact fuze before actual impact.

For two years, the Salton Sea crew traveled back and forth from Salton Sea to Yucca Flat as needed. A reporter visited them in 1956 to watch a B-52 aircraft drop test. He noted that Bill Moore, Elmo Hirni, and Al Boles manned the radar, which had its antenna atop a trailer. In a weather trailer were Tommy Earp and Haskell Jacobs relaying weather data collected from balloons. Frank Moore and Dave Danielson manned the telemetry trailer. Ben Davis sent the tracking instructions to camera stations operated by Ray O'Neill, Curley Saxton, Carl Cianciabella, Art Cary, Bob Wagner, Joe Dirnberger, Carl Hildebrandt, Ed Barber, and Harvey Harter. In the control center monitoring telemetry was Gordon Hawley, and in radio contact with the pilot was Bobby G. Edwards. Supervisor Howard Austin told the reporter that, in addition to drop tests, the range crew also assembled information on shock damage from the aircraft breaking the sound barrier. This then was a major concern and the subject of many public damage suits prior to the ban of supersonic booms over populated regions.

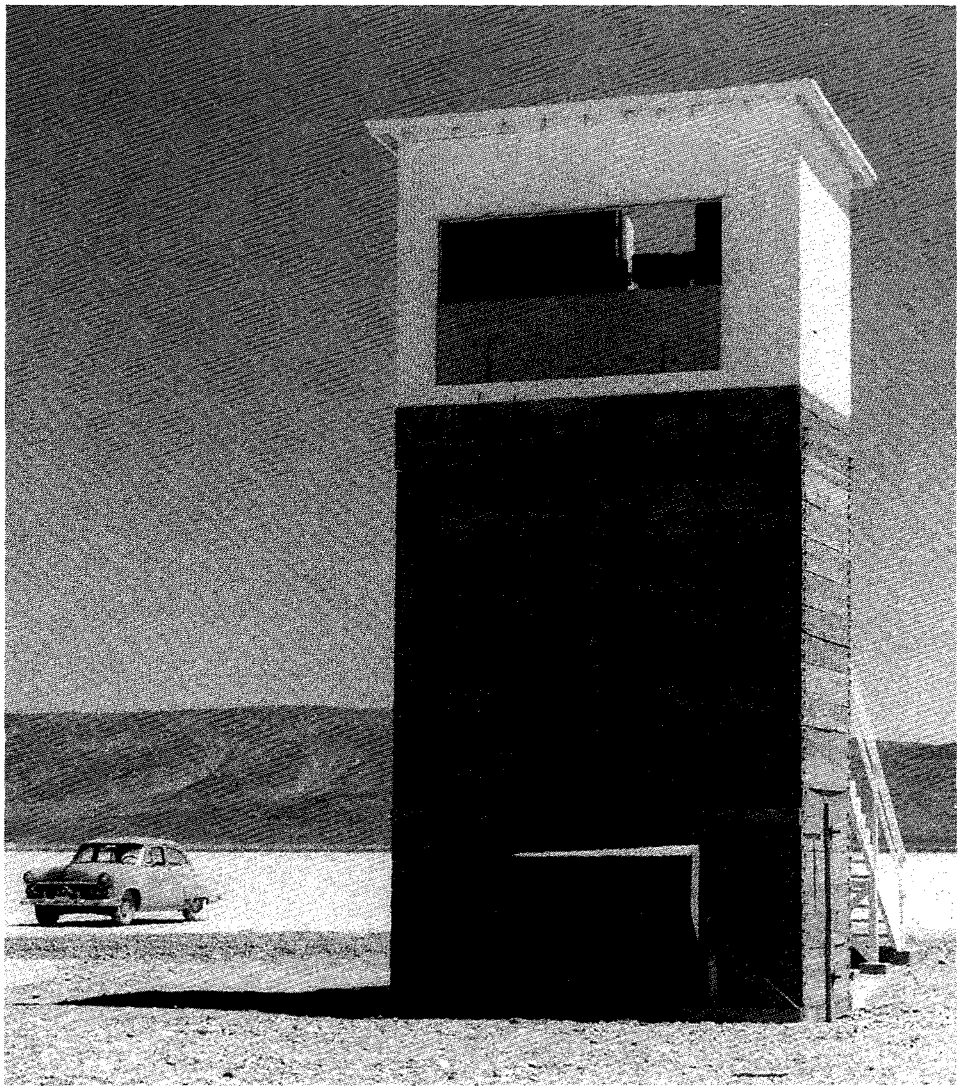
Several problems with Yucca Flat as Sandia's test range soon became apparent. Sandia's testing came second to the use of Nevada Test Site for atmospheric and underground nuclear testing. While Yucca Flat was adequate for high-altitude drops, mountains on three sides obstructed aircraft approaches for low-altitude drop tests. Moreover, Sandia needed a hard concrete target to test low-altitude bomb drops onto enemy aircraft runways and concrete structures. Already, Sandia's mobile and remote ranges group was conducting drop tests at Dalhart airfield in Texas and Melfa airfield near Chincoteague, Virginia, where old concrete runways could be smashed. Neither of these two sites could long serve for testing, however, because of nearby population growth.



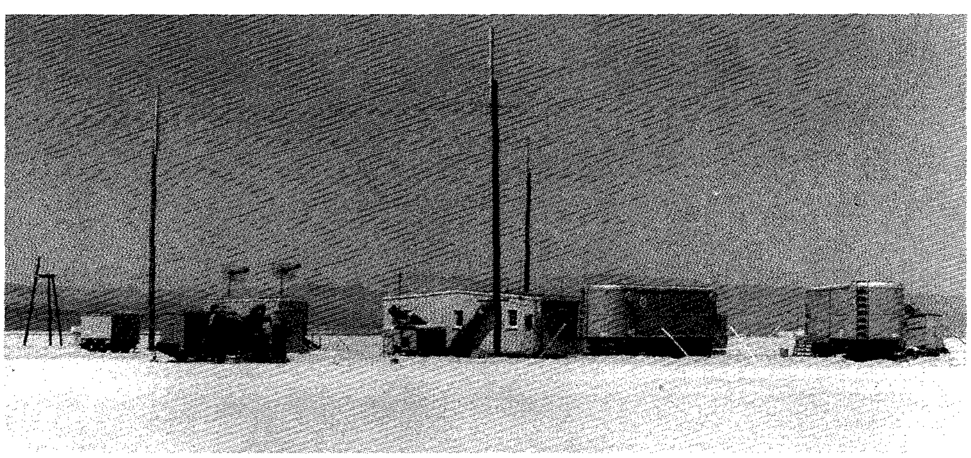
The test reference pole equipped for night operations at Yucca Flat. In the left background is a camera station



Sandia test range crew erect portable stadia at Yucca Flat.



Cameras at Yucca Flat were elevated in this structure for maximum test coverage.



Sandia's telemetry trailers and control building at Yucca Flat.

Sandia's mobile radar, portable generators, and control building at Yucca Flat in 1955.

Years later, radar operator Bill Moore had vivid memories of his Yucca Flat testing experiences. He said:

> *It was miserable work—hot, dusty, slow, lots of waiting. They were big weapon shapes, the MK14 and 17, and some were smaller MK5s and MK21s. They were dropped at night from B-47s and B-36s. We were living in tents. Most of the drops happened at 3 or 4 a.m. to get a precision fix on the altitude of the fuzing event. The test unit was rigged to fire a flashbulb at the moment of activation. At the time, even Tonopah Test Range looked good.*

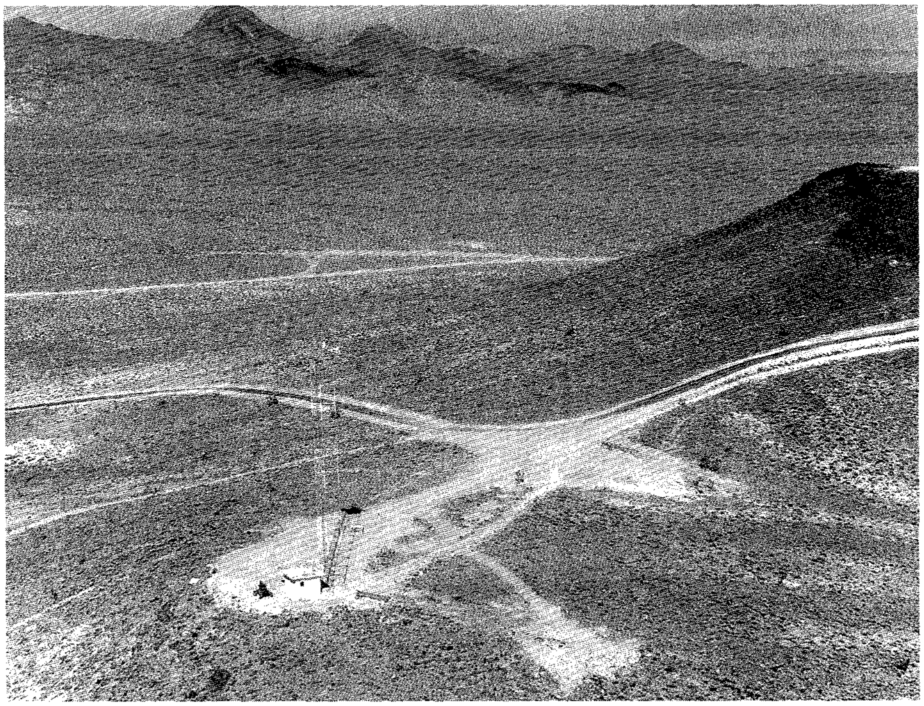
Cactus Flats

Make straight in the desert a highway.
Isaiah, 755 BC

In 1955, Sandia president James McRae and Kenner Hertford of the AEC joined Secretary of Air Force Donald Quarles (former Sandia president) and Brigadier General Alfred Dodd Starbird of the AEC Military Applications office in forming the Joint Ballistics Range Committee to search out a test range that could serve Sandia along with the Air Force and Navy for low-altitude drops and rocket tests as well. After studying sites near Clovis, Grants, Tucumcari, and Magdalena, New Mexico, the committee chose a tract on the Navajo reservation near Winslow, Arizona. When the committee submitted a lease to the tribal council, however, Navajos who would have been forced to relocate opposed the lease. During the resulting delay, the Air Force withdrew from the plan in 1959, electing to use instead its Eglin range on the Gulf of Mexico.

During joint committee studies, the Navy expressed interest in a site known as Cactus Flats. This was in the northwest sector of the Air Force's Las Vegas bombing range, later renamed the Nellis Air Force Base Range. One weekend while testing at Yucca Flat, Howard Austin and Bobby G. Edwards drove to Cactus Flats and were impressed. The site was open, dry, and barren—excellent for camera coverage of bomb drops. It was on Air Force property bordered on the north by lands of the Bureau of Land Management, and Sandia use of the range would force no people to relocate. It was so remote that commercial aircraft, highway traffic, and urban development were insignificant. In fact, even radio signals that might interfere with telemetry were at a minimum. Cactus Flats had already been used as a bombing range by an Army Air Force base built near the town of Tonopah during World War II; the referee towers where bombing accuracy had been judged still stood on the range.

Howard Austin, Bobby G. Edwards, Don Beatson, and Ben Benjamin surveyed the range boundaries and staked out station locations during early 1956. Known first as Tonopah Ballistics Range, it was conceived initially as a temporary site to serve only until the joint ballistics range planned near Winslow was completed. The AEC's Las Vegas office leased the land from the Air Force for Sandia and approved building temporary facilities, contracting with Reynolds Electrical and Engineering Company (REECO), the integrated contractor at the Nevada Test Site, for the construction. Construction began on August 27, 1956, and was completed by November. Costing $490,000, the temporary facilities consisted mostly of metal Butler buildings shipped from Albuquerque to the range and reassembled, plus a 600-foot well drilled for water supply.



View of Cactus Flats from Radar Hill at Tonopah Test Range.

Ben Benjamin surveys a base line at the Tonopah range site in 1957.

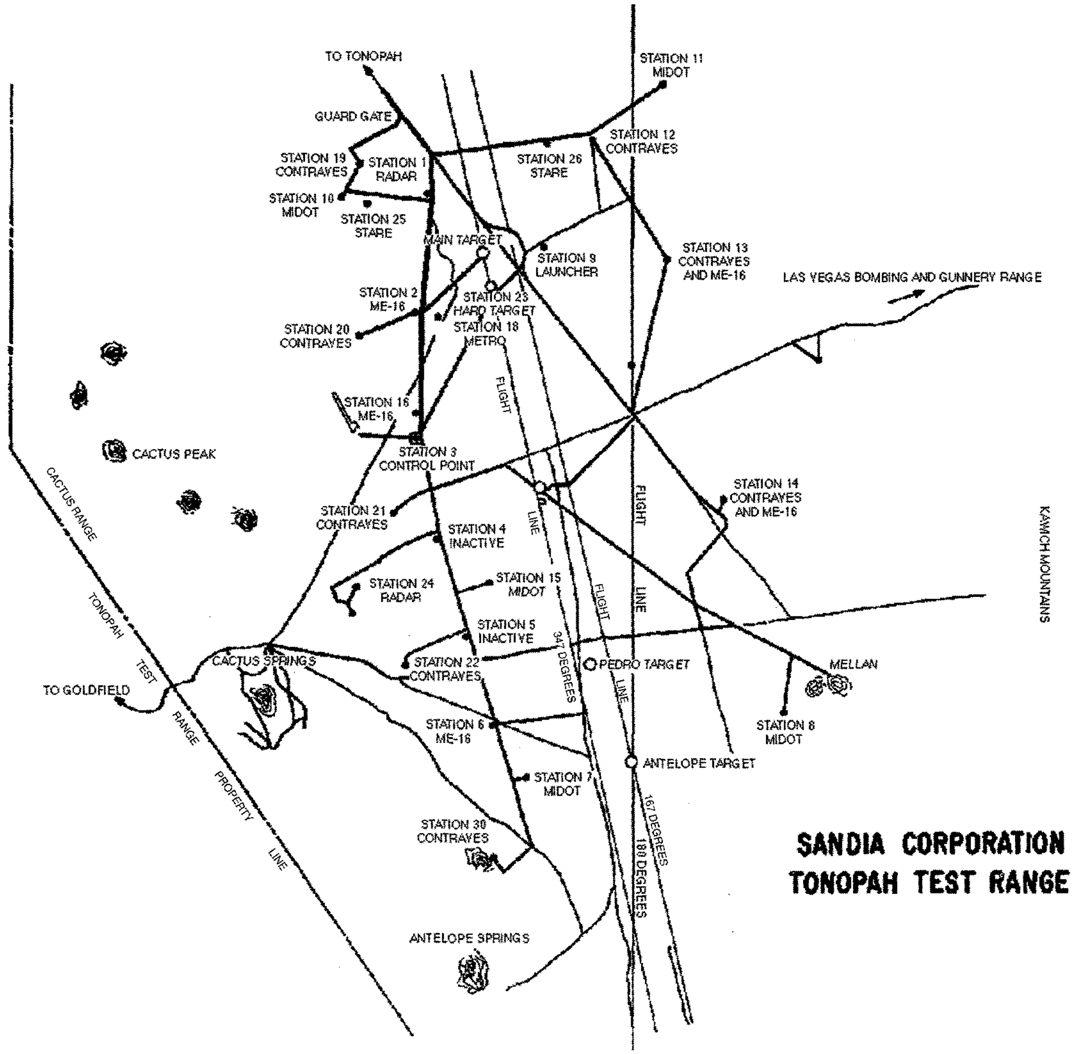
As laid out, the range had an irregular boundary, about 24 by 26 miles across, encompassing nearly 525-square-miles of desert—seven times the area of the Salton Sea range and half the area of the state of Rhode Island. A useful feature was the series of dry lakebeds strung out along a nearly north and south axis. These were ideal as targets along the flight path, and the most northerly lake, called Pork Lake, became the main target on the range. The range crew marked the bomb target point initially by spraying a ring of road oil onto the dry lake surface. This sufficed until a hard concrete target was completed in 1961.

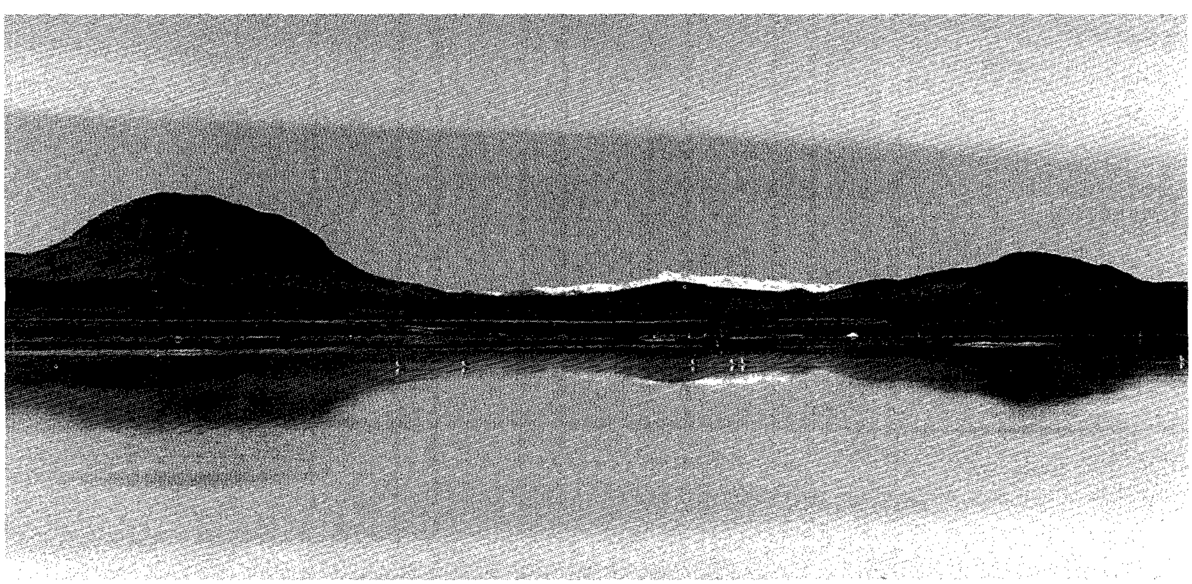
The other dry lakes in the valley provided alternate targets. Created like Yucca Flat by runoff from mountainsides dropping suspended sediment in the depressions, the lake surfaces were nearly level. Their soil called *playa* was fine, powdered, alkaline clay in which nothing grew. Hundreds of feet deep, this soil was covered by a few inches of water after rains or snows, but the moisture evaporated in a day or so. The dry lakebeds were known to crack from top to bottom, leaving narrow chasms dangerous to vehicle operators ignorant of the formation. Such an accident has not happened, however, during the range's history. The lakebeds were self-healing, sediment soon filling the cracks and restoring a level surface.

Clem Rawlins of the optical team became the first Sandian stationed at Tonopah, sent there in 1956 on temporary duty to coordinate the construction by REECO of the first facilities. Because costs of living there were higher than in Albuquerque, Rawlins received a subsidy to cover additional expenses, and this practice became standard for Sandians sent to the range. Joining him in 1957 were Lloyd Young, Pete Chevalier, Harley Davidson Moody, and Allan Gruer. Gruer became the first range manager in 1959.

Roland Millican and Bobby G. Edwards brought Sandia equipment and range crew from Salton Sea and Yucca Flat to Tonopah in early 1957, and on February 8 they conducted the first drop tests at the new range. They tracked a MK-5 bomb casing dropped that day, followed by an MK-15 that night. B-36 and B-47 planes of the 4925th Test Group (Atomic) out of Kirtland airfield made the first test drops, with bombers making the round trip nonstop and fighters refueling at Nellis or another Air Force installation.

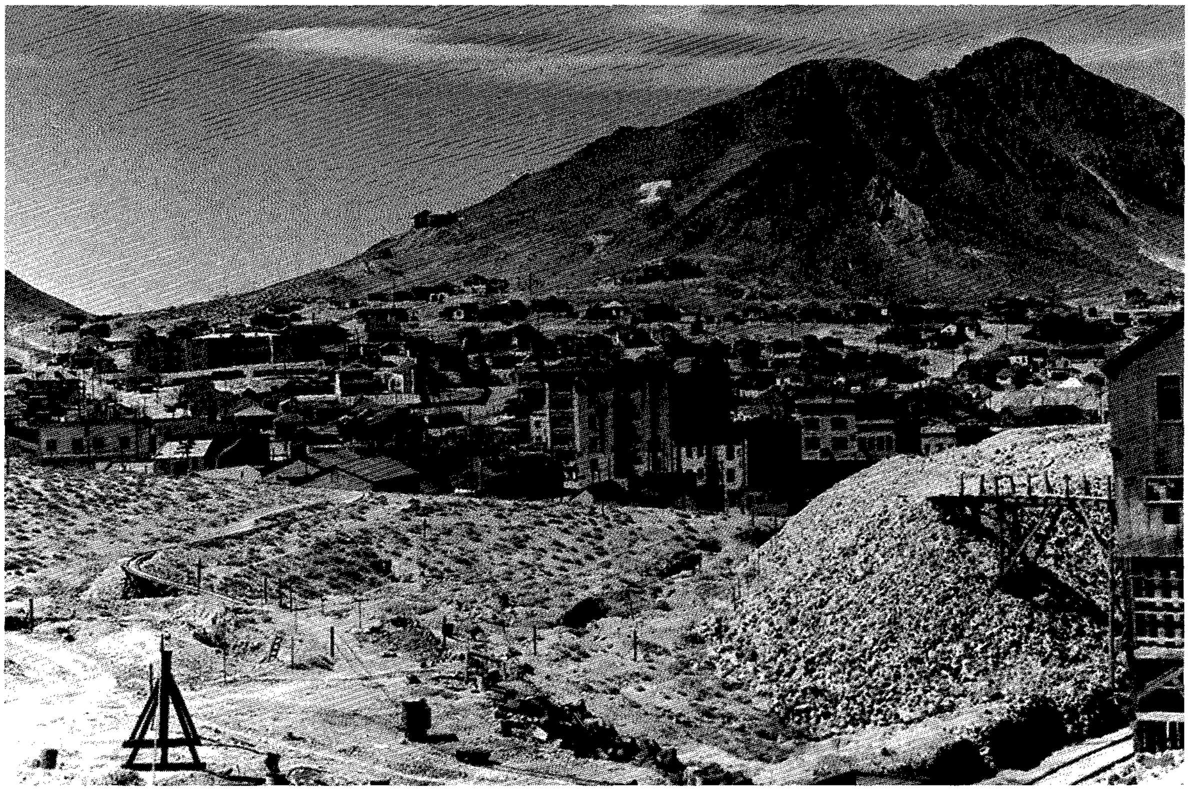
Operated in a campaign mode, with the Salton Sea crew traveling to Tonopah as required, Tonopah operated eighteen weeks in 1957 and fifteen weeks in 1958, completing 25 bomb tests in 1957 and 46 in 1958. Although too far from Kirtland airfield for round-trip, nonstop fighter plane testing, the site proved satisfactory for tests with high-speed aircraft flying at low altitudes.





Rain sometimes pooled a few inches of water on the dry lakebeds at Tonopah Test Range before quickly evaporating.

Reynolds Electrical and Engineering Company received the contract for operations support and maintenance on the new range, and it supplied the diesel generators used at each range station before commercial power came to the range a decade later. A fire at the new range in May 1957 destroyed one of the metal buildings brought from Kirtland, along with the generators, electrical stores, and office equipment it housed. Although the fire was discovered early, by the time a fire truck arrived from the town of Tonopah it could only spray the embers to prevent sparks from igniting other structures.



Tonopah, Nevada, as it looked during the 1950's.

It Really Flew

I've always found field test work exciting.
Howard Austin, 1989

According to an amazing story by Howard Austin, Tonopah saw its first rocket launch in the summer of 1957. It was a Friday afternoon when Austin was warned to stay at the range awaiting a fellow enroute from California to launch an experimental rocket. The fellow brought his rocket and launcher on a tractor trailer and parked it in Tonopah for the night. The sheriff awakened Austin during the night and told him to have the rocket moved; it was pointed at the theater and made the sheriff nervous.

Saturday morning out on the range, the fellow opened a suitcase full of explosives and pyrotechnics and mixed his rocket igniter on the spot, then launched it with the help of the range crew. "It really flew," said Austin. "We don't know exactly where—still don't know today—since we didn't instrument or track it. But I do know for sure that it was the first rocket launch at Tonopah Test Range."

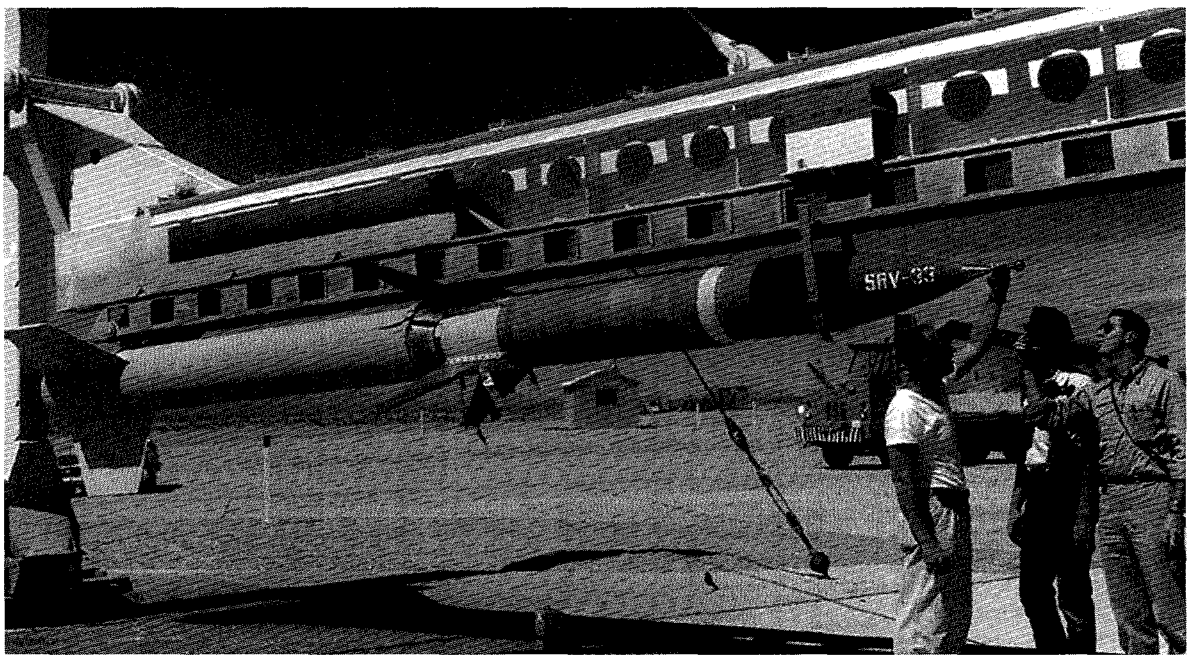
Officially, rocket testing began at Tonopah on July 27, 1957, with launch of six single-stage and seven two-stage rockets in the "Doorknob" series. These, and most subsequent launches at Tonopah, were sounding rockets rather than missiles. Harold Vaughn of Sandia's aerodynamics department initiated the sounding or diagnostics rockets program, and Charles Force served as engineer for the Doorknob project. These rockets were sixteen-inches in diameter, capable of carrying a 150-pound payload to a 250,000-foot altitude. Those launched from Tonopah had instrument packages that could monitor high-altitude nuclear weapons testing, or carried metal chaff for release into the jet stream to be tracked by radar. Leon Smith managed the jet stream studies that were important to high-altitude bomb delivery. Then, defense strategists worried that enemy aircraft might ride a 300-mile-an-hour tail wind over the United States. And as the Tonopah range crew knew from radar tracking, the United States during the late 1950s had U-2 aircraft riding the jet stream on secret reconnaissance missions. Sandia launched four chaff rockets monthly to monitor seasonal changes in the upper atmosphere.

In addition to the Doorknob series, Sandia launched rockets for high-speed aerodynamics research and for supersonic parachute research during the late 1950s. In July 1958, four Regulus II missiles launched at Edwards Air Force Base also came into Tonopah test range.

Early view of the Tonopah control point.

Preparing for an August 1957 rocket launch at the range are Gene Dirnberger, Walter Drake, Frank Reeder, Ben Davis, Dewey Stout, J. Dirnberger, Bobby G. Edwards, John Keller, Haskell Jacobs, and Pierre "Pete" Chevalier.

The research rockets developed by Sandia had no internal guidance systems and relied on launcher rails to aim them, as a rifle barrel does a bullet, into the proper trajectory. Sandia's George Neun designed the launchers installed at Tonopah and other sites. Sandia used two types of launchers: the smaller high-altitude diagnostic launcher with a 4,000-pound capacity for firing Nike-type rockets, and the larger Universal launcher with a 14,000-pound capacity, used for Honest John, Talos, and larger rocket systems. Both types had tubular-steel pedestals with an upper turntable section rotating on ball bearings. Attached to the upper section was a boom supporting a guide rail, which could be raised or lowered with an electric jackscrew. Interchangeable guide rail sections could provide differing lengths for various rocket boosters—a 14-foot rail for a Nike booster, or a 12.8-foot rail for a Terrier booster.

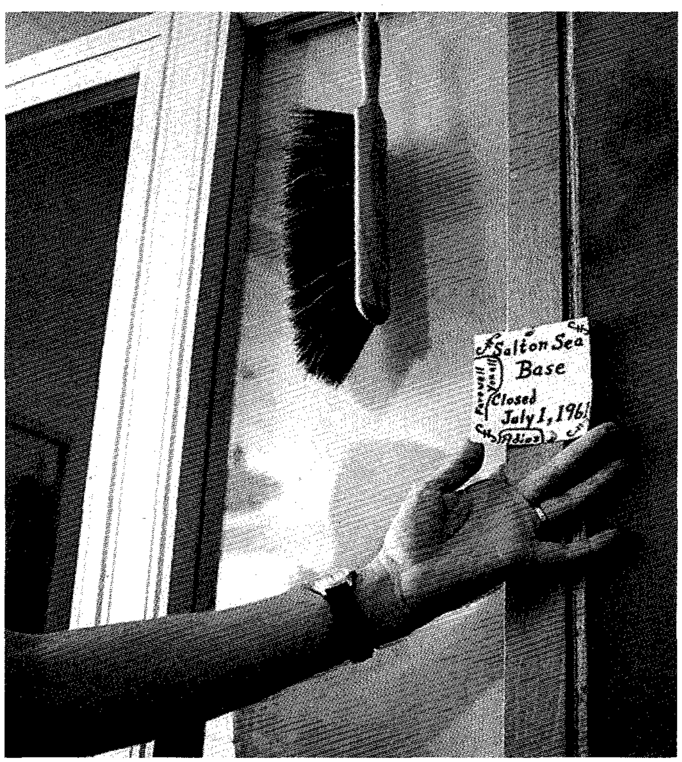


The range crew checks a two-stage rocket on its launcher ready for firing.

A Permanent Test Range

Sandia's management in 1958 still considered Tonopah a temporary facility for use until a joint ballistics range was completed in Arizona, but rocket launches at Tonopah went so well that management considered retaining the range for rocket testing alone. When the Air Force withdrew from the joint ballistics range program in Arizona, Sandia in February 1959 decided to make Tonopah Ballistics Range its permanent test range. Except for tests requiring water targets or other special conditions, Sandia's field testing would be consolidated at Tonopah and the Salton Sea range would be closed. Don Shuster of field testing directed that the transfer from Salton Sea to Tonopah be completed by September 1, 1960, and Allan Gruer, the first Tonopah range manager, opened a temporary office next to the Tonopah bank to assist Sandia personnel with relocation.

As the range crew departed, Salton Sea test base went on standby with only a caretaker group of seventeen directed by Don Fifield and M. J. Lesicks. This proved a painful time for the employees at Salton Sea, who were forced to transfer to Tonopah or Albuquerque or to resign from Sandia to stay in the Imperial Valley where their families had made homes for twelve years. Public information officer Ted Sherwin said that "many of the people at Salton Sea were reluctant to move to Tonopah because of the much higher cost of living and the lack of adequate housing." The caretaker group stayed on at Salton Sea until the end of July 1962, when Sandia relinquished control of the facility to the AEC Sandia Area Office.



SANDIA CORPORATION

HAS A LIMITED NUMBER OF OPENINGS FOR

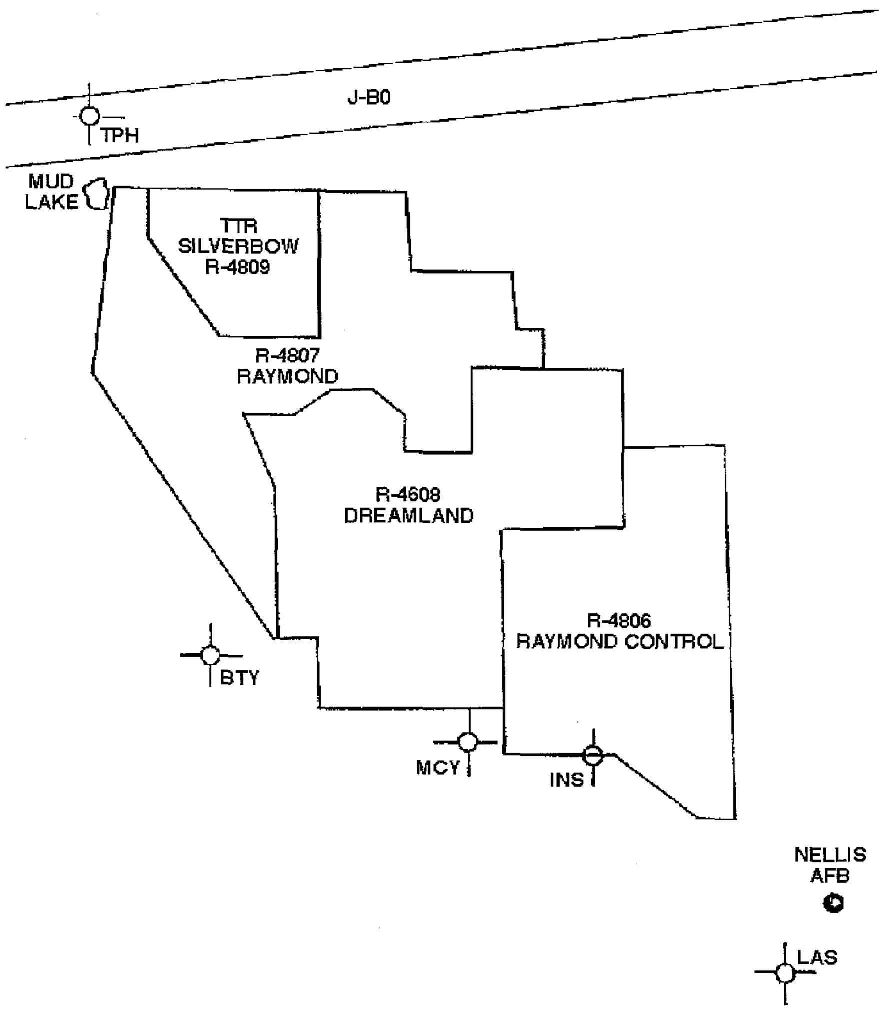
PART TIME EMPLOYEES

AT TONOPAH TEST RANGE

Hours May Vary on a Day to Day Basis

No Experience Necessary

APPLY AT SANDIA CORPORATION OFFICE ON MAIN STREET, TONOPAH, NEXT TO FIRST NATIONAL BANK BLDG., ON OCTOBER 17, 18 OR 19.



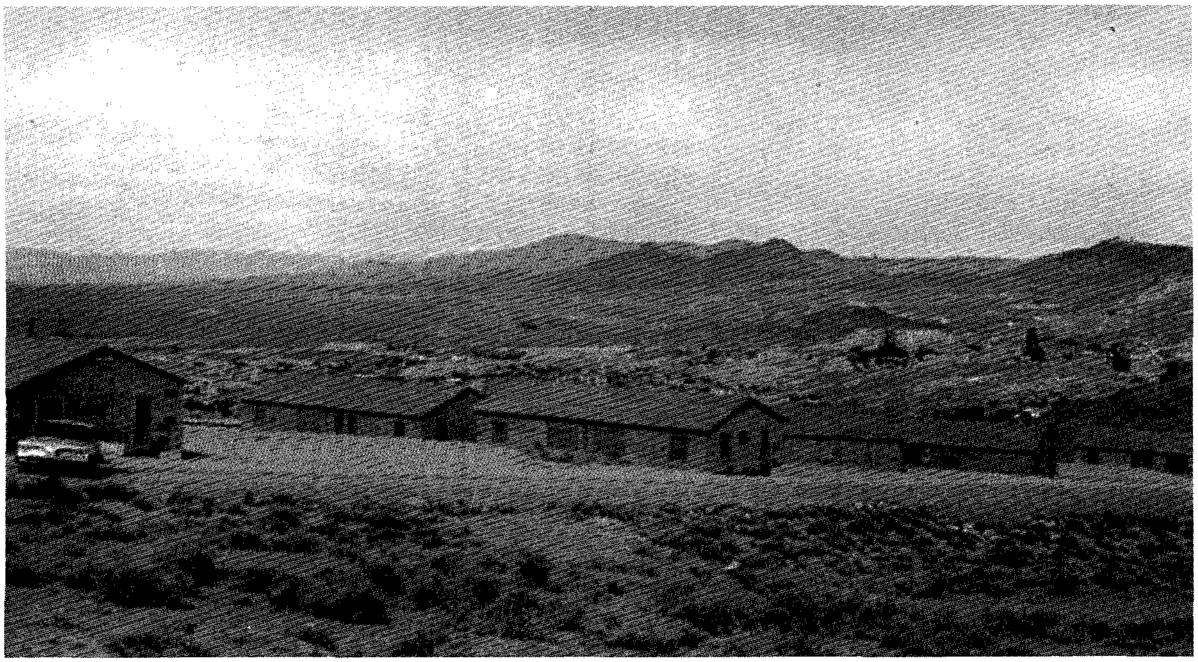
On the Nellis Air Force Base sectional control map, Tonopah Test Range (TTR) is referred to as Silverbow.

At Tonopah, range manager Allan Gruer had great difficulty finding housing for the range crew. A mining town established at the turn of the century, Tonopah in the 1950s had only 3,000 residents and had little housing available for either sale or rent. Gruer, assisted by Ted Sherwin, Glenn Fowler, and Sandia president Julius Molnar, negotiated with Tonopah civic leaders to explore FHA funding of new housing, or contractor construction of housing for rental to the range crew. But the first personnel assigned to Tonopah had either to rent substandard housing or buy house trailers.

On July 22, 1959, Tonopah and Nye County civic leaders gathered at the Mizpah Hotel to hear Glenn Fowler present Sandia's plans for the range and a response from Nevada Governor Grant Sawyer. Fowler explained that Sandia intended to make Tonopah its permanent testing range and would contract for range maintenance and security, offering employment opportunities for more than two dozen Nye Countians. Welcoming Sandia to Nye County, Governor Sawyer proffered state assistance with Sandia's relocation difficulties and sent state highway officials to accompany Gruer and Fowler on an inspection of road conditions from Tonopah to the range. State improvements to this highway section and the construction of a new school in Tonopah soon followed the 1959 meeting.

Range manager Gruer quickly found a place in the Tonopah community, becoming president of the chamber of commerce and part-time manager of the Tonopah airport as well. To his surprise, he had the honor of welcoming the King of Nepal to Tonopah in May 1960. The king had come to hunt mountain lions (these have attacked people as recently as 1991 in the Tonopah vicinity). "Americans go to India to hunt tigers," Gruer said, commenting on the king's visit: "This case I think is the very first time that a visiting monarch has hunted game in the United States." The king's hunt was successful, and he took a stuffed mountain lion back to his palace.

As a small town, Tonopah offered few amenities other than hunting. To resolve the housing problem, Sandia in May 1960 acquired surplus World War II buildings from the Hawthorne Naval Depot and contracted with REECO for their removal to Tonopah and installation there complete with utilities on a ten-acre hillside tract. As range crew families arrived from Salton Sea, they settled into the houses. The crew commuted daily by bus from Tonopah to the range.

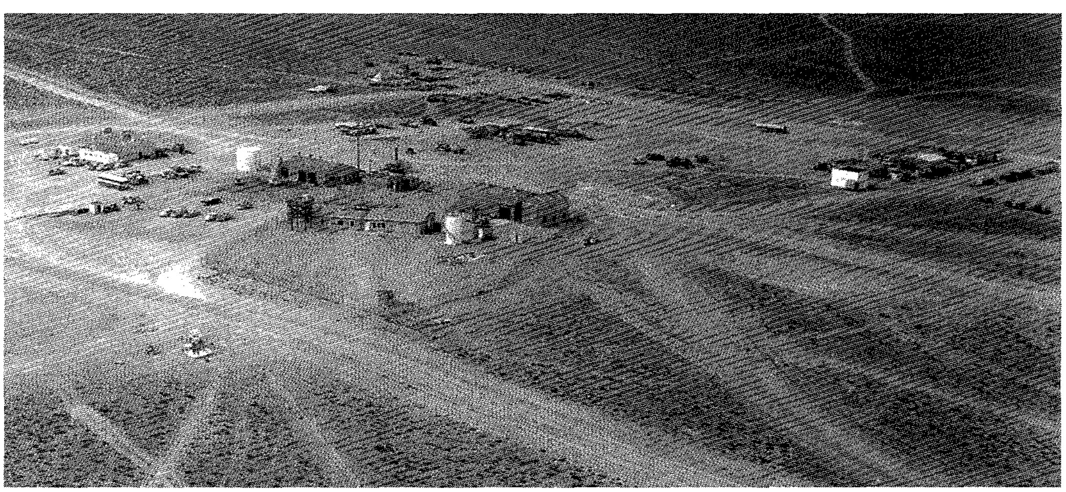


Sandia's housing on the hillside above Tonopah, Nevada, in 1965.

As the range crew settled in during 1960, Lembke Construction of Las Vegas under AEC contract proceeded with the range's permanent facilities. High on the priority list was construction of a hard target, a foot-thick concrete strip in the shape of a cross resembling a highway intersection. Each leg of the cross consisted of high-strength concrete, 150 feet wide by 750 feet long. Sandia in 1960 was testing its TX-43 laydown bomb on old concrete airfield runways in Texas and Virginia. Because radar could detect high-altitude aircraft and take defensive action, as proven in 1960 when a Soviet missile brought down Francis Gary Powers and his U-2 aircraft, Sandia was rushing development of a laydown bomb that could be delivered by high-speed aircraft flying near the ground to elude detection. Laydown bombs had to withstand impact with hard targets and keep on ticking long enough for the delivery aircraft to escape the blast envelope. The laydown bombs required development of impact-hardened components, parachute-delayed delivery, spike and honeycomb impact-resistant casings, and other features, all of which Sandia had to test on a concrete target. Finished in 1961, Tonopah's concrete cross supported these tests. Later, Sandia had concrete placed between the legs of the cross to complete a circular target.

In addition to the hard target, the initial range construction included pads for camera and instrument tracking stations, range-maintenance structures, a balloon-inflation building, and central control building. The Control Point (CP) area in 1961 included five buildings serving as control center, administration, range maintenance, garage, and warehouse. On the list of original range stations were four Mitchell, two 70-mm, three RO-10, and eight Contraves tracking cameras.

The range's concrete hard target completed in 1961 had an X shape. Farther out the flight line is a circular target marked on the lakebed.



Tonopah Test Range control point in 1960.

The Contraves phototheodolite tracking cameras used 35-mm motion-picture color film and a 60-inch telephoto lens, printing the azimuth and elevation angles and time on each film frame. Made in Switzerland, the eight Contraves stations could pinpoint objects in space and provide a three-dimensional plot showing the object's speed and course.

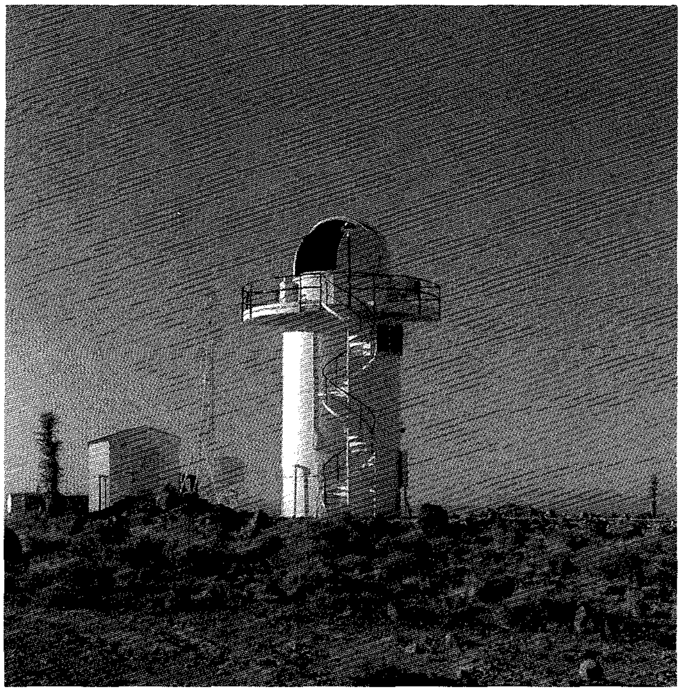
ME-16 tracking telescopes were mated with various camera types to record the telescopic images. Sandia engineers had designed and built five of the ME-16s for the range at a cost of $100,000 each.

The MPS-25 radar on Radar Hill cost more than $2 million. A monopulse, one megawatt radar with a 12-foot diameter reflector, it weighed more than ten tons. Mounted on a pedestal, hydraulic motors pointed it toward targets.

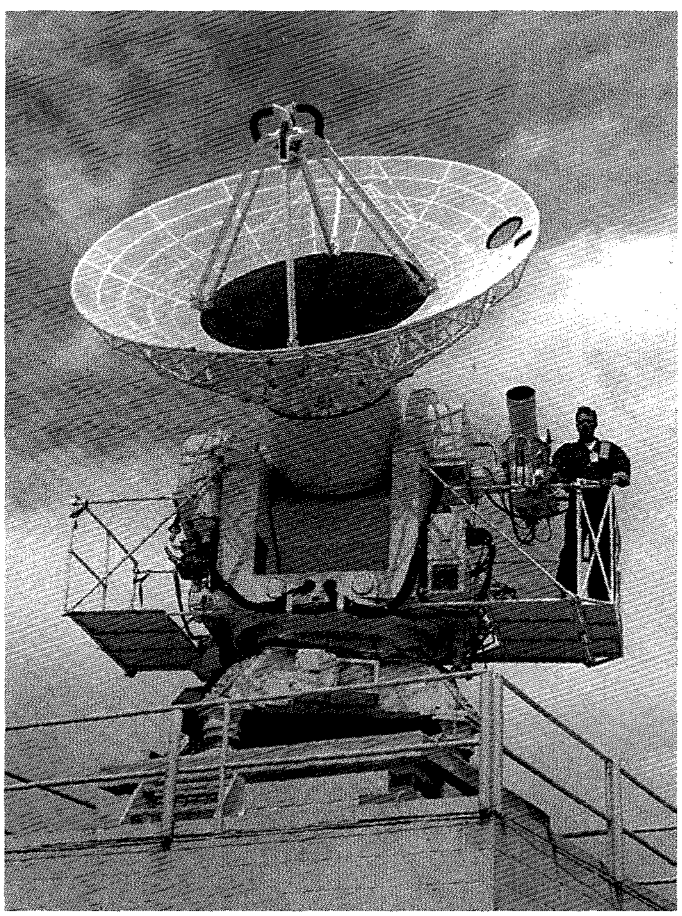
To support rocket testing programs, the AEC awarded contracts in 1960 to build launch pads, an assembly building, two rocket payload buildings, an underground control room, and earth-covered storage igloos. Seven launchers could dispatch Sandia's experimental research rockets to what then were considered extremely high altitudes.

When these basic facilities were completed in 1961, a routine began that varied little during the following third of a century. Robert Statler, Tonopah range manager from 1960 to 1964, outlined a typical test day:

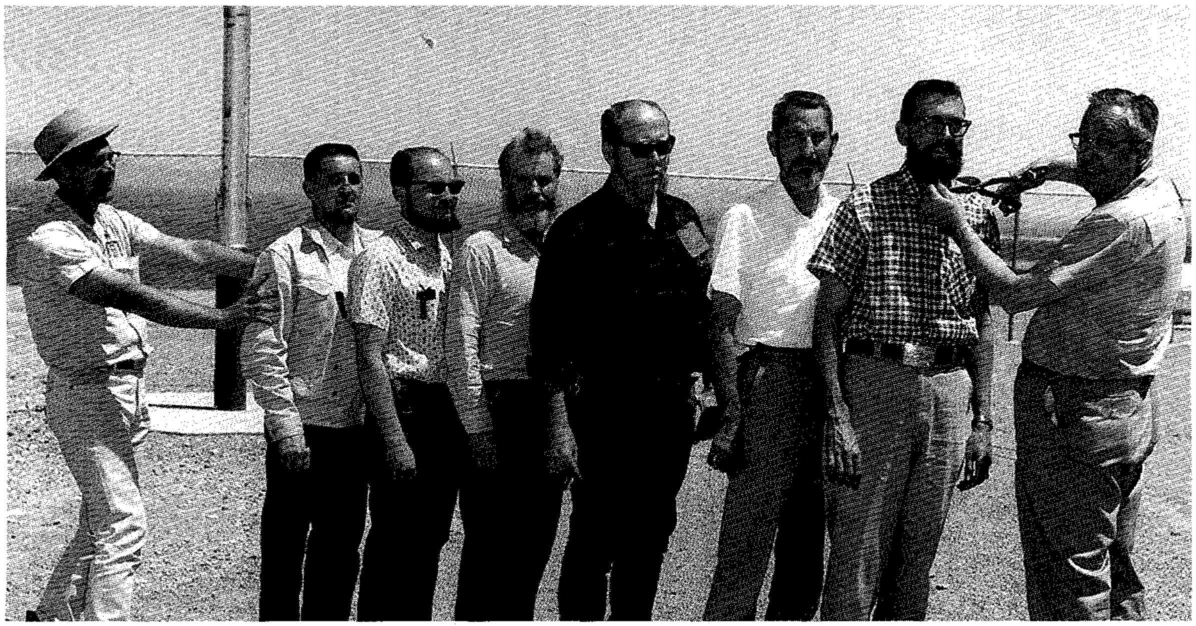
> *The Range personnel arrive from Tonopah at 6 a.m. on the morning of a low-altitude, hard-target drop. Preparations for manning the ground instrumentation stations are immediately begun. These preparations include such things as gathering up the film magazines, magnetic tape, oscillograph paper, etc., to loading the recording instruments.*
>
> *By 6:30 the stations are manned and preparations begin for a system check of all stations at 7. When the system checks are completed and the final adjustments made, a dummy run is conducted at 7:40. The line run and drop are made at 8 a.m., and by 8:15 cameras and other recording instrumentations are unloaded and preparations are begun for the next test.*
>
> *On an operations day, it is quite likely that the Range will be the scene of low-altitude, hard-target tests in the morning, high- altitude drop tests during mid-day, and rocket firings towards later afternoon.*



A Contraves cinetheodolite tower in 1961 at Tonopah Test Range.



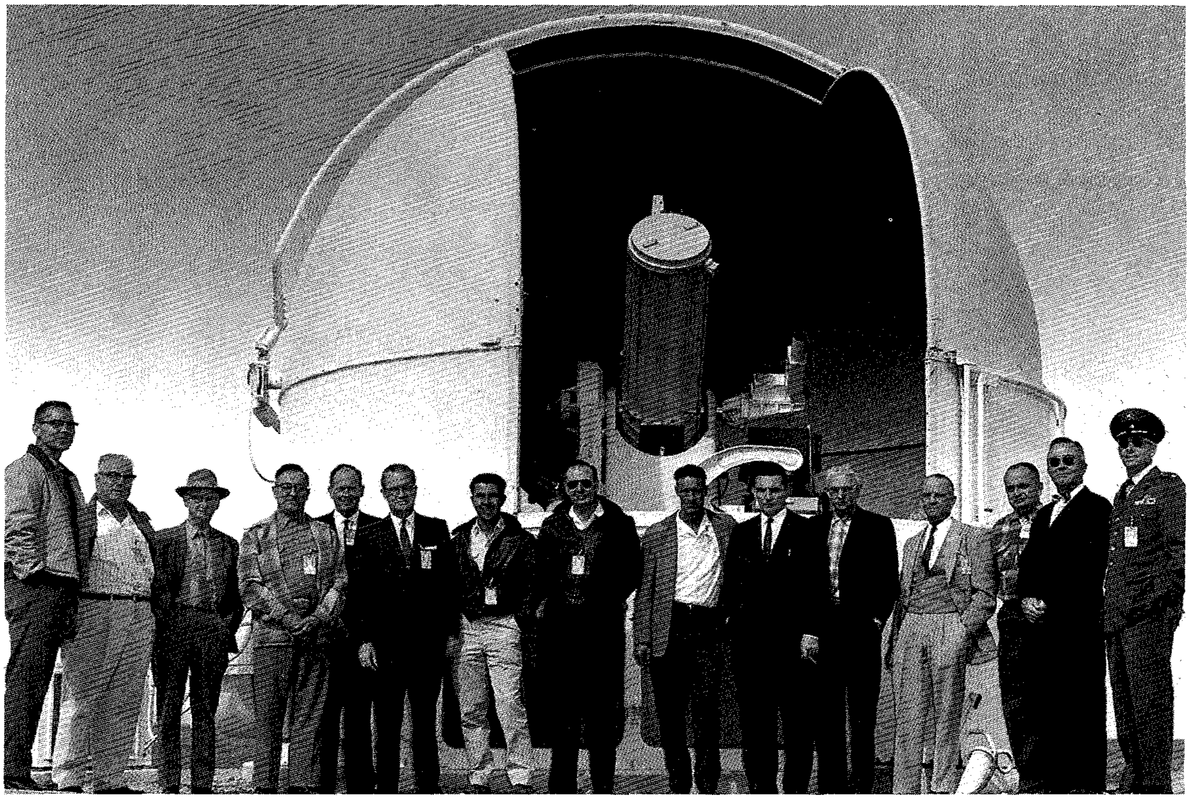
MPS-25 radar on Radar Hill at Tonopah in 1964.



Some of the range crew grew beards for the Nevada Centennial. From the left, Bob Statler, Lloyd Young, Grant Gardner, Dewey Stout, A. Korbe, F. Steel, K. Datz, D. Brown, and Dick Browne, successor to Statler as range manager.

Travel from Albuquerque to the range was problematic at first. Visitors could either land at the Tonopah airport and motor an hour to the range, or land on a dirt airstrip left over from World War II and then drive twelve miles from the airstrip to the range control point. But when a 5000-foot airstrip was completed in January 1962 a short distance from the control point, Carco Air Services provided small aircraft transportation from Las Vegas to the Nevada Test Site and on to the range on a regular schedule. Transport problems further eased in June 1962 when twelve-miles of paved road opened from state Highway 6 into the test range. These improvements encouraged visitors, and the range soon enjoyed visits from Nevada Senator Alan Bible and a national conference for representatives from test ranges throughout the United States.

In 1962, a project group from Sandia Laboratories at Livermore, California, brought two 155-mm guns and two 155-mm howitzers from Fort Sill and Benecia Arsenal to the range as the foundation of a unique shock-testing facility. Rather than live ammunition, these cannon fired artillery shells with explosives removed and replaced by miniature telemetry components developed at Livermore. During the first year, the range crew fired 127 rounds from the cannon, vertically, into sawdust berms, or fifteen miles down-range. This research tested the effects of high shocks and acceleration on components within the shells. The ballistics of artillery shells, because of their high spin rate, differ substantially from bombs and missiles, and this difference concerned the researchers designing tactical nuclear shells. Artillery shell testing, with the 155-mm cannon and later with 8-inch and barrels of other dimensions, soon became one of the larger testing programs on the range.



Bob Statler hosted U.S. Senator Alan Bible and visitors in 1961 at Tonopah Test Range.. From the left, Statler, Leroy David of Tonopah, Glen Jones of Nye Co., Nick Banovich of Nye Co., Glenn Fowler of Sandia, Senator Bible, Richard Blakemore of Nye Co., Thomas Johnson (Senator's pilot), Ralph Lisle of Nye Co., Jack Carpenter (Senator's aide), Ira Jacobson of Tonopah, Thomas McCullough of Tonopah, Don Shuster of Sandia, C. C. Campbell of AEC, and Alan Meridith of the Air Force.

The highlight of 1963 on the range was Operation Roller Coaster. About 700 people undertook this operation to investigate the abilities of weapons storage igloos to contain accidental blasts releasing plutonium. Project direction came from the AEC Nevada Operations Office, with James Shreve, Bryon Murphey, and Jack Reed of Sandia furnishing scientific guidance. Of the four tests in the Roller Coaster series, three designated Clean Slate took place on the range with radiation monitoring instruments surrounding the area and also overhead in tethered balloons.

Clean Slate involved placing the casings of nuclear bombs inside three weapons storage igloos, one without cover, another with two feet of earth over it, and a third under eight feet of earth. Nuclear pits had been removed from the casings, which were filled with high explosives and traces of plutonium. When the bombs detonated, the relative ability of the three igloos to contain the explosions and suppress the spread of plutonium became apparent. Doubtless the information provided by this operation proved useful in the design of weapons storage facilities and also during the remediation following the 1966 Palomares accident, when American aircraft collided over the coast of Spain, releasing bombs that scattered plutonium along the coast.

More high explosives jarred the range in 1964, when Sandia's Luke Vortman brought Project Plowshare—studies of using nuclear explosives to excavate canals and harbors—to Tonopah. Vortman planned a series of thirty-six cratering experiments with four charges each of non-nuclear explosives at Antelope Lake. The sediment at Antelope and other dry lakes provided a uniform consistency to depths of hundreds of feet, an ideal geologic condition for comparative testing of the excavation efficiencies of varying patterns and depths of explosives. "This study will provide information, on a model scale, which might be useful to decide how to dig a harbor with nuclear devices," Vortman explained, adding: "A harbor could be excavated using a large single device buried very deep, but it might be more desirable to have a large shallow area excavated by a number of small detonations."

Using high-speed cameras and pressure measuring devices, Ralph Holland, Carl Northam, Bill Gault, Howard Gipson, Bob Zumwalt, Cecil Lang, and Joe Geltz at Tonopah conducted the cratering tests. By 1967, Vortman reported their work had permitted developing a formula for "predicting crater size as a result of the size of the charges, the burial depth, spacing between charges, and the geological composition of the surrounding earth." Although the cratering tests at Tonopah and full-scale blasts such as the Sedan crater at Nevada Test Site promised successful excavation, nuclear test ban negotiations delayed use of the technology. In time, the United States abandoned it altogether.

Pleased with Tonopah

When the range completed its first five-years service in 1964, it had proven its capabilities. It supported the testing needs of varied and rich research justifying continuing increments in its staffing and facilities. Each year, small construction contracts added warehouses, small buildings, more stations, and minor capital improvements, and each year the staff increased. About forty Sandians served as range crew in 1964, with twenty guards under contract for security and approximately fifty contract personnel employed by Reynolds Electrical and Engineering Company providing operations support and range maintenance.

Richard Browne, range manager from 1964 to 1965, pointed out that Tonopah had become a trinity of three ranges in one. At its primary target were fixed cameras for coverage of ballistic drops. Back from the target area along the flight line were the telescopes, cameras, and radar to track high-altitude aircraft and rockets. Third were the firing and launching platforms for rockets and artillery. In addition, the range supported Operation Roller Coaster and Project Plowshare.

From 1957 through 1964, the range crew conducted 680 bomb drops and 555 rocket tests, and they acquired more than 95 percent of the data needed on these tests. "A lot rides on each test," Browne pointed out. "Most ballistic test programs are on a tight schedule," he added, "and failure to get test data on time could cause design and development engineers to miss their schedule." Without testing data to confirm design criteria, no engineer could have full confidence in a design.

Tonopah during the early 1960s conducted about 500 tests annually, and more work was pending. Still, Browne and Sandia's field test managers had difficulty recruiting professional staff from Albuquerque and Livermore. In this effort, Browne even published recruiting publicity extolling the virtues of Tonopah. One asserted that "Sandians who have lived in the west and appreciate its opportunities for outdoor life and scenic wonders will be pleased with Tonopah—the town with a past, present, and future."

Tonopah's Peak

Ray Brin, range manager from 1965 to 1967, served during Tonopah's peak years for testing. Principally as a result of low-level delivery testing, the range crew participated in 1100 tests in a single year during the mid-1960s.

By order of the Joint Chiefs of Staff, Joint Task Force 2 (JTF-2) formed in 1964 with headquarters at Sandia Base in Albuquerque. It was an all-services force commanded by Major General George Brown initially and Major General Winton Close later. As Sandia's Glenn Fowler explained, JTF-2 sought means of evading enemy radar by finding and striking targets while flying fast and low. It marked a major departure from the earlier strategy of delivering bombs from high-altitude aircraft.

According to Fowler, Sandia's job was to identify the most effective methods of finding targets while flying low by examining and testing different systems for low-level reconnaissance and attack. "It was a tremendous instrumentation job, because telemetry and position-location systems on the ground couldn't see the low-flying planes, so we had to observe the delivery aircraft from C130s positioned above the targets, then compensate in data reduction, for the location of the C130s in defining how well the delivery aircraft were doing."

To manage this complex effort, Sandia created a JTF-2 mission group headed by Donald Shuster and John Eckhart. Tom Sellers managed the development of airborne instrumentation; Jim DeMontmollin supervised planning and test programming. The list of Sandians involved when JTF-2 testing began at Tonopah in May 1965 numbered thirty-seven, not including the range crew.

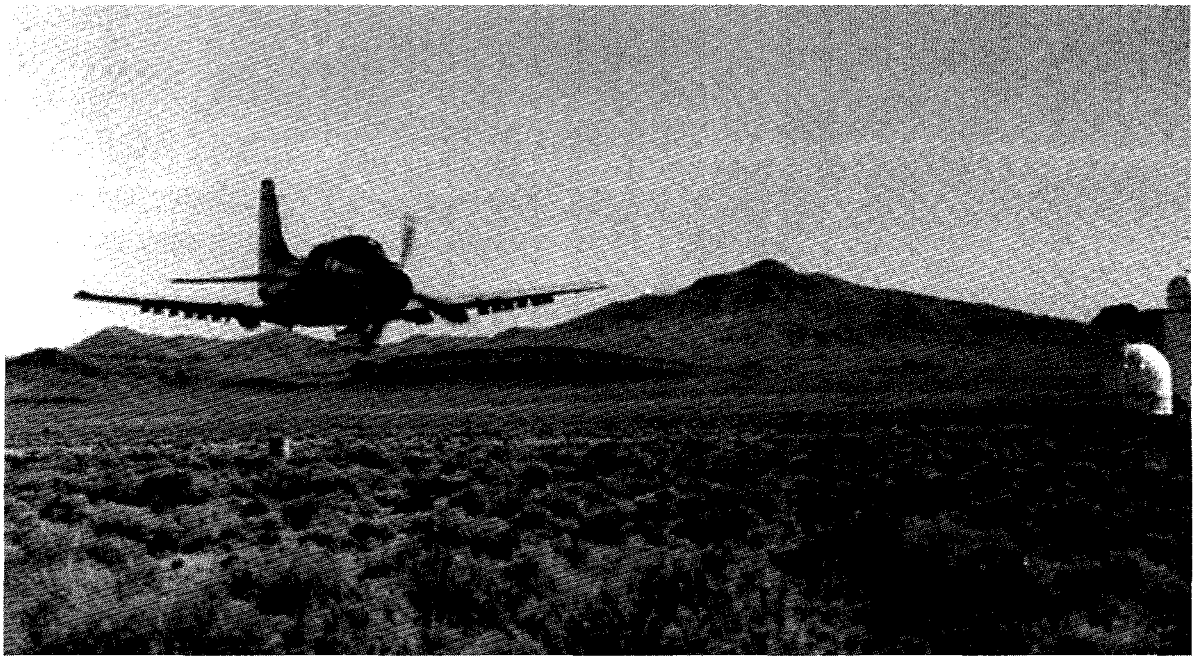
The range crew and contractor support marked three flight paths at Tonopah and the adjacent Toiyabe National Forest. One covered flat terrain, another followed rough territory, and the third crossed the mountains. Planes carrying the instrumentation pods designed by Tom Sellers' team flew all three flight paths in a single 150-mile run, following an "S" pattern marked by orange barrels on the ground visible to pilots traveling near the speed of sound only fifty feet off the deck. Aircraft and crews from the Air Force, Navy, and Marines participated in JTF-2, and Glenn Fowler later observed: "Interestingly enough, we found that success depended less on which delivery system was used than on the training and skill of the delivery crew."

In preparation for JTF-2, Sandia paved the 5,600-foot compacted earth airstrip at Tonopah range in 1965, and late that year a small Strategic Air Command plane became the first jet-powered aircraft to land at the test range. JTF-2 involved approximately 550 test flights at Tonopah in 1966, supplementing the 500 tests then the usual annual average at the range. When JTF-2 test flights ended at the range, a group of Sandians went on travel to support continued low-level flight testing over parts of Arkansas, Louisiana, Oklahoma, and California during 1967.

An interesting sidelight of the JTF-2 program was Sandia's development of what may have been its first "realistic" flight simulator. Using a wide-angle 70-mm camera, film of an actual low-level flight test run over Arkansas was taken and brought to Sandia, where it was projected onto a curved movie screen. From a mockup cockpit placed within the 160-degree arc of the screen, the reactions of pilots could be timed and tested during maneuvers and as they approached targets.

Check of the low-level flight instrumentation pod on a fighter plane of the Joint Task Force 2 tests at Tonopah.

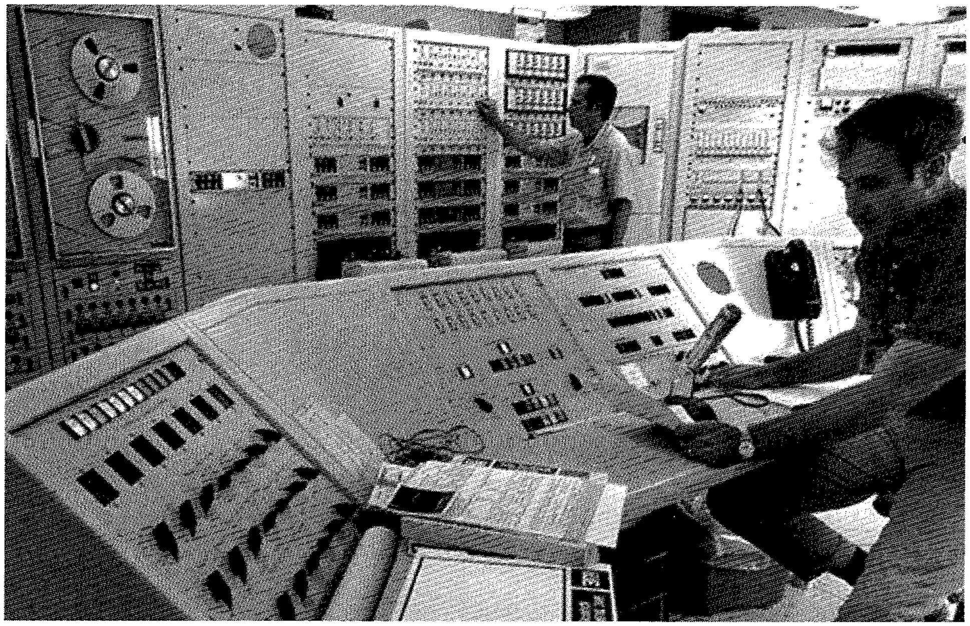
Test range maintenance crew delivers orange barrels by helicopter in May 1965 to mark the flight path for Joint Task Force 2 tests.



A fighter plane of Joint Task Force 2 makes a low-level test run in 1965 at Tonopah Test Range.

While the JTF-2 program continued, experiments were in progress with Sandia's high-altitude sounding rockets such as the Nitehawk 12 and the boosted Sandhawk. These traveled so high and far that a larger area for recovery of their instrumentation became necessary. Negotiated leases in 1967 extended the test range from its basic 525-square-mile configuration to a 4,000-square-mile area northeast of the range. By lease agreement, when the rockets were fired, Sandia had the additional area evacuated for protection of the people and to permit recovery of rocket payloads. Ken Johnson, radio operator at the range, remembered these evacuations and the necessary coordination with state and local agencies as difficult operations.

The range lent support in 1967 to NASA's experimental rocket program, tracking the supersonic X-15 rocket ship as it crossed over the range and covering with camera and radar the deployment of its external fuel tanks. Capable of flying 4,000 miles an hour more than seven miles high, the X-15 suffered several setbacks. The range crew tracked one X-15 that crashed into the Mojave Desert, and they saw two up close during consecutive years when each made a safe emergency landing on Mud Lake near the range. Gary West recalled also that when test range instruments tracked and recorded data on another secret aircraft, an intelligence agency confiscated the data.



Bob Beasley and Al Brazda work in 1971 at the range's telemetry monitoring center.

Harold Rarrick and Tex Samuelson in 1971 check one of the range cameras.

The range's tracking capabilities improved in 1967 when it acquired a Sandia-designed data processor. Leslie Minnear and Gary West led teams that developed the processor and its allied systems. The combined system could align all twenty-two tracking stations at the range on the elevation and azimuth of a target. Still, at times during most tests, the station operators went to manual control because the human touch could follow targets more effectively than computers. Although computers improved by quantum leaps during the following quarter century, the human touch remained important at Tonopah.

Despite the range's heavy and challenging workload during the late 1960s, discontent still raised its head occasionally. R. L. "Mike" Levesque, for example, presented a paper pointing out that photooptic professionals, so important at Tonopah, got no respect. They were often called "photographers," and while Levesque admired the art of photography, he resented the description. "Have you ever attended a salary review meeting," he asked, "and found out there is no job description to cover the thirty employees you represent?" He mentioned that the Government Accounting Office lumped all cameras from thirty-dollar throwaways to the million-dollar Contraves at Tonopah as the same type of equipment. He noted that when *Life* magazine published a two-page centerfold of satellite tracks crossing in the heavens that had been taken by Sandians, the only reward given the photo-optics experts who stayed up all night to make the picture was a free copy of the magazine.

HO for Vegas

Trouble brewed at Tonopah in 1968, and by that year's end the range crew left town. Reasons assigned for this abrupt departure remain a matter of debate.

After Samuel Moore became range manager in 1967, he became active in the Tonopah community. At the tenth anniversary of the range in 1967, Moore celebrated by opening the range's gate to families of the staff and also to community, county, and state officials. He joined the Tonopah chamber of commerce and headed its industrial development committee. Governor Paul Laxalt appointed him to the Nevada Economic Development Board, and Moore also chaired the Nye County Republican Committee. Sandia encouraged its employees to take part in community affairs, and the Albuquerque and Livermore communities benefited greatly from this policy. Moore's leadership of the Republican party, however, was sometimes listed by the range crew as a reason they left Tonopah at the end of 1968.

Many of the range crew had adjusted well to life in Tonopah. They enjoyed the small town atmosphere, the outdoor sports opportunities, and other amenities; their children married into Tonopah families. They had no desire to move. On the other hand, Tonopah's pioneer families often referred to them as "those Sandia people up the hill." For shopping and recreation, the Sandians were apt to drive to Bishop, California, or larger communities than Tonopah. Further, as renters of government property, they were exempt from local property taxes. Their amalgamation into the community was incomplete.

In addition to these matters, the range crew also mentioned an event involving Sandia president John Hornbeck. By their account, Hornbeck visited Tonopah to discuss community needs and became involved in loud disagreement with a civic leader. Since range employees and their families soon afterward moved to Las Vegas, they attributed their move to the earlier disagreement and an abrupt decision by Hornbeck.

The decision paper by Lee Hollingsworth, then director of field testing, discussed none of the reasons mentioned by the range crew. He emphasized the difficulty Sandia had in recruiting staff for the range. The original staff at both Salton Sea and Tonopah had consisted chiefly of field operating personnel, but it was his and Hornbeck's goal to attract personnel with qualifications similar to those required for research and development at Albuquerque and Livermore. These recruiting efforts had failed, and Hollingsworth summed it as follows: "While the jobs have been technically challenging, the remote location, poor living standards, cost of living and lack of those things we consider normal to the US way of life have caused people to consistently refuse in large numbers to be assigned to TTR on a permanent basis."

According to Hollingsworth, when Tonopah became a permanent test range in 1959, Sandia president Julius Molnar had considered moving the Salton Sea staff to Bishop, California, or Hawthorne or Las Vegas, Nevada, and shuttling them by air service to the range. Fearing loss of the entire range crew in an airplane crash, however, Molnar had rejected the idea in favor of settling the crew in Tonopah. Hollingsworth in 1968 revived the former concept.

During its first decade, the range had converted from a ballistic bombing range into an outdoor technical laboratory serving a wide-ranging segment of Sandia's research and development programs; and Sandia, with support from the AEC Division of Military Applications, expected in 1968 to fully use this capability for the foreseeable future. In fact, plans for the range included constructing several more buildings, installing commercial power to replace portable generators, paving range roads, acquiring improved radar systems, and updating data acquisition equipment to increase the range's versatility and sophistication. Sandia was fully committed to the range's future.

Hollingsworth thought the range crew should have the option of investing in their own homes as they would if working at Albuquerque or Livermore. Moreover, he wanted increased flexibility in assigning personnel to either Tonopah or the Nevada Test Site. He recommended that Las Vegas be made a Sandia permanent duty station, that the transfer of personnel from Tonopah to Las Vegas be required, that Sandia pay for transportation of personnel between Las Vegas and the range, and that a per diem allowance be paid to the employees. Richard Bice and John Hornbeck approved his recommendations.

Between school terms during the Christmas holiday of 1968, the range crew began packing their belongings to leave Tonopah for Las Vegas. Sandia granted few exceptions to the transfer, and for many it was a painful separation, leaving behind their friends of eight years and their children who had married in Tonopah. It took merely a few months for adjustment to the Las Vegas ambiance, however, and by April 1969 range-crew wives declared their delight with new homes, especially the convenient shopping and medical services.

Sandia arranged charter air service to transport Samuel Moore's crew from Las Vegas to the test range. Before dawn each work day, the crew went to McCarran Field and boarded a Fairchild F-27 plane for the 160-mile commuter trip to the range, requiring about fifty minutes flight time. It may have been the longest commute to work in the United States, and someone kept track of the commuting miles. During the following quarter century, long-time range employees accumulated more than a million miles of commuter travel.

During 1969 and later, Hollingsworth added staff members, mostly electronics and computer specialists, to the Tonopah crew, bringing them to Las Vegas from Albuquerque and Livermore. Contrary to the popular image of Las Vegas, these permanent residents were family people. "It's a great place to raise kids," one said, declaring, "The schools are excellent."

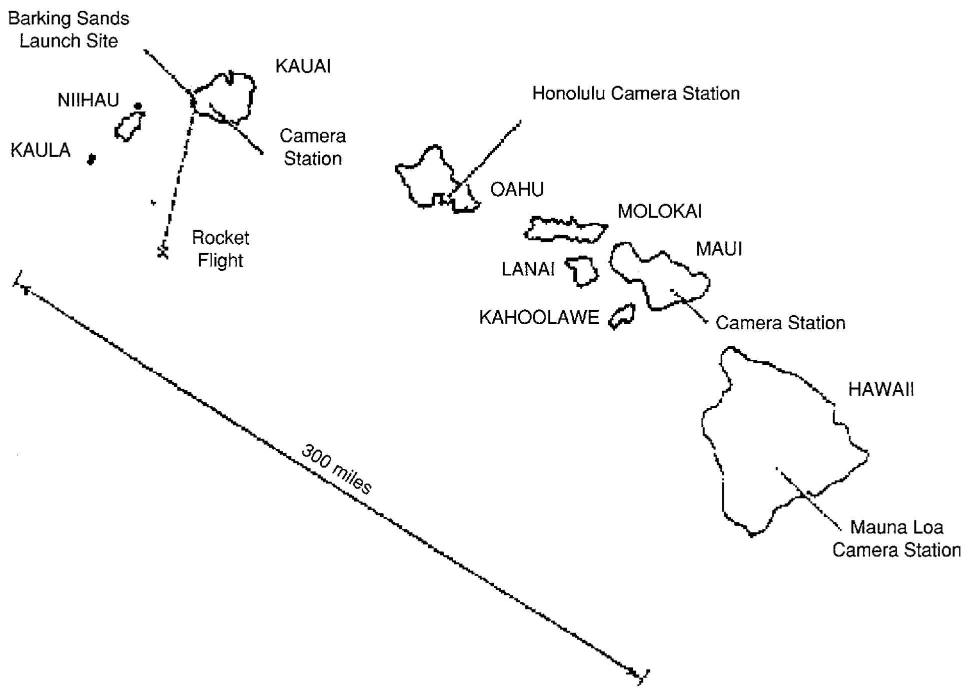
As the 1960s ended, developments at Tonopah range in addition to the usual ballistics and rocket testing aroused public interest. With sponsorship from Lawrence Livermore National Laboratory, the range's facilities were used for astronomical studies. The range launched Nike-Tomahawk rockets, for example, toward the sun to obtain information about solar x-ray activity.

The Tonopah range crew began their daily air commute to the job from McCarran Field at Las Vegas.

Dan Parsons, who developed large tracking telescopes and cameras for Sandia, led efforts to use radio-controlled model aircraft as targets for calibrating equipment and practice for the range operators. At considerable savings in time and funding, the model aircraft provided targets for evaluating a new Air Force tracking mount. Parsons and associates even rigged a mechanism allowing the models to carry and release foot-long wooden "bombs," and in 1970 they built the "Beast," a five-engine model aircraft with a twelve-foot wing span, used for test drops of projectiles weighing up to twenty-five pounds.

Barking Sands and Edgewood Test Ranges

During Operation Dominic, the full-scale atmospheric tests in the Pacific by the United States in 1962 as response to Soviet violation of the test moratorium, Sandia established a rocket launching facility on Kauai in the Hawaiian Islands. First known as the Barking Sands rocket complex because nearby coral sand made crunching noises when stepped on similar to the yapping of a dog, it became the Kauai Testing Facility.



Sketch of Sandia's Kauai Test Facility location in Hawaii.

After the Dominic tests ended, Sandia used the Kauai facility in 1963 to support a NASA project for study of the upper atmosphere. It involved launching Nike-Apache, Deacon-Judi, and other rockets into the upper atmosphere to release metal chaff, reflective balloons, and clouds of orange-colored sodium. The Navy's Pacific Missile Range radar system tracked the chaff, balloons, and clouds to investigate high-altitude winds. Sandia's Lawrence Smith served initially as scientific advisor, John Miller as project engineer, Alfred Young as Kauai manager, and Dale Fastle as director of camera stations on Kauai, Maui, and Hawaii for the sounding rocket program.

Sodium clouds, which merely reflected light, proved unsuitable for photographic coverage of the launch results, so the research team substituted compounds that reacted with oxygen in the upper atmosphere and glowed, permitting launchings any time of day or night. During the 1970s, in research sponsored by Los Alamos and Livermore laboratories, barium released from rockets formed moving clouds described as light green, changing to red as a result of ionization of the barium by sunlight. The resulting colorfully luminous and moving clouds revealed the flow patterns of the jet stream. Doubtless they also became a cause of UFO sighting reports.

To the scores of sounding rocket launches at Kauai for atmospheric research were added the firing of experimental rocket systems. Sandia used the range to test various designs and combinations of motors, nosecones, fins, and instrumentation for high-altitude rockets. The Nitehawk, Sandhawk, and Strypi high-altitude rockets were perhaps the most memorable of Sandia's rockets tested and used both at Kauai and Tonopah. Sandians from Albuquerque and Livermore traveled to Kauai for the testing "campaigns," and between the test series a small staff managed the facilities under the direction of John Miller, Keith Smith, Al Huters, Jack Canute, and others at various times. Reynolds Moore, the brother of Samuel Moore at Tonopah, served as director of several test projects at Kauai.

By the 1970s, the Barking Sands complex had been named the Kauai Test Facility, with capability for both rail-guided and vertical rocket launches. Sandia maintained the launching, ground-handling, and control equipment in support of scientific research and reentry vehicle development. The scientific packages launched from Kauai included experiments by Los Alamos and Livermore laboratories and also by universities at home and abroad. Among the research supported by Kauai were studies of "black holes" in the universe, of x-ray emissions from stellar sources, and of cosmic rays for Leiden University in the Netherlands and Nagoya University in Japan.

Leo Scully, Jack St. Clair, Larry Rollstin, and Richard Howell in 1971 plan a rocket launching test.

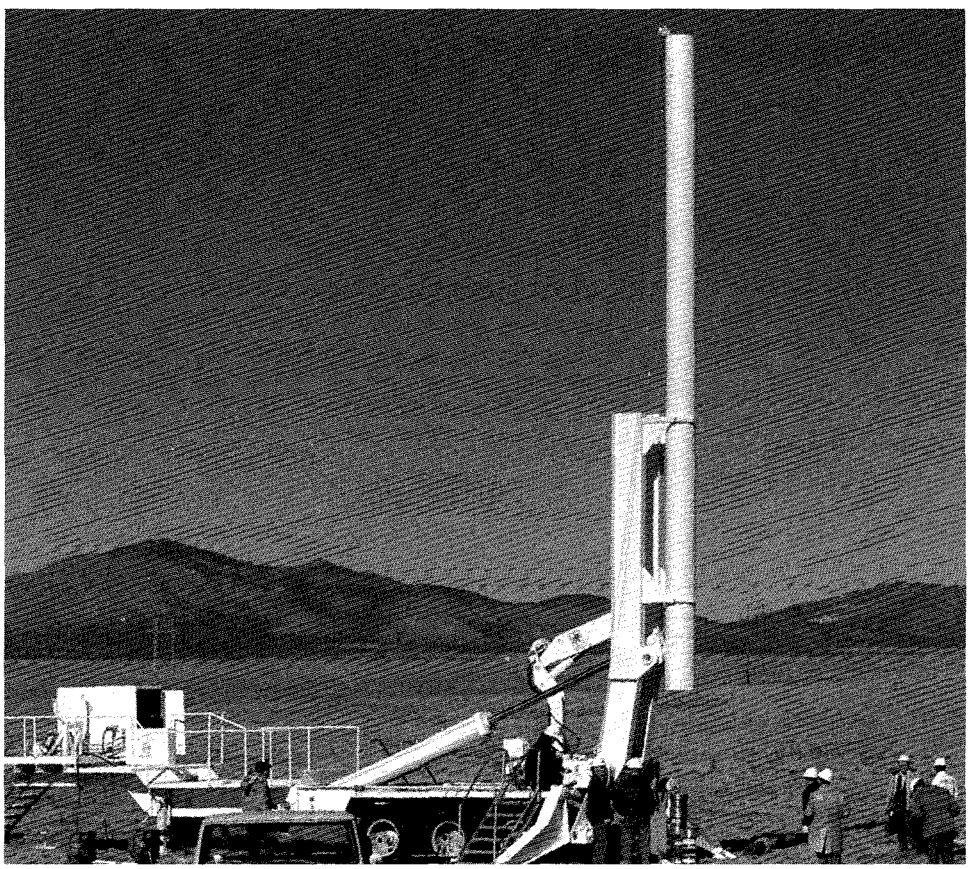
Much closer to home was the testing accomplished at Edgewood, a test range Sandia established twenty miles east of Albuquerque in 1968. The testing at Edgewood related not to the cosmos, but mostly to the infantry slogging through mud in Vietnam. As the Vietnam conflict escalated, the resources of Sandia were increasingly marshaled by Robert McNamara's Defense Department. Much of the research accomplished at the Edgewood range related, in fact, to the creation of "McNamara's Wall."

The geology and soils of Tonopah and Kauai were unsuitable for modeling conditions in Vietnam. Flat, soft, muddy soils were desirable, preferably near Albuquerque for travel savings and in a wide-open area for easy coverage of test drops. Sandia found this near Edgewood in the Estancia valley, a broad plain with soft soils which then had a small population of ranchers. Sandia leased parcels of the range land, brought in electric and phone lines, graded an airstrip, drilled a well, and installed an irrigation system to saturate the soils into rice-paddy mud. Gordo Miller of the remote ranges group brought in other equipment needed for testing, with Ed Stout serving as test controller and Clyde Walker as test program manager. Nick Perea operated the radar van, Les Harris the telemetry station, Terry Leighley and Joe Llamas the mobile tracking telescopes, and Fenner Jones and Cal Cox the position and release control instruments. Most test drops at Edgewood came from an old Beaver aircraft made during World War II as an observation plane and modified with bomb release racks and electronics by Sandia as substitute for more expensive military aircraft or helicopters. An interesting sidelight of testing at Edgewood was the drop from a Skycrane helicopter of a nuclear-reactor fuel shipping cask to assess its resistance to shocks.

While the tests done earlier at Salton Sea and Tonopah chiefly involved aerodynamics, or the ballistics of bombs and rockets passing through the atmosphere, many of the tests at Edgewood involved terradynamics, a science created and named at Sandia in 1960 by Alan Pope and Bill Caudle. Terradynamics concerned the ballistics of weapon shapes as they passed through soils. A weapon that could drive deeply underground before detonating could destroy enemy tunnel complexes or subsurface bunkers. But testing at Edgewood during the 1960s and early 1970s related chiefly to soil implantation of seismic sensors capable of detecting the passage of enemy equipment and troops.

As part of its nuclear testing verification program, Sandia had developed sensors for detecting distant nuclear underground blasts, and these were so sensitive they could record the footsteps of passing troops. During the 1960s, Sandia combined these sensors with ground penetration projectiles that could be dropped from aircraft to imbed in soils. Trailing a cable-towed antenna camouflaged to resemble vegetation, the sensors relayed signals to a central command station for analysis. The military deployed thousands of these seismic penetrators in Vietnam, where they formed "McNamara's Line" across the country. Deployed tactically during the siege of Khe Sanh, the seismic sensors were credited by American troops with allowing a successful defense of the fortification.

To enhance terradynamics research, Larry Seamons and Wayne Young of Sandia designed an enormous Davis gun (recoilless rifle) and tested it at Edgewood in 1974. Consisting of a 35-foot-long gun barrel open at both ends, it fired by sandwiching a propellant charge between a projectile and a reaction mass. When fired in a vertical position, the projectile drove into the ground while the reaction mass blew out the top of the barrel. The projectile contained instruments for transmitting data on the rock and soil strata through which it passed—useful information for several purposes. The Davis gun could be aimed at small targets of particular types of soil or rock, and it could fire projectiles at up to 3,000 feet per second, compared to 1,400 feet per second for projectiles dropped by aircraft. In 1975, Sandia moved its Davis gun to Tonopah Test Range, where it saw heavy service.



Sandians at the Edgewood test range in 1974 prepare to fire a recoilless Davis gun.

The Guns of Tonopah

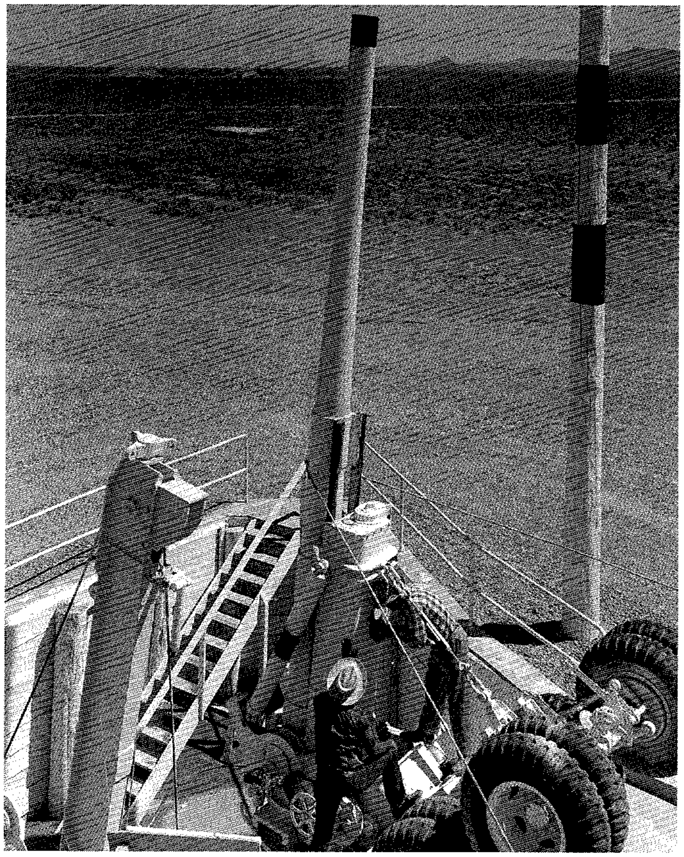
With the Davis gun added to its arsenal, Tonopah Test Range's capabilities during the 1970s covered everything from subsurface ground conditions to the upper atmosphere—from the heavens to the netherlands and every space between.

Sandia's sounding rockets found competition during the 1970s from Tonopah's big guns, the 155-mm Long Toms that provided low-cost means of acceleration shock and destruct testing for components and instrumentation hardware. Managed by Ralph Holland and H. M. Bowen, the guns were fired by Cecil Lang, Tom Laws, and Jim Weber from a bunker near the gun site. Test instrumentation consisted of breech pressure and muzzle velocity measurements, in-barrel telemetry, photographs of projectiles in flight, and environmental conditioning of the projectiles. The latter was done in an assembly building near the guns where the projectiles could be heated or cooled before firing. Data sent from telemetry inside the projectiles was recorded in an instrumentation trailer adjacent to the guns.

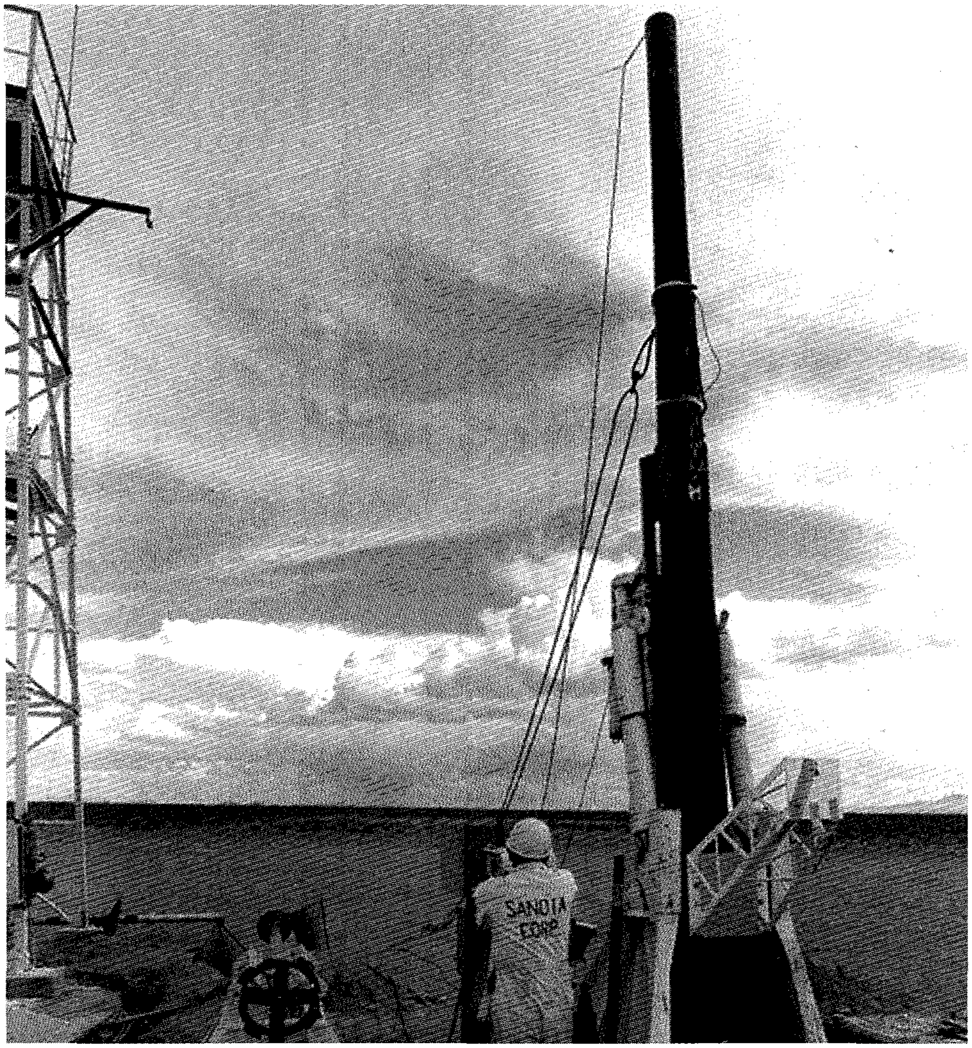
Adding 8-inch and larger caliber barrels to its arsenal, Tonopah's guns completed many tests of the W33, W79, and W82 artillery-fired atomic shells for the Army to assure that they could withstand acceleration loads up to 17,500 times normal gravity weight and spins as high as 17,500 revolutions per minute. Sandia not only designed and installed instrumentation inside the shells capable of surviving such stresses, it also found a way to recover the shells for post-firing examination. The first method tried involved firing the shell into a large berm box filled with sawdust, but damages to the shell were such that it proved difficult to determine "whether they were caused by terminal deceleration or by the initial acceleration, or both." The shells then were fired vertically and photographed with a 120-inch tracking telescope to observe their performance ten miles up.

Sandia's parachutes laboratory with Don Williams designed a parachute system that could bring the shells safely back to earth for examination. After the guns of Tonopah fired the shells ten miles high, a small explosive blew open the nose of the shell and deployed a small parachute. When the shell descended, the range crew could recover it for inspection. Sandia completed hundreds of artillery tests of this sort from the 1960s into the 1990s.

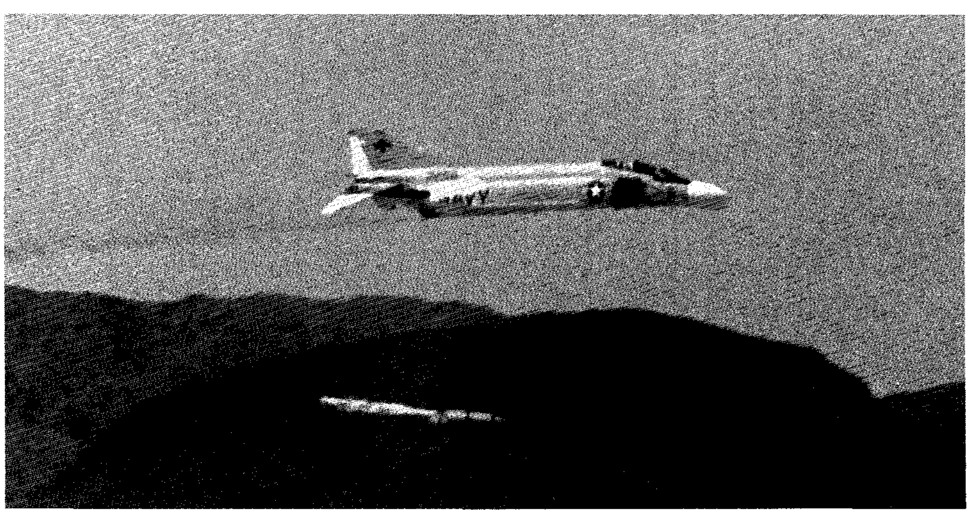
A howitzer at the test range used to test artillery shells.



A 1968 view of the crew rigging a howitzer for firing vertically. In the background are storage bunkers.



In 1971, the crew prepares to fire a 155-mm gun raised to an 89-degree firing angle.

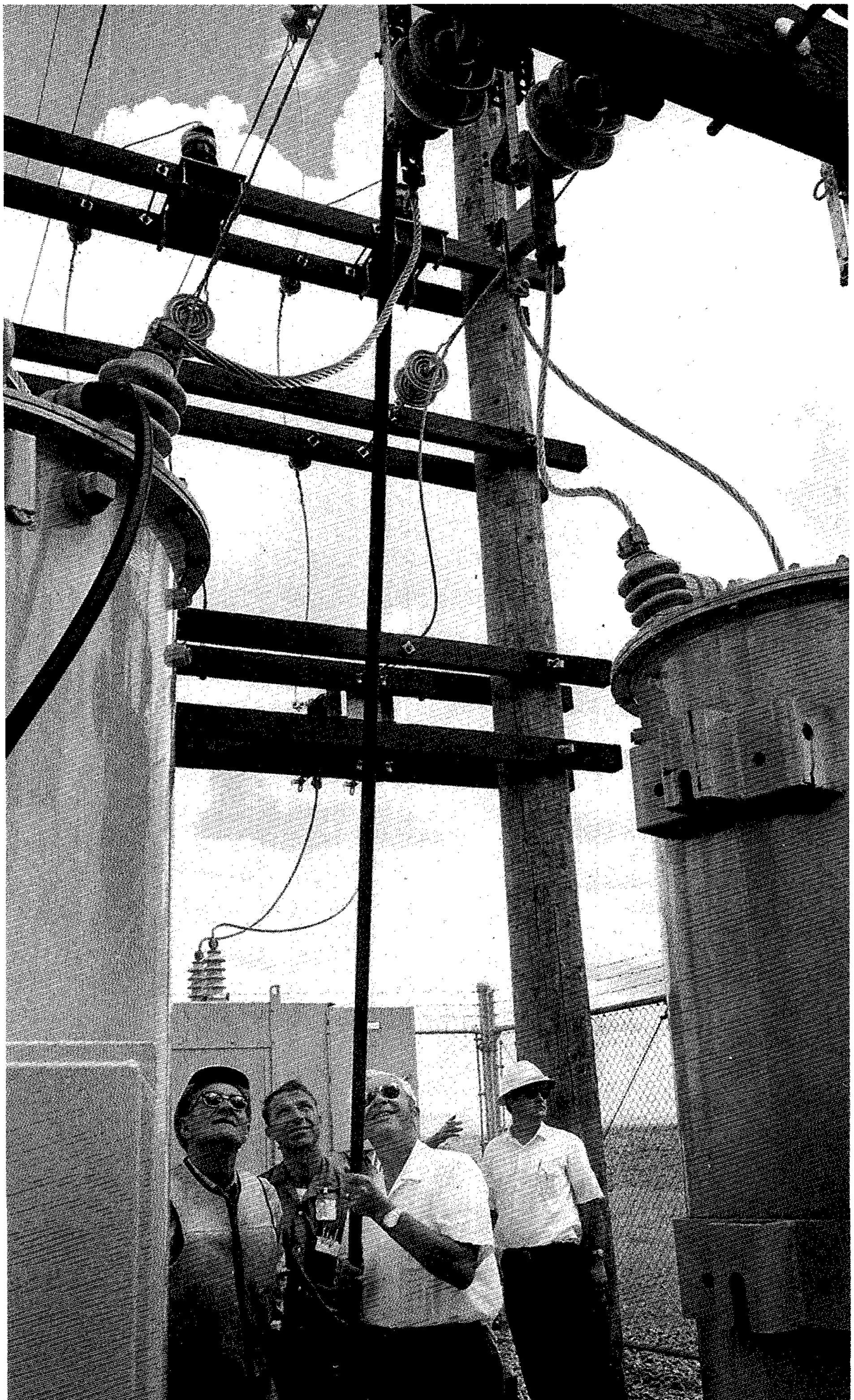


A 1976 test drop of a B61 bomb with its parachute deploying

Mobility Upgrades at Tonopah

When the functions of the Atomic Energy Commission transferred to the Energy Research and Development Administration and the Nuclear Regulatory Commission during the early 1970s, it had little apparent impact on activities at Tonopah Test Range. The energy crises of those years, however, produced efforts to save energy use and costs at Tonopah as they did elsewhere.

As energy shortages resulted in higher petroleum prices, Rush Robinett questioned the wisdom of continuing to produce electric power at the range with diesel generators. He compared the costs of diesel generation with those of installing commercial electric power and concluded that the range would recover its initial investment in commercial power installation within five years in diesel fuel savings. At a cost of nearly a million dollars, Sandia installed a substation, transformers, 37 miles of power lines on the range, and a 16.2-mile connector to a commercial transmission line.

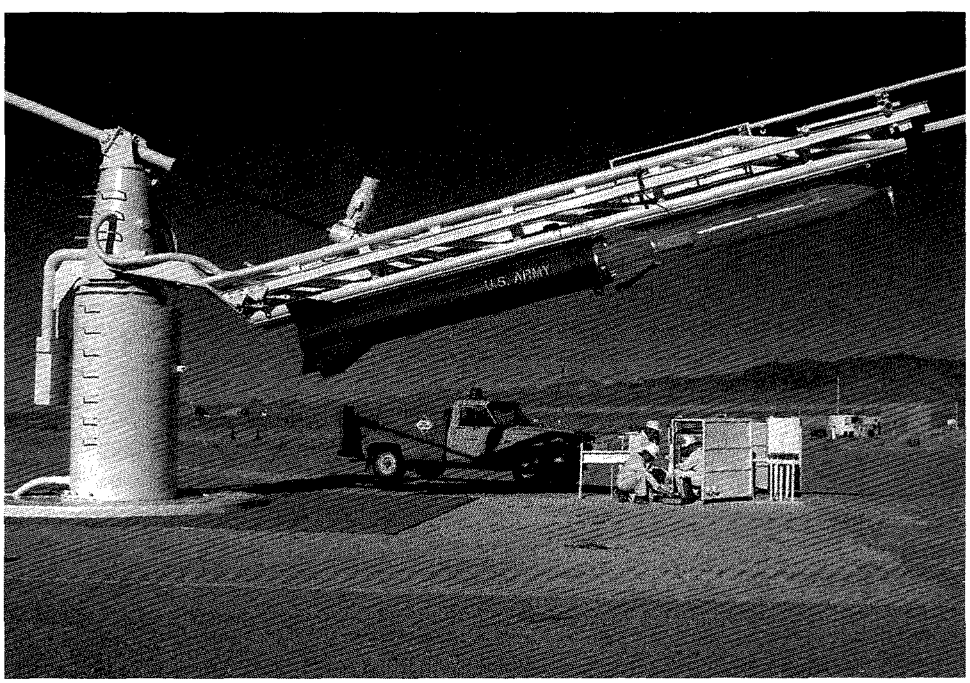


Range manager Sam Moore flips a breaker to turn on commercial power at the range in 1971. At left is Art Carey and Cliff Rudy.

In May 1971, range manager Samuel Moore flipped the switch to bring Tonopah onto the commercial power network. It allowed synchronizing test operations because power frequencies thereafter were the same at every tracking station, and it permitted programming electronic equipment to be operational at set times, saving the time previously required for starting the diesel generators and warming the equipment.

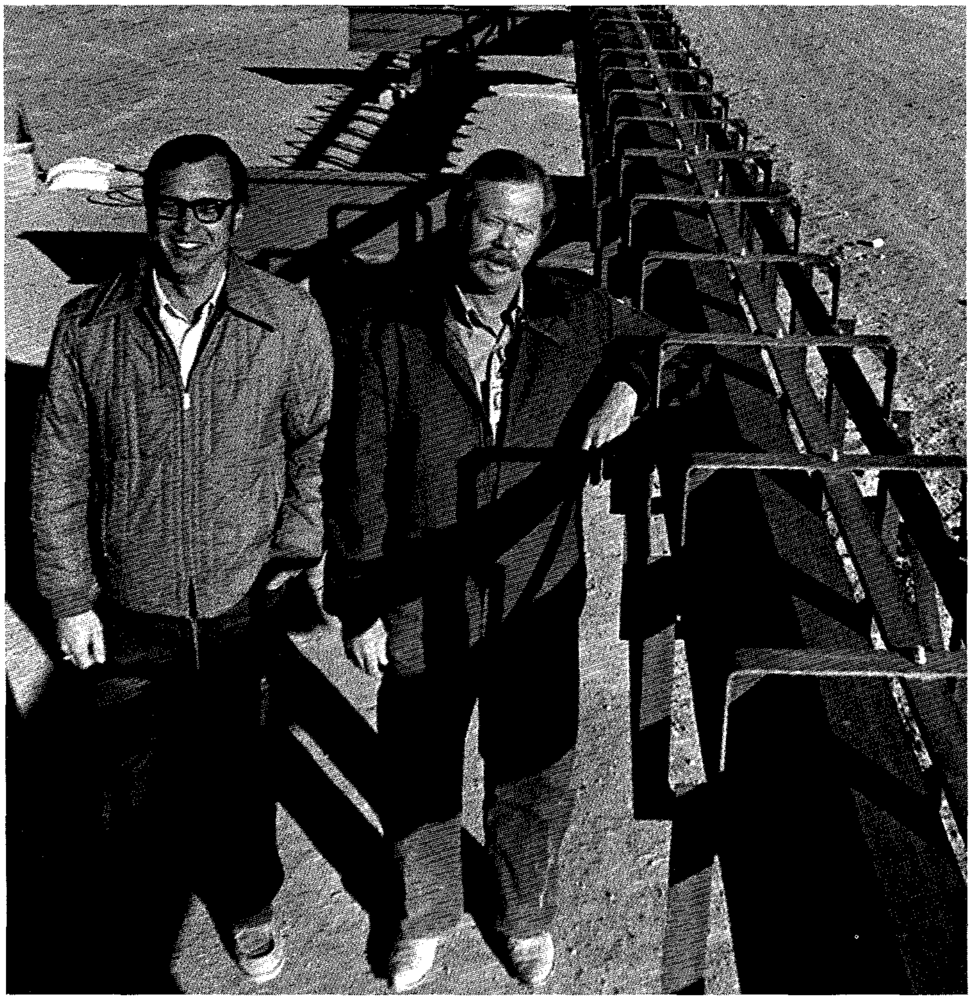
A year later, the range acquired an advanced MPS-36 radar, one of fourteen that RCA built for the armed forces and Atomic Energy Commission. It was transportable by trailer from site to site, where it could be installed on concrete pedestals. Able to track a football-sized object for 87 miles, or a rocket for 31,000 miles, the radar transmitted its data to a digital computer that replaced the older analog computers. Tom Hoban and Gary West of Sandia provided technical and design guidance for acquiring this radar and bringing it into operation.

During the spring of 1973, the range acquired highly mobile tracking telescopes on mounts devised by project engineers Grover Hughes, Al Shaut, and Don Greenwoll. The truck-mounted units could be used either at Tonopah or other sites for photometrics including television coverage of testing, and the optical trailer-mounted unit carried two 60-inch focal length telescopes and four high-speed cameras. "The mobility and flexible photo optical capabilities of the units," said Leo Scully, "should prove of great value to all types of field testing activities."

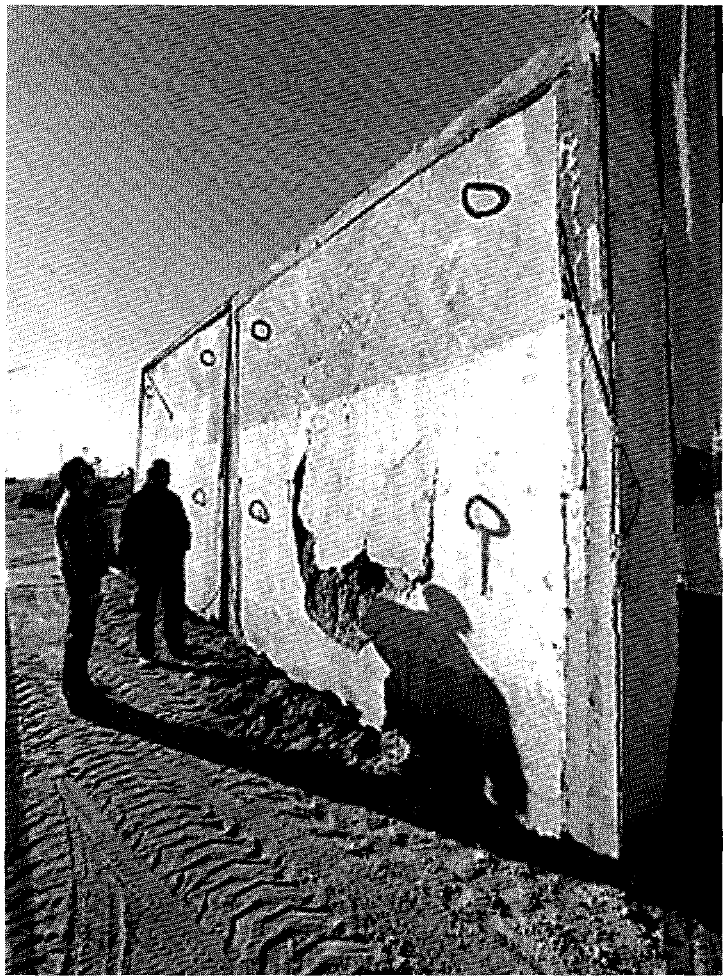


An Honest John rocket boosting a test vehicle on a launcher at Tonopah Test Range.

One of the few non-defense tests performed at Tonopah occurred in early 1976, when the Electric Power Research Institute funded tests of the ability of nuclear power plants to withstand the forces produced by tornadoes and windstorms. Al Stephenson managed these tests, which involved constructing reinforced concrete slabs from one to two feet thick to simulate containment structures at power plants. A 130-foot-long steel sled track assembled at Tonopah guided rocket-propelled objects such as steel pipes and telephone poles into the slabs to assess the resulting damages to the concrete. These tests made the analysis of potential tornado damages to nuclear power plants possible and indicated that the concrete walls could be reduced from a 27-inch to an 18-inch width without loss of safety. As Stephenson remarked, this was "useful not only to the Nuclear Regulatory Commission but also to the world's construction industry."



Al Stephenson and Jack Windsor in 1976 stand in the rocket sled track at Tonopah used for tornado safety studies.



Al Stephenson and Jack Windsor examine the damage done by the impact of a twelve-inch pipe to a reinforced concrete slab after a test at Tonopah.

Nosecone Testing

Sandia in 1973 had underway a major research program for the Air Force on the materials used in missile nosecones. To test these materials in extreme launch and reentry environments at 10,000 feet per second, Sandia's aerodynamics department put together a three-stage rocket combining existing boosters: first stage from a Talos rocket, second stage from a Terrier, and third from a Recruit. Taking the first letters from the three systems, the new design was called TATER and first tested at Tonopah in August 1973. Dave Schafer, who manned a tracking telescope during the test later remembered TATER as his greatest tracking challenge. "It was very fast," he said, "and it was practically on a horizontal trajectory. It was only 35 or 40 seconds from launch to impact and I still don't know how I managed to keep it in the viewfinder." Range data indicated the total heat onto the TATER nosecone during the test was typical of that for an ICBM reentry, and Sandia launched a total of nineteen TATERs at Tonopah and at Wallops Island, Virginia, before this research ended.

Other nosecone materials tests sponsored by the Defense Nuclear Agency followed TATER into Tonopah during the mid-1970s. A fast F-4 aircraft launched the testing vehicle, a two-stage rocket called FLAME, that propelled the experimental nosecone into the atmosphere near Tonopah. The nosecone glowed like a fiery meteorite as it plunged down, then a parachute popped out to drop the nosecone onto the range for recovery and examination. Harold Rarrick managed this testing program at the range.

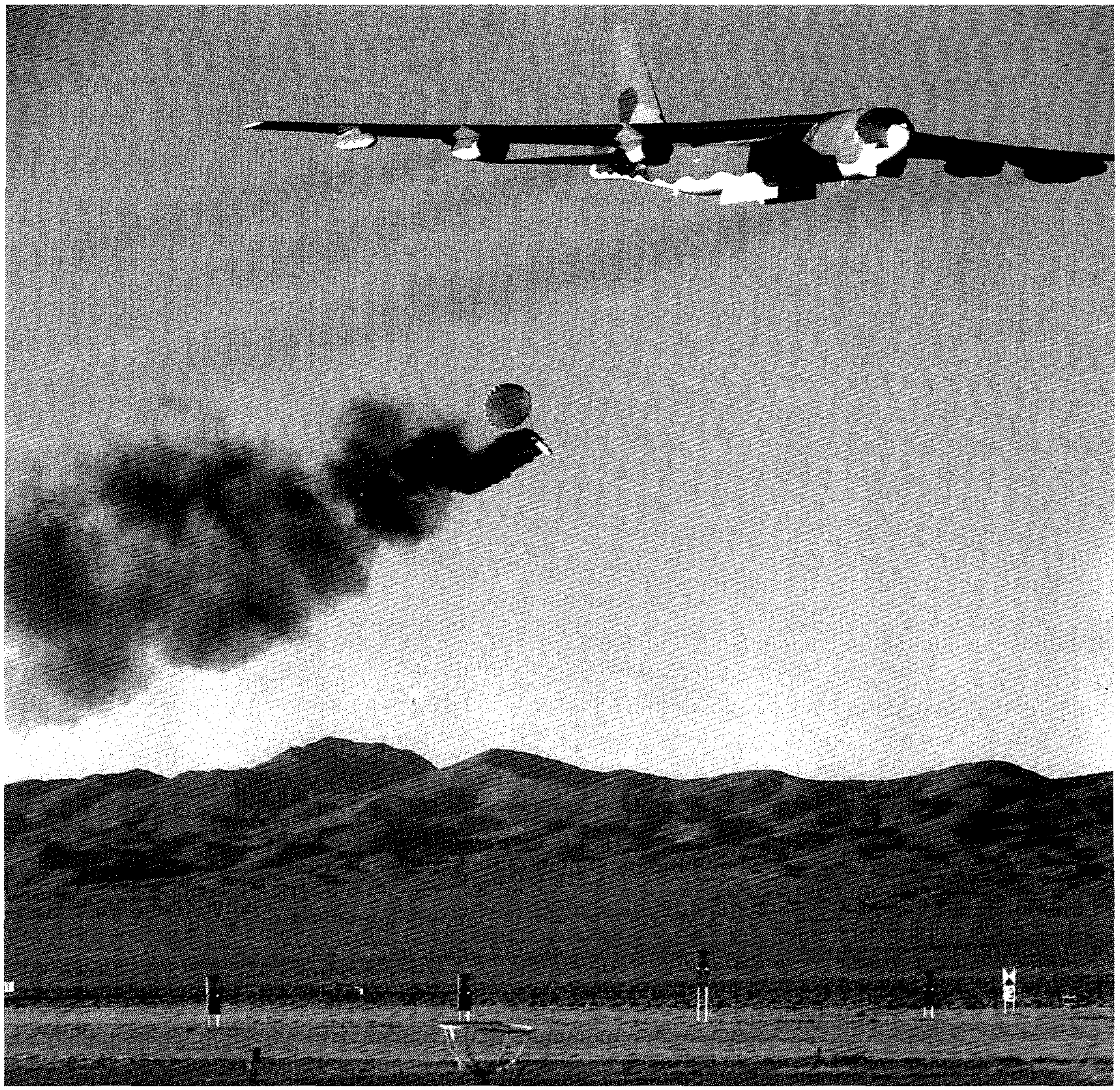
Tonopah Test Range Air Force Base

In April 1975, Colonel Joseph Salvucci of the Air Force tactical fighter center announced Air Force creation of an electronics warfare training area at Tonopah Test Range. He explained that pilots would fly the test range, where they would receive electronic impulses from simulated ground weapons and would then react as in an attack situation. He told people living in Tonopah that they would not be aware that the tests were in progress and would seldom see any of the aircraft involved.

The Air Force initiated construction of its Tonopah Test Range installation during the late 1970s. It was an elaborate installation with the housing, hangars, and other facilities standard to modern Air Force bases, dwarfing the size of Sandia's test range facilities. Sandia's landing strip for the F-27 bringing the range crew from and to Las Vegas was extended and resurfaced to serve also as the Air Force runway.

Although the range entered into cooperative arrangements with the Air Force base for such matters as security and waste management, the range crew for security reasons never admitted seeing the base, much less the experimental aircraft tested there. For their tight-lipped stoicism, they later received Air Force commendation.

While the Air Force fighter development program was in progress, the test range continued its customary support of Sandia's weapons programs. In 1977, the range provided what Arnie Rivenes described as "beautiful" photographic proof that a B-52 aircraft could drop B77 bombs from 200 feet, using a lifting parachute to delay bomb impact. "In fact," Rivenes said, "we deployed it successfully at just 150 feet. And it impacted both vertical and slow, just as desired when you want to survive impact on a hard, irregular target."



A 1977 test drop of a laydown B77 bomb by a B52 aircraft onto the range's concrete target.

Other tests of the late 1970s involved the Extended Range Bomb, a weapon prompted by observations of the 1972 Israeli-Egyptian war, where anti-aircraft systems took a heavy toll on Israeli jet aircraft. This proved that successful air attack would require high-speed approach to targets at 200 feet or less in altitude. The Extended Range Bomb allowed the pilot to overfly his target, then release the bomb. With an independent propulsion and guidance system, the bomb could turn around and fly back to strike the target after the launching aircraft had departed the vicinity.

Wayne Lathrop during the 1960s had proposed that Sandia acquire one of the Army's 280-mm atomic cannon to use as a low-cost alternative to sounding rockets. His study indicated these great guns could fire thirty-pound projectiles thirty miles into the atmosphere. This was not done, but Lathrop in 1977 became director at Tonopah for tests of a high-altitude gun fired for the Aberdeen Proving Grounds. A five-inch smooth bore gun with a special 40.5-foot-long barrel installed at Tonopah, it fired dart-like research projectiles fifty miles into the air. After deploying a parachute, the projectile took three hours to float back to the range for recovery.

Ground penetration with a mobile air gun continued at Tonopah in 1978 as part of a NASA program. Sandia had proposed to NASA that a space probe sent to the planet Mars should carry ground penetrators. After entering orbit around Mars, the spacecraft would fire units to penetrate the surface of Mars. On impact, the back antenna section of the unit would separate to remain on the surface while the front section would burrow forty-five feet into the planet. It would transmit signals to the antenna and thence to the spacecraft and earth, relaying seismic data and other information about the red planet. Sandia tested this system at Tonopah eighteen times in 1978, firing it into various soils and rock. The system, however, has yet to be tested on Mars itself.

The Davis gun in 1979 fired a prototype of the Pershing II earth penetrator into a dry lake bed; the 400-pound test unit drilled more than 67 feet down, carrying in its case an electrical system and explosive mockup together with a telemetry package. Designed by a Sandia team led by Bill Patterson for the Army's Redstone Arsenal, the Pershing II could be carried by a missile, separated at reentry into the atmosphere, and driven into the ground before exploding. Small payloads could thereby create large craters. Using a magnetometer probe designed by Jim Bushnell, range crew located the Pershing II penetrator underground and drilled a hole alongside it to recover the device for inspection. Test engineer Jim Lohkamp managed subsequent penetrator tests to evaluate the weapon's capabilities in differing earth strata.

Range Modernization

Before retiring in 1978, Harlan Lenander, director of development testing, broke ground for a new operations center at Tonopah Test Range, and the range crew awarded him the honorary degree of "Range Rat Emeritus." With his departure, and in recognition of a declining weapons testing program, the Tonopah Test Range and the Mobile and Remote Ranges division from his organization merged into the Field Engineering directorate under Carter Broyles. The Broyles organization had earlier been known as the Underground Experiments directorate and included the Nevada Test Site plus Sandia's nuclear waste management and fossil energy programs. In addition to Sandia New Mexico and Sandia California (referring to the Sandia laboratories at

Albuquerque and Livermore), someone proposed that this organization be called "Sandia Nevada," because many of its personnel were indeed located in Nevada or were forever traveling back and forth to Nevada.

The shovel wielding by Lenander, assisted by Samuel Moore, in April 1978 initiated a long-planned modernization for the twenty-year-old Tonopah facilities. "Our equipment has grown old and worn out," explained Ron Bentley, manager of the modernization effort, adding, "Some of our cinetheodolites have been used for twenty years." Bob Beasley had charge of integrating the new communications data networks and Al Faychak coordinated requirements with the Plant Engineering directorate, while Bob Finnell programmed a network of thirty new minicomputers to calibrate the tracking stations and permit off-range operations.

The $8-million upgrade involved constructing a new equipment-maintenance building and a new operations-control center, purchasing seven modern and mobile Contraves cinetheodolites, adding new computer networks, replacing obsolete electronic gear, and improving the existing road system. The range crew performed much of the design, development, and installation in addition to their usual testing duties to attain technical command of the systems—skills useful when maintenance or modifications became necessary.

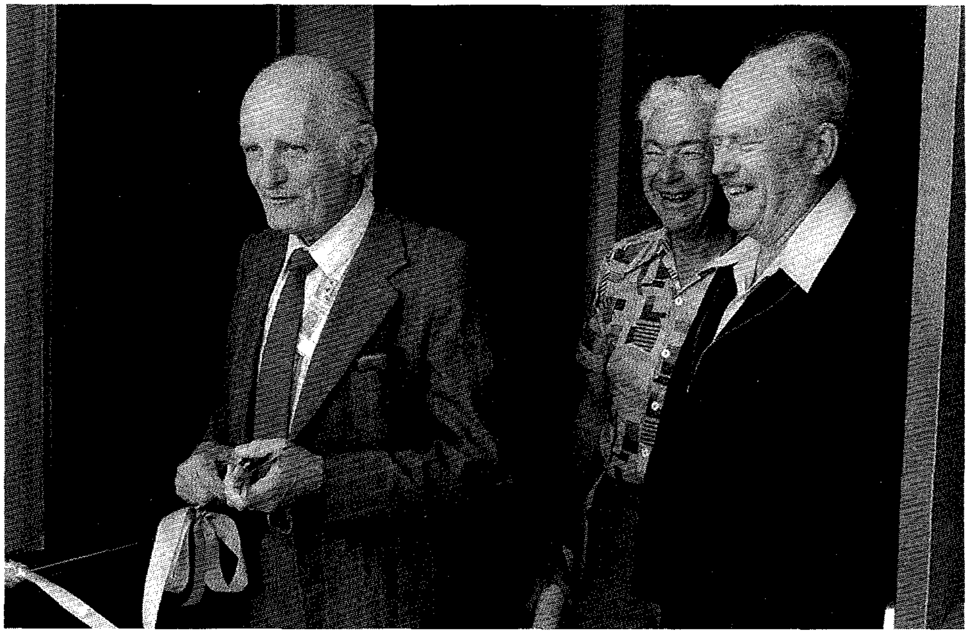
With the extended runway available, the range crew switched in 1980 from the old F-27 turboprop aircraft, in which they had commuted hundreds of thousands of miles, to a jet-powered DC-9, able to fly from Las Vegas to the range in half the time. A more comfortable aircraft with room for seventy passengers, the DC-9 allowed the range crew more time with their families during evenings after their ten-hour workdays on the range.

Aboard the DC-9 in 1982, Al Brazda became the first Sandian to complete a million miles of commuting from Las Vegas to Tonopah, initiating what the crew called the Royal Order of the Jet Set. Within a few years this million-mile Order had grown to fourteen members: Brazda, Dave Schafer, Lance Wilson, Don Anderson, Ken Johnson, Lloyd Young, Gene Arndt, Paul Roper, Art Rodriguez, Bill Moore, Jim Enlow, Howard Gipson, Diwiatt Barker, and Bob Beasley. These made about 175 round-trips annually from Las Vegas to the range. Jim Enlow, Jerry McCorkle, and others worked as flight attendants aboard the aircraft under an arrangement with the charter company to provide services required by law. For a quarter century, the commuters to Tonopah never experienced a crash or even a major emergency—a record indicating they probably were safer in the air from Las Vegas than making the 38-mile drive from the town of Tonopah to the range.

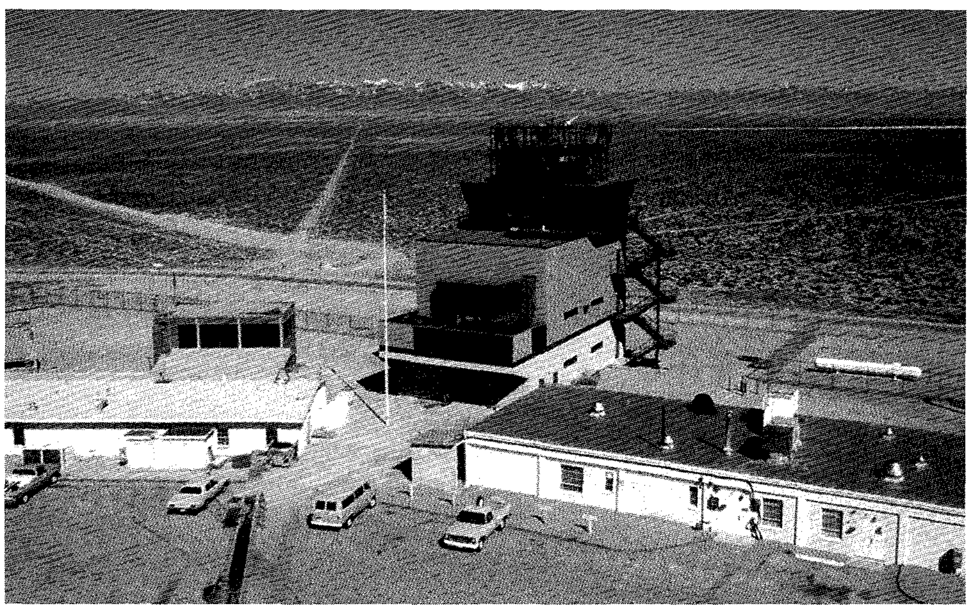
The test crew arriving at the range in February 1982. At top of stairs is Sam Moore, then Ron Bentley, Dave Denton, Wayne Lathrop, and Ben Sewell. In back row from left, John Willems, Jim Enlow, Dan Tebbs, Mike Bakos, Russell Brown, Al Brazda, Dick Williams, Palmer Nelson, Dwight Barker, Hoot Gipson, Rick Orzel, Jim Van Meter, Andy Jones, Al Faychak, and Leo Convissor. Second row, Steve Reynolds, Paul Roper, Bob Beasley, P. K. Goen, Don Anderson, Jim Clemons, Bill Moore, Ross Sinkey, Joe Bradshaw, Bill Kluesner, and Lance Wilson. Front row, Noris Rose, Cecil Lang, Lloyd Young, Dave Greene, Mark Montavon, Ron Haines, Art Rodriguez, Ken Johnson, Gary Martinez, Henry Stuckert, Dave Scafer, Gene Arndt, and Mick Cockrill.

Sandia president Morgan Sparks and vice president Glenn Fowler visited the range on April 21, 1980, to assist Samuel Moore with ribbon-cutting for the new four-floor, 8500-square-foot Operations Control Building, centerpiece of the modernization program. "Our range modernization program has brought Tonopah's instrumentation systems to the edge of available technology," crowed Moore, adding: "We can match the sophistication of the most advanced weapon systems and provide performance data in depth, plus offering flexible scheduling and extensive support services."

Leaving the range in commendable condition, these "old guards" retired during the following three years. They recognized conditions were changing at Tonopah as elsewhere. "When I began, we faced a common threat, and we knew we had to put forth everything we had to overcome it," remembered Fowler, who as director of field testing had approved the Salton Sea and Tonopah range sites. "Our view of the world now appears much more restricted," he lamented in 1983, "we don't seem to have a common goal, a common purpose, anymore."



Sandia president Morgan Sparks, Sam Moore, Glenn Fowler cut the ribbon opening the test range's new control center in May 1980.



The tall building is the Test Range's new control center in 1980.

After fifteen years as range manager, Samuel Moore retired in 1983 and Ron Bentley succeeded him. Bentley, a telemetry expert, had led the range modernization program during the previous five years. Wayne Lathrop, previously test director at Tonopah and Kauai, became the range operations supervisor. They enjoyed long, hot, and grueling summers of heavy test scheduling during the early 1980s.

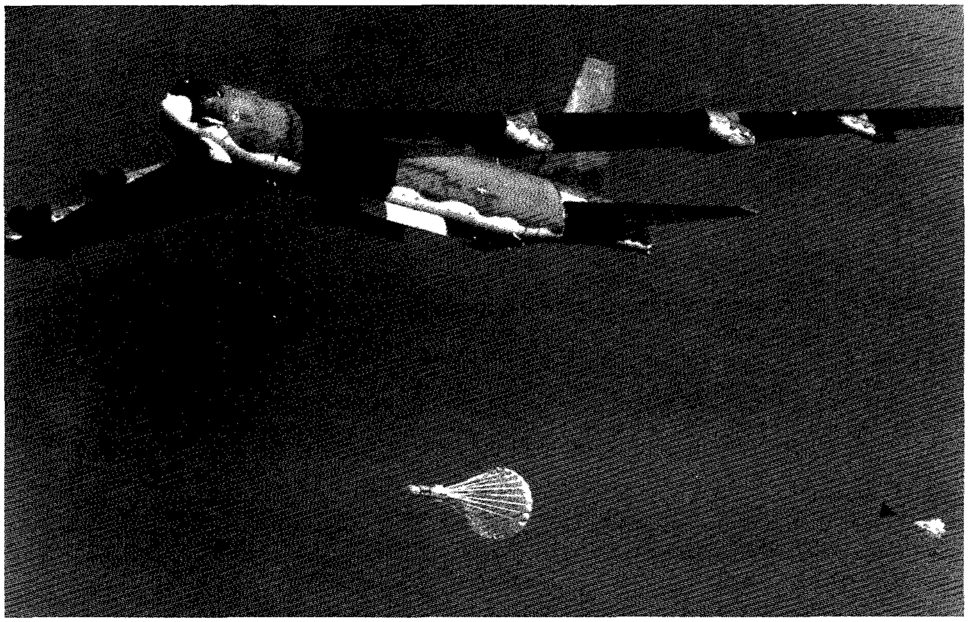
Among the interesting tests of the early 1980s were the firings of a modified Honest John rocket for the Army's Harry Diamond Laboratory. Its hydra-headed nose sported five separate fuzes, each protruding from the nosecone. Sandia's B83 strategic bomb saw tests at Tonopah in 1981. Designed to destroy railroad yards or steel plants, the 2400-pound bomb had to hit such hard targets and then delay detonation long enough for the delivery aircraft to escape. Gary Beeler, who headed the design project, declared it resembled designing a compact car that could crash at sixty miles an hour and its radio would continue playing. Tonopah's hard target, a foot-thick concrete circle that had replaced the old cross mark, proved useful during the B83 testing.

Also in 1981, Tonopah participated in tests of a Navy Tomahawk cruise missile, launched from a submarine in the Pacific and flying a crooked 500-mile course to hit a target the size of a house on one of the dry lakebeds. Capable of carrying either conventional explosives or Sandia's W-80 warhead, it could follow a specified course at treetop level and offer only an elusive target. During the test, a chase plane tailed the missile to control it if it left course, but on its first try the Tomahawk hit its target. "The cruise missile tests stretch the capabilities of our instrumentation to its fullest," boasted Ron Bentley, "but the systems are performing without a glitch."

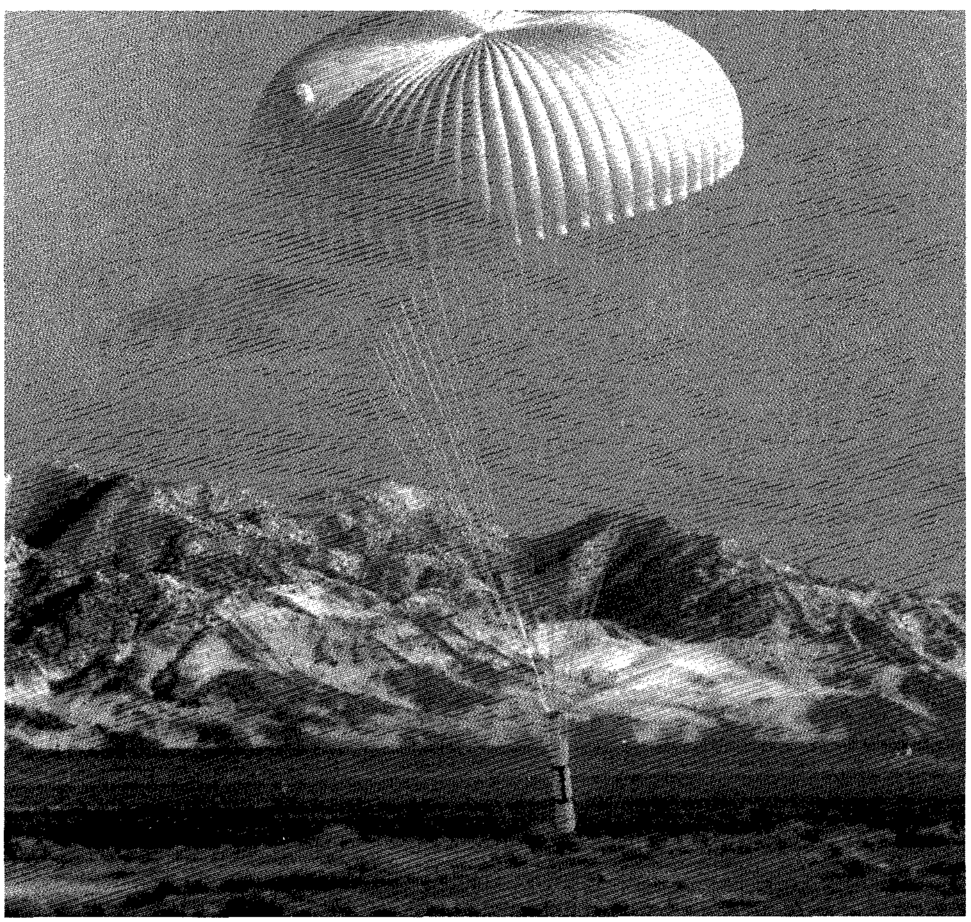
According to test director Palmer Nelson, the summer of 1982 was simply grueling for the range crew. "We've had high altitude drops, low level drops, parachute tests, JTA tests, rocket shots, and gun round firings. In one five-week period, we worked only three days on a normal schedule and put in three extra Saturdays."

Normal weekly schedule at the range was four ten-hour days, but during 1982 the crew often arrived early from Las Vegas and stayed late to perform tests at sunrise and sunset when lighting conditions for photography were best. Support, technical, and security personnel from the contractors REECO, EG&G, and Advanced Security, put in similar long hours. Noting that the range was running nearly 300 tests annually, Wayne Lathrop observed, "Many would appear to be routine, but there are enough of the special requirements to keep us on our toes. For instance, last fall we tracked an air-launched cruise missile continuously for four hours around various check points on the range with pinpoint accuracy and instrumented its terminal functions. There were a lot of requirements for high speed photography and an urgency on the data reduction. It was an extremely successful test."

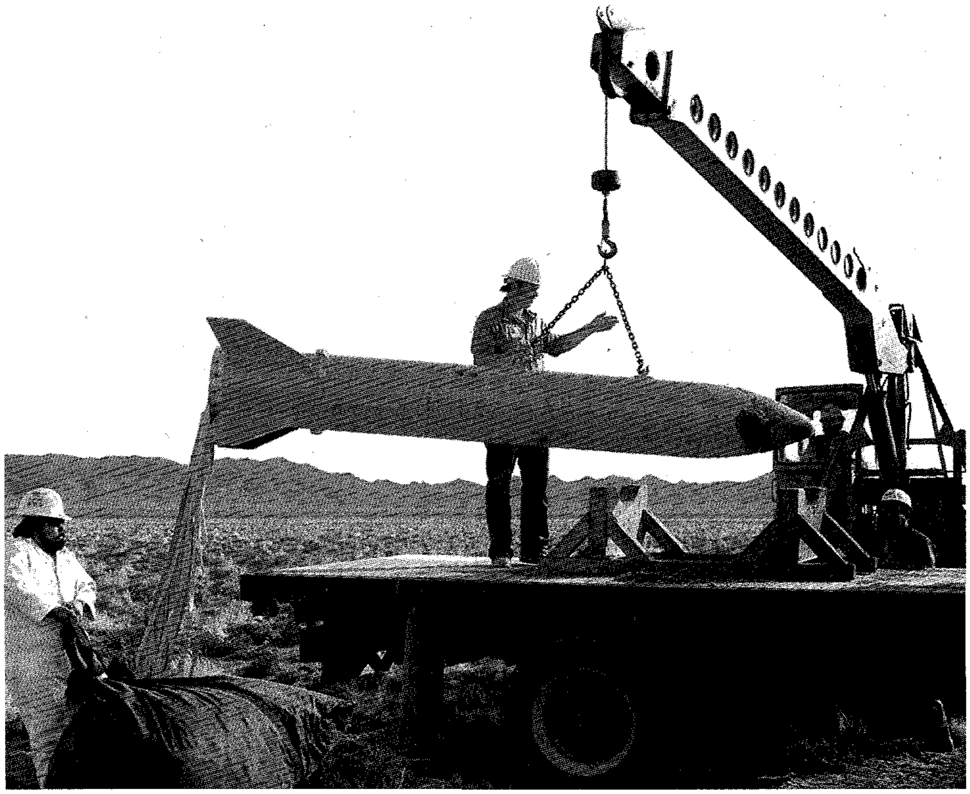
During the busy 1980s, Sandia vice president Orval Jones recalled that someone earlier had suggested that, given a tight budget, Tonopah Test Range was a luxury Sandia could do without. "But even in tight times, we need to keep our testing facilities intact," Jones said, "and, in hindsight, that turns out to have been a wise decision."



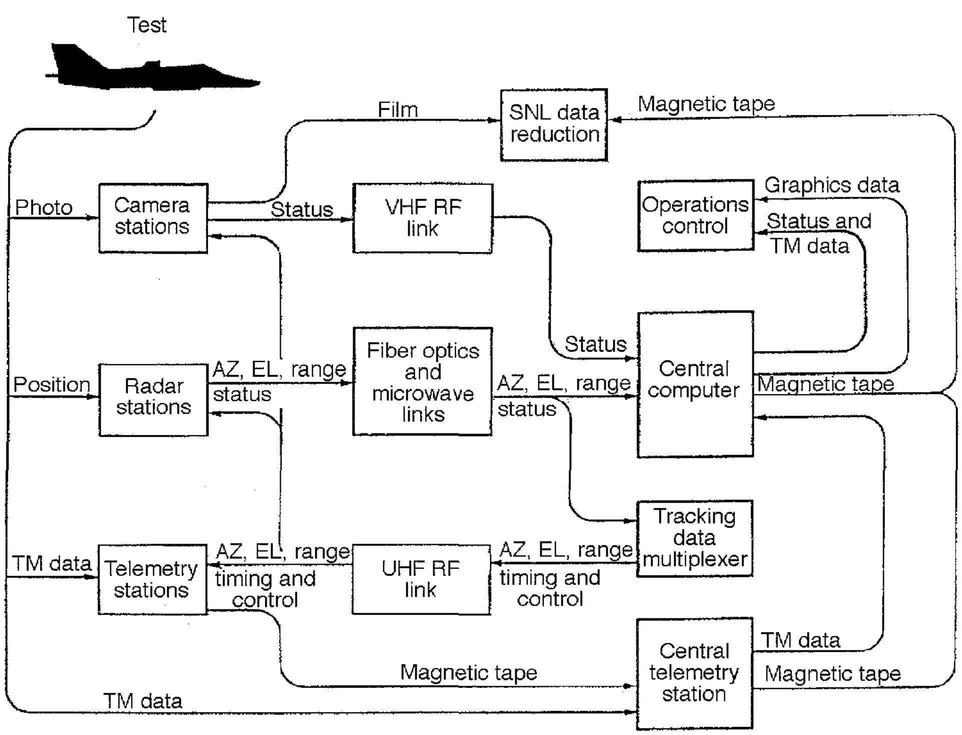
A 1983 Test drop of a B28 modification from a B52 aircraft at Tonopah.



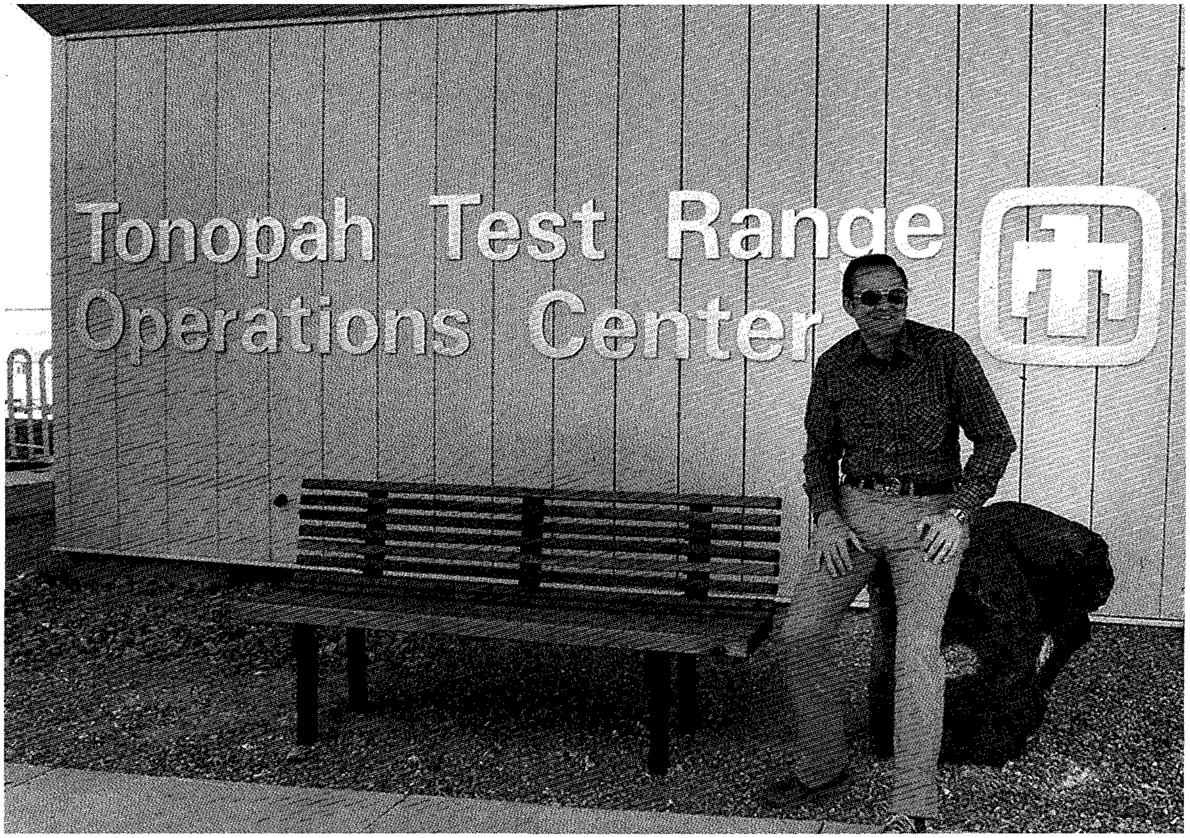
A laydown bomb hits the target at Tonopah Test Range.



Recovery of a laydown bomb and parachute at Tonopah Test Range.



Functional block diagram of a typical Tonopah Test Range for an air-drop test. Telemetry (TM); Elevation (EL); and Azimuth (AZ).



Range manager Ron Bentley in 1984.

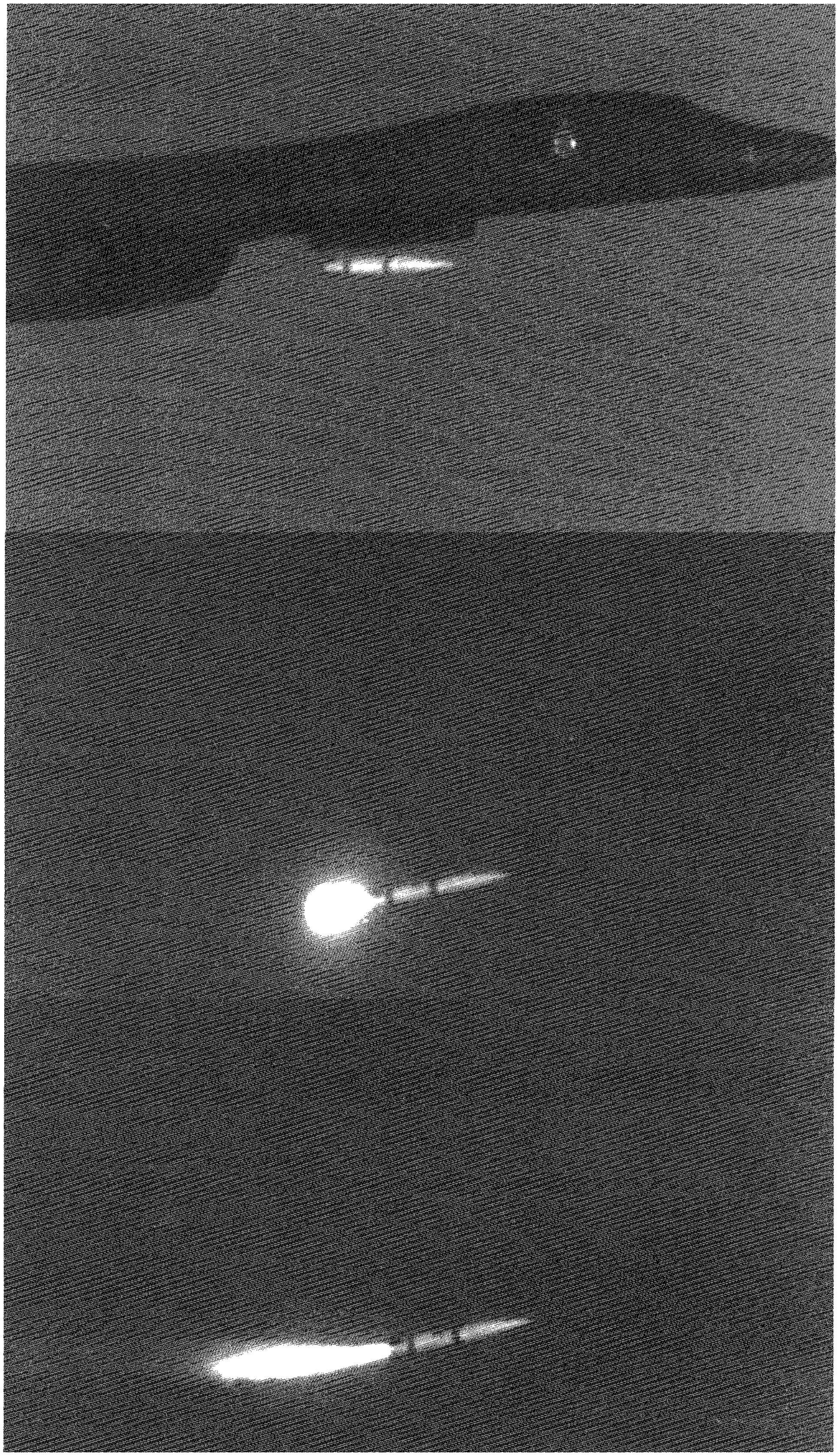
For the first time, Tonopah Test Range received the attention it deserved in November 1988. Hearing accounts of sightings of strange looking aircraft, reporters began nosing about to learn what was happening at the range in addition to testing. Some arranged distant views from the air and were surprised to find that the range's landing-strip had been extended to twice its original length; moreover, there seemed to be a newly built complex uphill from the test control center. Rumors flew. They ended in late 1988, when the Air Force opened doors on the hangars it had built on the range and rolled out the Stealth F-117 fighter planes that could elude radar detection. That day, the remote, isolated, unknown Tonopah Test Range became famous. Ironically, not for its thirty years of secret weapons testing for the Departments of Energy and Defense, but for its decade of Air Force use as the developmental testing range for the Stealth fighters.

According to the range crew, they had little to do with the secret Air Force program. The Stealth aircraft were flown mostly at night, when the crew was in Las Vegas. Ken Johnson, the range's communication expert, said that he and the range security force investigated crashes of Stealth planes on the range, but were forbidden to describe them off the range. When Johnson mentioned he had investigated an airplane crash, and someone asked what kind? His reply simply was: "Can't say." When visitors went to the range during the 1980s from Albuquerque or Livermore, they could not help but notice the large buildings clustered near the landing strip, but when they asked what the complex was, the range crew replied: "You don't see anything!" For their taciturnity, the Air Force commended the range crew, but it was a relief to the crew when the Air Force lifted the wraps from its new aircraft in 1988.

Another new weapon appeared on the range in 1988. The Army's Sergeant York automated air-defense guns that resembled armored tanks. When the Defense Department canceled the Sergeant York program, Cecil Lang learned the Navy had acquired a surplus York for the cost merely of shipping charges and was using it as a mobile target spotter. It had radar, laser range finders, and computers on board. Lang told Carl Smith, optical supervisor at Tonopah, of this, and Smith recruited Louise Bland to acquire a few Yorks for use as mobile tracking units and also for range security.

During 1988, the range crew conducted 293 tests, highlighted by launching missiles from a permanent test pad installed at the range in accordance with the Intermediate-range Nuclear Force (INF) treaty negotiated by Reagan and Gorbachev in 1986 to curtail the arms race. NATO sponsored multiple rocket tests using live charges to verify performance of a European designed fuze. In support of these efforts, the range acquired a new C-band radar that could be easily transported by vehicles.

When the Defense Department in 1988 approved development of a nuclear earth penetrator weapon, Sandia initiated its W61 Earth Penetrator Weapon, using components from the B61 bomb to reduce development costs and time. This program brought work for the range's Davis gun together with airdrops for testing ground penetration devices and notably for Tim Eklund and Don Stoner's data recovery system. The range crew repeatedly slammed this recording system, encased in ballistic projectiles, into Tonopah's ground and even its rocks at 1700 miles an hour. "Our biggest problem in designing the data-collection system was to find batteries that would survive the impact shock," Eklund said later. Other penetration tests at Tonopah were fired by a mobile 6-inch gas gun into Antelope Lake. The dry lakebed's uniform soil consistency allowed Mike Forrestal and the Advanced Munitions group to verify computer codes for analyzing shock-hardened projectiles during high-velocity earth penetrations. Probably the best known ground penetration testing at Tonopah occurred during the Persian Gulf War of 1990-91.



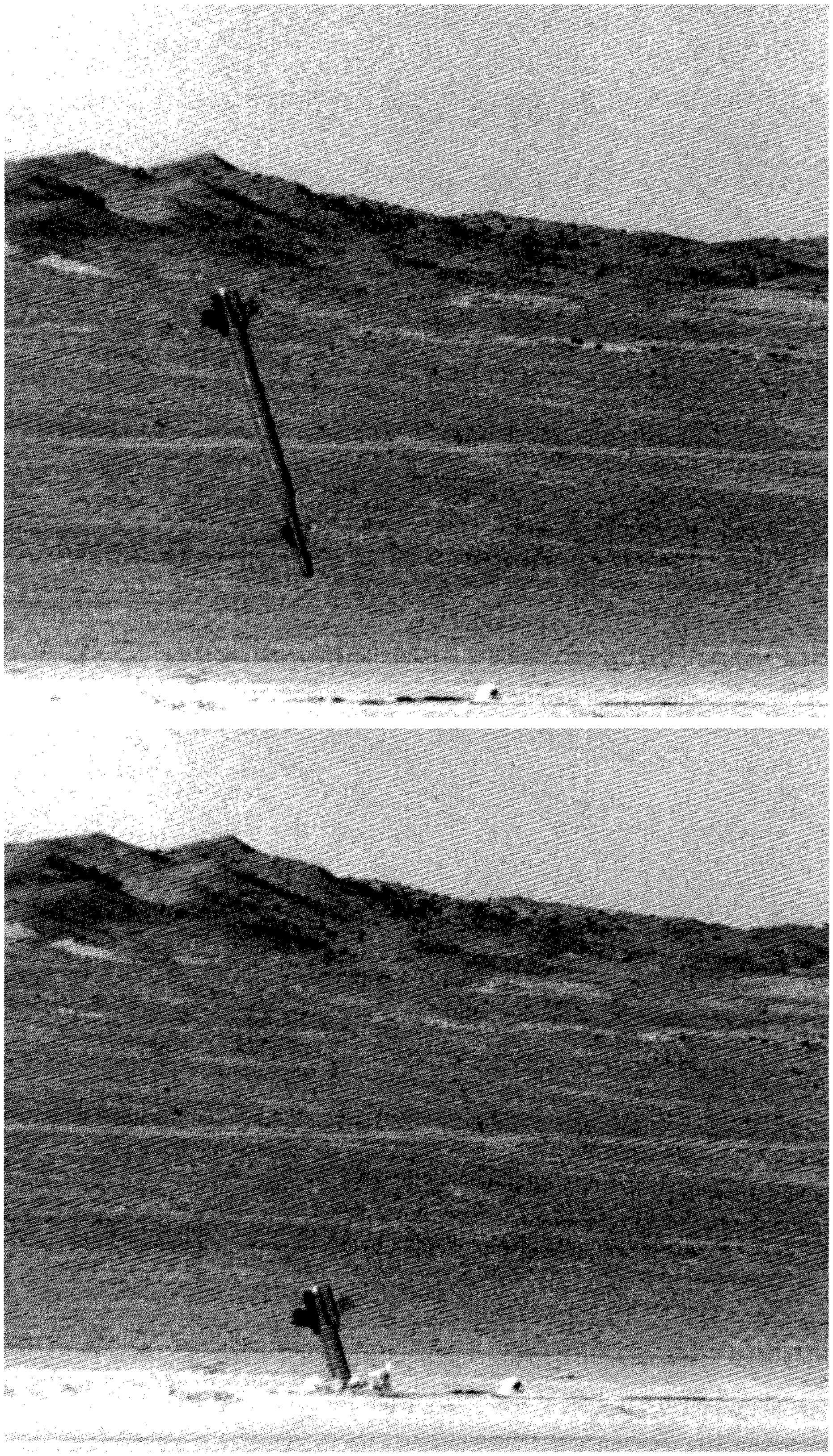
Short Range Attack Missile (SRAM)

Desert Storm

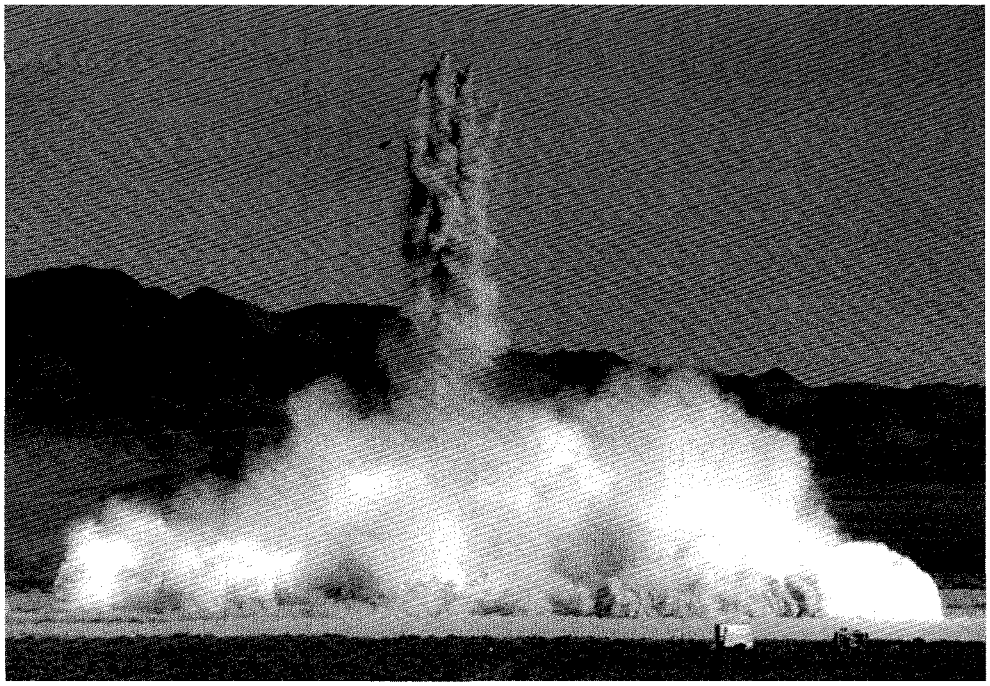
Tonopah Test Range could easily simulate the conditions to be encountered in the desert Middle East of Kuwait and Iraq, and as Operation Desert Shield began in 1990 the range's capabilities mobilized in support of the armed services. Mike Hightower and a Sandia team, for example, tested a 450-gallon propane fuel-air-explosive. This device could be sent on a remote-controlled vehicle to destroy buried land mines or to neutralize a defensive line.

As Desert Shield turned into Desert Storm in early 1991, the range received more requests for assistance, notably from the Air Force for testing a "bunker-buster." This was the GBU-28/B, a laser-guided penetrator bomb for use against deeply buried bunkers in Iraq. Test Director Ronald Bump noted that the Air Force, which was still improving the bomb, changed testing requirements several times as the program evolved—different altitudes, telemetry, and communications frequencies. For the test, the range crew set up an old concrete target surrounded by a 40-foot square, black-plastic tarpaulin. At sunrise on a cold February morning the "bunker buster" rammed into the target and drove so far into the ground that it could not be dug out with the range's equipment. Bump later received news that two of these bombs wiped out command bunkers in Iraq. He and Tonopah's testing team also received Air Force commendation for their cooperative flexibility during the tests.

Another Desert Storm-related test concerned the ability of Tomahawk missiles to follow a course to targets at night. Gary West, range operations supervisor at Tonopah, said the crew created an artificial desert town on the range for the tests by moving trailers and other structures into positions to simulate a town, complete with street lights. After night flights of more than an hour, the Tomahawks flew onto the range, recognized the "town," and fired a strobe light to indicate when they would have detonated in combat, as they did later in Kuwait and Iraq.



Tests on the "Bunker Buster" show the quick turnaround capabilities of TTR. Three days after this test, this bomb was successfully used in Desert Storm.



Fuel Air Explosion (FAE) Test: Five hundred gallons of propane was spilled onto the dry lake bed, mixed with the air, and ignited. This technique is used to detonate mines. Shortly after this test was completed, the procedure was used in Operation Desert Storm.

TTR is one of only three ranges in the country with ground launchers capable of launching the Tomahawk Cruise Missile.

Bittersweet Victory

At the peak of Desert Storm support programs, Tonopah Test Range was staffed by about 60 Sandians with contract support from 65 REECO employees, 20 EG&G technicians, and 65 Advanced Security guards and employees. Less than five years later, its staff had dwindled to about 20 Sandians and 25 contractor employees. This dramatic decline resulted largely from bittersweet victory in the Cold War.

As the development and testing of new nuclear weapons for potential Cold War use waned, Tonopah Test Range's future became an issue at Sandia. Without significant new nuclear weapons development programs, the essential services provided by Tonopah's facilities for the Department of Energy increasingly consisted of stockpile quality assurance—the JTAs. Its other testing activities were comprised of "work for others," principally the armed services, which funded only specific tests and not general range operations and maintenance overhead or capital improvements. For Sandia's management, funding Tonopah as a permanent installation competed with the needs of other programs, notably the environmental, safety, and health initiative of Admiral James Watkins, Secretary of Energy during the George Bush administration.

Under the Watkins' initiative, Sandia's environmental, safety, and health program expanded rapidly, and in 1989 the Department of Energy inventoried environmental hazards throughout the nuclear weapons complex. This inventory identified three significant hazards at Tonopah Test Range. A problem with leaking oil drums was simply solved by removing the oil, drums, and visibly contaminated soil for proper disposal. A leaching pit for the range's photographic processing laboratory contained contaminants such as silver that might threaten the range's water supply; the range eliminated future contamination by recovering silver from chemicals before they went into the leaching pit. The third problem of low-level plutonium contamination left from the 1963 Roller Coaster tests seemed less amenable to solution. The contaminated areas were double-fenced, posted, and monitored by security forces. Moreover, the range was off limits to the public. Of less immediate concern was an unlined landfill used until 1985 at the range, where wastes possibly could leach downward over time into ground water; because of the range's dry desert character and a water table 400 feet below ground surface, ground water contamination at the range seemed improbable.

The emphasis and increased funding for environmental, safety, and health programs corresponded with a decrease in defense funding. In 1988, 62% of Sandia's budget came from defense programs; five years later, only 53% came from defense programs and the percentage was predicted to decline in the future. Sandia enjoyed many research challenges in addition to defense programs, but in the 1990s it was having difficulty moving personnel from the traditional defense programs into new program opportunities.

"Certainly, there's a natural desire to hold on to what's been in place, what's familiar," admitted Orval Jones, Sandia's vice president, "but we're simply going to have to break with that feeling. We have to make significant shifts of people to different programs. That's going to require Sandians to be flexible, open-minded, willing to reeducate themselves, and willing to work in new areas." President Al Narath agreed with Jones and remarked that for many Sandians formerly leading the weapons development and testing programs, American victory in the Cold War was a "bittersweet" success.

Management's decision was to return the test range to the "campaign mode" under which it had first operated during the 1950s. A small staff remaining on the range would maintain the facilities and conduct routine tests, and during larger test series they would be joined by teams sent from Albuquerque and Livermore for the campaigns.

"Tonopah Test Range is in transition from being a full-time test facility to operating in a campaign mode," explained Sandia vice president Glen Cheney early in 1993. "The ES&H team working these issues is concentrating on the operating attributes needed at TTR so testing can be done safely and in compliance with laws and regulations...including the new DOE Radiation Control Manual, explosive and electrical safety, disposal of waste streams, and proper use and control of toxic and hazardous materials."

Kathleen McCaughey, who served on the environmental, safety, and health team inspecting Tonopah, returned in 1992 as site manager to team with the four on-site managers—Bob Beasley, Wayne Lathrop, Carl Smith, and Dan Finnegan—in a program redirection forced by major cuts in revenue. Management in 1993 reduced indirect funding for the range from $12.8 million to $7.2 million, and another $4.8 million reduction came in 1994. Moreover, the Air Force moved its Stealth fighter command from Tonopah Test Range to Holloman Air Force Base at White Sands; it mothballed its base at Tonopah and no longer shared in costs nor performed waste management functions. These reductions made it necessary for McCaughey and the Tonopah managers to reduce operational costs by $10 million annually, or face total closure of the range.

Kathleen McCaughey managed Tonopah Test range in 1992 - 1993.

The managers accomplished the necessary reduction by several expedients. First, they achieved better understanding and control of every cost of doing business at the range in order to implement reductions at every level. They rebuilt relationships with the administrative and environment, safety, and health support offices in Albuquerque in order to obtain their services, rather than attempting to administer these programs internally. The contract for support services at the range, formerly provided by integrated contractors REECO and Raytheon went to competitive bids and was awarded to KMI on a reduced effort basis. At the cost of an additional hour or more in daily commuting time from Las Vegas, the range gave up the DC-9 jet plane in exchange for a slower, more economical propeller-driven aircraft.

Finally, and most traumatically, they switched to the campaign mode of test operations. This meant keeping a range crew only large enough to maintain equipment and support small tests, while additional staff came from Albuquerque to undertake larger and more complex testing. This change disrupted the lives of most of the range crew. Younger technicians transferred to Albuquerque, Livermore, or elsewhere, often to start new careers. Some older technicians retired, including Lloyd Young, the last of the original crew that had transferred from Salton Sea to Tonopah during the 1950s. For these, and for range managers, 1993 was to be remembered as a year of great pain.

Wayne Lathrop in 1994 and Vernon Gabbard in 1995-1996 served as Tonopah range managers in charge of a reduced crew while management debated the range's future. Thinking the range critical to fulfilling its missions, Sandia's Defense Program sector committed in 1994 to continued use of the range in the campaign operational mode for at least three years. Late that year, however, Bob Nelson of the DOE Nevada office agreed to pay for institutional costs including transfer of the range from the DOE Albuquerque office. The Nevada office expected to use the range in the future for the existing weapons testing program and also for a new role in counterproliferation. The transfer occurred on December 12, 1995, and the range continued operations.

As during the previous third of a century, the range crew gathered early each morning in Las Vegas to board the aircraft and commute to Tonopah, some still keeping track of the millions of miles flown in the service. At the range, flexibility became the key to test performance. During tests, clerical personnel might become camera operators. Whatever needed doing was done. At the end of their ten-hour days, they boarded the aircraft, sometimes pondering the range's future as they returned to Las Vegas and their families.

The wilderness and solitary place shall be glad for them;
and the desert shall rejoice, and blossom as the rose.
Isaiah, 755 BC

Observations

The future of Tonopah Test Range is self evident, because the future has no place to come from but the past; hence, the past has predictive value. Whether by management decision sooner, or by evolutionary changes in weapons technology later, testing at the range will cease. Abandoned defense facilities found throughout the United States and the world mutely testify to this. Consider the Army's 19th century forts in the United States, or the medieval castles of Europe.

When the Department of Energy abandons its lease, the range property will revert to the US Air Force, or its successors in charge of the bombing range from which the test range was originally carved. Already mothballed, the fate of the Air Force Stealth fighter base on the range seems evident as well. Unless another use for the base is found, in time it will be closed and scrapped. Management of the range land will pass eventually from the Air Force to another federal agency, probably the Bureau of Land Management or its successors.

In a century or less, historians will recognize the significant contributions by the Tonopah Test Range and its crew to concluding the Cold War peacefully. Its role in deploying the nuclear weapons that deterred aggressor nations along with its role in testing conventional weapons used in the Vietnam, Persian Gulf, and other conflicts will become subjects of major historical and public interest. In brief, the range will in a century take on the trappings of a historic site resembling the frontier fortifications managed by the National Park Service during the 20th century. Or perhaps a more appropriate parallel might be Harpers Ferry Arsenal in West Virginia, the center of Union Army weapons development in 1861 and now a superb public educational attraction.

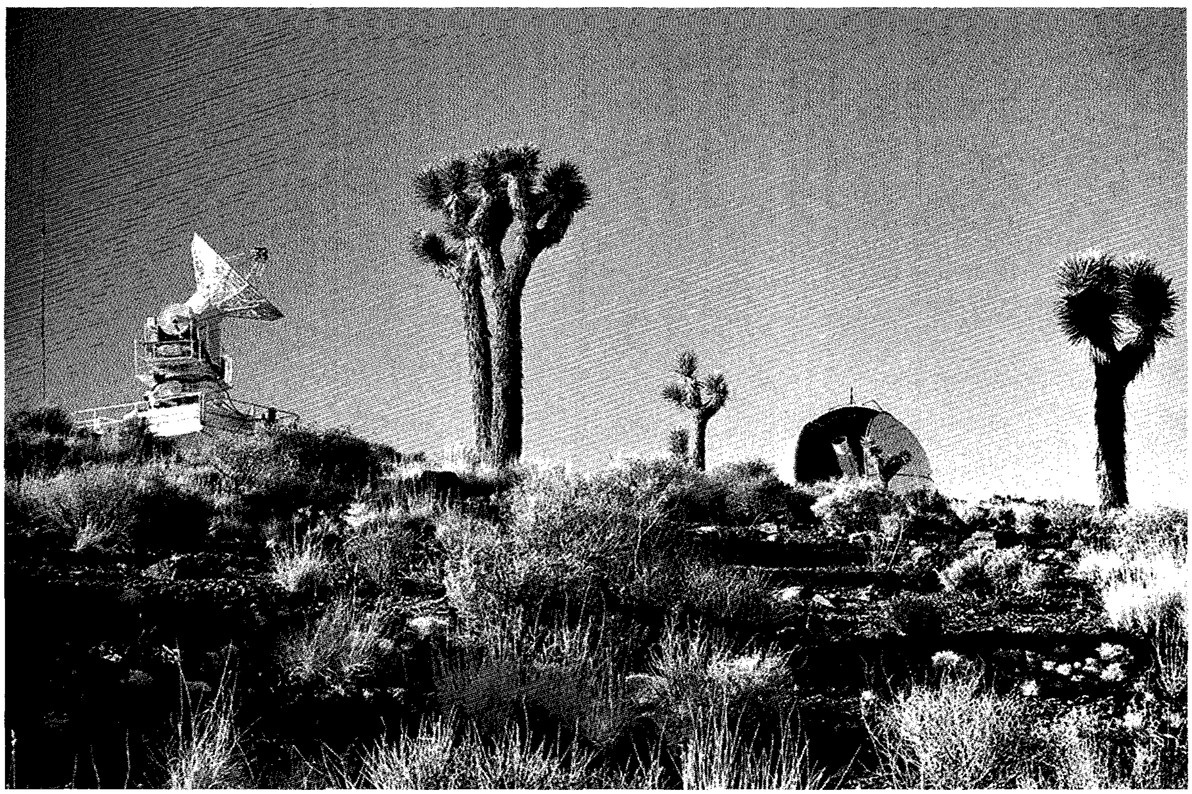
Historians of the 21st century will study range operations and personnel tomorrow as they do 19th century forts today. It therefore becomes imperative for Sandia to archive and preserve all documents pertaining to Tonopah Test Range as a public trust.

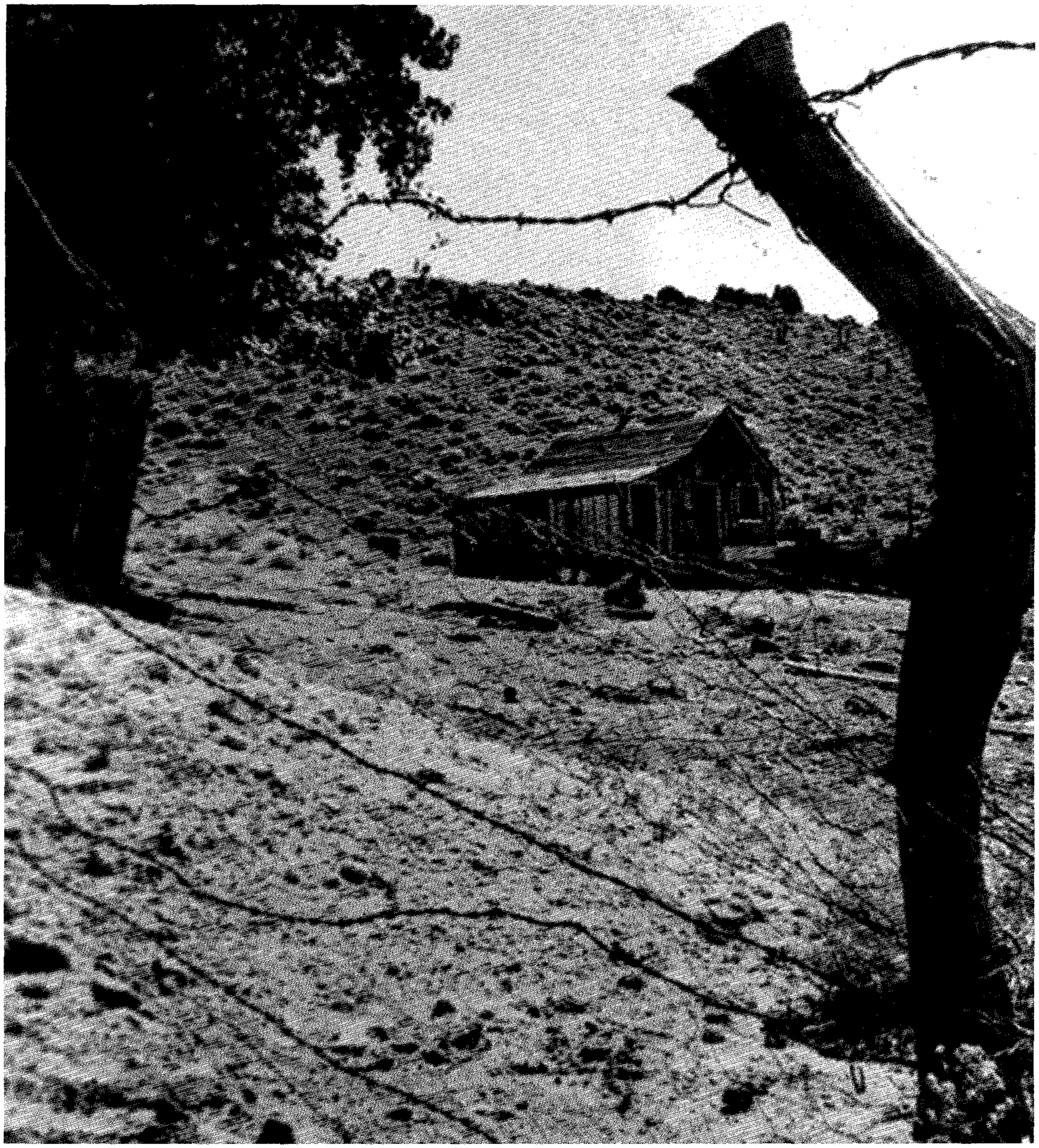
For educating the 21st century public about the Cold War services of Tonopah Test Range to national defense during the 20th, preservation of certain structures at the range becomes desirable. Some existing structures are perishable and will be removed in time by wind and weathering, if not removed for salvage after Sandia discontinues their use. Concrete and steel foundations and structures, underground bunkers, and earth-filled silos that supported tracking equipment will remain intact, however, for centuries unless deliberately destroyed. Their historical future must be considered when the time comes to dispose of these structures and equipment.

Preservation of obsolete equipment should be considered as well. Items such as the Askania and Contraves cinetheodolites should be offered to the National Atomic Museum, the Smithsonian, or other public institutions that preserve the artifacts of historical technology.

In addition, there are homestead ranches, mines and mine equipment, and other artifacts abandoned on the range periphery during the 1930s. These remnants of Nevada's early history are potentially eligible for the National Historic Register at present, and in a few years the entire test range could receive designation as a site significant to national history.

As the home of pioneer Nevada enterprises, of the secret Stealth aircraft development, of the Tonopah Test Range, the range has considerable potential for future development as a historic site. With ample water supply from existing wells and a novel fierce beauty all its own, the range can become a worthwhile public educational attraction—in a century or less. Futurologists can conceive of the public, perhaps transported in Maglev vehicles, following an Atomic Trail from Sandia and Los Alamos to Las Vegas to Nevada Test Site, Tonopah Test Range, and on to Livermore in the year 2096. Such predictions, however, are beyond the purview of historians.





Vacant since the Depression, the ruins of a few houses owned by miners and ranchers are seen around Tonopah Test Range.

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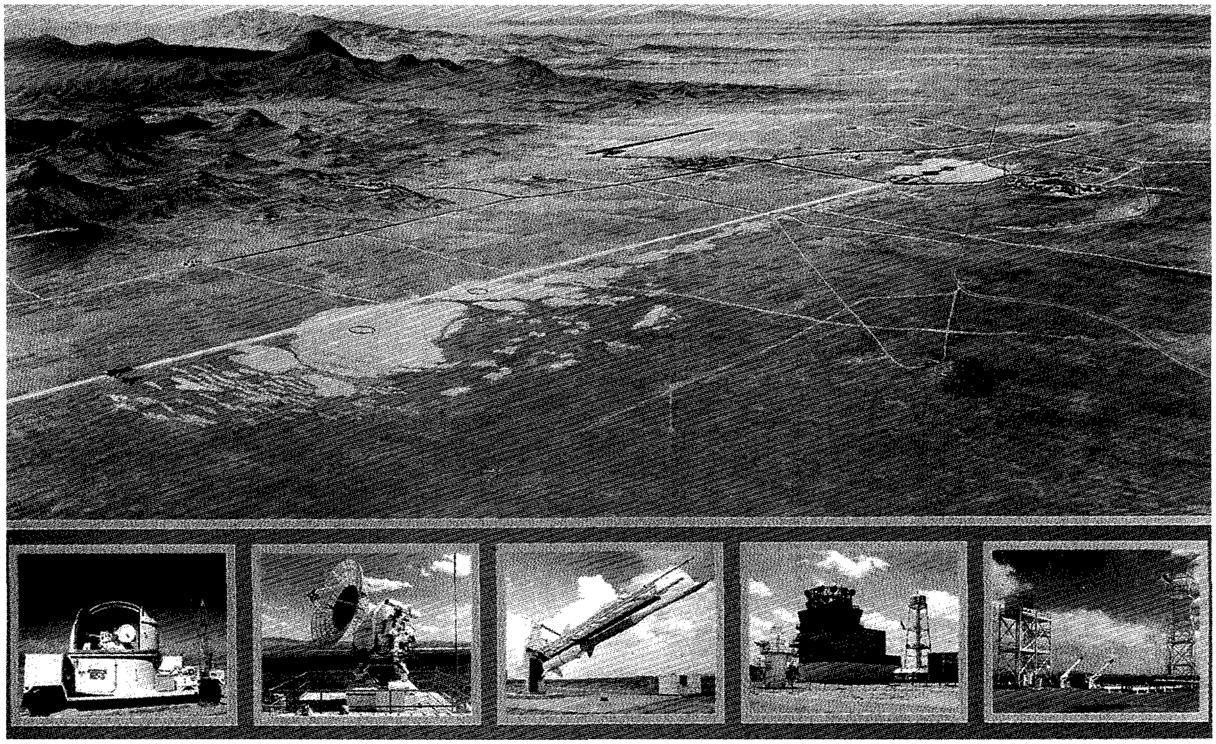
APPENDIX
Tonopah Test Range Managers

1959-1960	ALLAN P. GRUER
1960-1964	ROBERT D. STATLER
1964-1965	RICHARD N. BROWNE
1965-1967	RAY L. BRIN
1967-1983	SAM A. MOORE
1984-1992	RONALD BENTLEY
1992-1993	KATHLEEN MCCAUGHEY
1993-1994	L. WAYNE LATHROP
1994-	VERNON GABBARD, JR.



Tonopah Test Range and Conduct of Operations Management in May 1995

Tonopah Test Range

Vernon Gabbard, Jr., Mgr.
Joe Dykes, Team Supervisor
Judy A. Ripley
Lori J. Chavez
Dennis S. Adkins
Donald F. Anderson
James A. Enlow
Karl S. Hess
Kenneth E. Johnson
Gerald H. McCorkle
Kendall L. Mulkey
Harold D. Smith
Robbie W. Smith
Roger A. Smith
Daniel J. Tebbs
Richard L. Williams
Robert R. Beasley
William D. Love
Tex E. Samuelson
Robert C. Sherwood
Michael C. Sypchala
Roger Goode
Joe Miller
Roland Phillips
Bernie Cardell
Marilyn Taylor
Bernadette Schultz

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