White Sands Missile Range,
V-2 Rocket Facilities
Vicinity of WSMR Headquarters Area
Dona Ana and Otero Counties
New Mexico

HAER No. NM-1B

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HISTORIC AMERICAN ENGINEERING RECORD

WHITE SANDS MISSILE RANGE
V-2 ROCKET FACILITIES

HAER No. NM-1B

Location:	White Sands Missile Range Dona Ana and Otero Counties, New Mexico UTM: Missile Assembly Building 1: 13.361600.3583300 Blockhouse, Launch Complex 33: 13.370400.3585500 100K Static Test Stand: 13.360850.3581200 500 K Static Test Stand: 13.361900.3580050 Quads: White Sands, Davies Tank (USGS 7.5 minute series)
Date of Construction:	1945-1952
Present Owner and Occupant:	U.S. Army
Present Use:	Part of rocket and missile testing range
Significance:	The development of the large liquid fueled rocket, which has profoundly affected events in the twentieth century, was initiated by the Germans in the 1930s and, after World War II, continued by the United States at White Sands Proving Ground (now White Sands Missile Range). In all, 67 V-2 rockets were assembled and tested at White Sands between 1946 and 1952, providing the U.S. invaluable experience in the assembly, pre-flight testing, handling, fueling, launching, and tracking of large missiles. In the late 1940s, several V-2s were combined with a smaller rocket, the WAC Corporal, to become the first large, multi-stage rockets to be launched in the Western Hemisphere. Additionally, scientific experiments conducted in conjunction with the V-2 program yielded significant information about the upper atmosphere and other areas of research, including the effects of space on mammals.
Historian:	Michael C. Quinn, July 1986

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Chapter 1

EARLY ROCKETRY AND THE IMPACT OF THE V-2

The development of the large liquid fueled rocket has profoundly affected events of the twentieth century. As a radically new delivery system, the large rocket made space flight possible and, paired with the simultaneously developed atomic bomb, recast the dynamics of international relations. It provided a propulsion system that could break free of the earth, taking humanity into space, and breach the ocean barriers that had historically protected the United States. While the U.S. was the first to develop the atomic bomb, Germany was the first to produce a large liquid fueled rocket, bringing it forcibly to world attention in 1944 by launching it, as Vengeance Weapon-2 (V-2), against London and Antwerp.

In the closing days of the war, the U.S. military embarked upon its own rocket development program and established White Sands Proving Ground (now White Sands Missile Range) in New Mexico as its principal site for rocket testing and development. Soon after, with victory in Europe, the U.S. successfully appropriated the German rocket program, sending to White Sands 20 newly hired German scientists and enough captured rocket parts, equipment, and research data to build and launch 67 V-2s. Over the next four years a slow incubation took place. America's initial interest in large rockets waned with its victory over Japan, a seeming monopoly on nuclear weapons, and a greater awareness of the limitations of the V-2. But work continued at White Sands, laying the theoretical and practical foundation for an extensive

American rocket program. The technical concepts and skills that would later create an ongoing arms race with the Soviets and land men on the moon were nurtured and advanced during this period.

Serious experimentation with liquid fueled rockets had begun almost simultaneously in Russia, the United States, and Germany in the opening decades of the twentieth century. In all three countries, initial work was conducted by both amateurs and scientists, largely working independently of one another and without governmental involvement. Inspired by the science fiction fantasies of Edgar Rice Burroughs and Jules Verne, these rocket pioneers hoped to develop a new means of transportation that ultimately would lead to the exploration of outer space.

A Russian mathematician, Konstantin Tsiolkovsky, probably first understood the advantages of liquid fueled rocket motors. (For a discussion of these advantages, and some of the technical difficulties encountered in developing the V-2, see Appendix A.) Tsiolkovsky developed his theories in the 1880s, publishing them in 1903.[1] While he may have been the first rocket theorist, his work did not reach his counterparts in Germany and the U.S. Rather, each country's rocket pioneers independently investigated the advantages of liquid fueled motors and initiated efforts along parallel lines.

In Russia, rocket experiments were halted by the Revolution of 1917, but the new Socialist state soon subsidized rocket research as part of an effort to achieve technological dominance and improve its capability for self defense. By 1929 the first Russian liquid fueled rocket motor was built and tested.

Stalin's purges in the 1930s so wracked Soviet institutions that further development ceased, but theoretical work continued. While the Soviet Union appeared to have limited technical abilities, it had in fact laid the foundations for its phenomenal successes in the 1950s and early 1960s, particularly in being the first to put man in space.[2]

Robert Hutchings Goddard dominated early rocket experiments in the U.S., developing the liquid fueled rocket further and more quickly than any of his counterparts in other countries. He launched the world's first liquid fueled rocket in 1926 in Auburn, Massachusetts, and continued his work through the 1930s in the less populous area of Roswell, New Mexico, not far from where White Sands Missile Range would later be established. Goddard anticipated many technical innovations that would be used in the V-2 and, later, in even more advanced rockets. But his work had little impact; Goddard shunned publicity and made his research known only to a small scientific community. It appears that he also ignored advances by his contemporaries in Germany. In World War II, Goddard helped produce and develop solid fueled rocket boosters to assist Navy airplanes during takeoff. He died in August 1945, just as the U.S. military turned to German experts to lead its rocket program.[3]

In Germany, rocket enthusiasts worked in groups, or societies, the foremost society of which was the Verein fur Raumschiffahrt (VfR), formed in Berlin in 1927. Its membership, which quickly numbered nearly a thousand, funded and assisted the experiments of a core group of engineers and scientists.[4] In 1931, the VfR launched its first liquid fueled rocket, attracting the interest

of the rearming German Army.[5] Banned by the Treaty of Versailles from building the large siege guns that had helped make its forces so overwhelming in World War I, the Army saw the rocket as a substitute weapon. Self-propelled rockets--even the VfR's small experimental ones--appeared to be the answer to the search for a powerful artillery weapon that was not prohibited by the treaty. Germany soon openly violated the Versailles treaty, but by then its Army had developed a lasting interest in rocketry.

The VfR, however, refused to cooperate with the German Army's militaristic plans. Organized to prove that "the planets were within the reach of humanity," the VfR spurned the Army's requests for secrecy and rigorous development in favor of public launches that would serve to increase its membership.[6] The two never cooperated, but the Army hired away the VfR's most proficient experimenters, among them Wernher von Braun, who in 1932 became the Army's chief rocket scientist. The VfR collapsed in early 1934.[7]

Adoption by the Army enormously accelerated the development of Germany's rocket technology. In 1935, scientists who had been scrounging for money a few years before received a budget of 11 million marks, hired hundreds of researchers, engineers, and mechanics, and began building a major research center and rocket range at Peenemunde on the Baltic.[8] A year later the German Army set its goals for the rocket that later became the V-2: it was to be more than twice as powerful as the largest siege gun; capable of delivering a warhead of 1,000 kilograms a distance of 260 kilometers, with 50 percent of shots landing within a two kilometer radius of the target; and of a size that could negotiate the tunnels and track curvatures of the German

railway system.[9] Three years later, in the summer of 1939, a scaled down prototype designated the A-3 was successfully launched. But the Army delayed development and production of the full scale rocket as early military victories made it appear unnecessary. Later, however, as defeats mounted, Hitler would seize upon the rocket as a miracle weapon to save his Reich.

The decision to begin V-2 production, not made until 1942, required overcoming enormous difficulties. While experimental needs could be satisfied by hand-built prototypes, war required mass production. A completely new weapon had to be manufactured, a field launching means had to be developed, and troops had to be trained to service and fire it. Hitler demanded 3,000 rockets a year, exacerbating these problems.

Allied forces bombed the first V-2 factory, an above-ground facility, in August 1943, before production had begun.[10] A complex of tunnels in the Harz mountains, near Nordhausen, was selected as a new manufacturing center and named Mittlewerk. The SS provided manual labor, setting up one of its more notorious concentration camps, "Dora," where ultimately about 20,000 prisoners died from brutal conditions.[11] By January 1944, the first V-2s were being produced and sent to Blizna, Poland, for trial firing for the development of range tables. The V-2 became operational in September, but by this time, the war was all but lost; nevertheless, Mittelwerk manufactured more than 600 V-2s a month from September through February 1945, producing 5,947 by war's end.[12]

The V-2 had virtually no impact on the outcome of World War II. But it had enormous repercussions in the military and intelligence communities of the Allies. The V-2 could not be defended against; none was intercepted after launch, and in fact, few were detected before impact. Of equal importance, Germany demonstrated that the liquid fueled rocket could be mass produced and that field troops could successfully prepare and launch it. The United States, Soviet Union, France, and England all realized that this new weapon would reshape future wars, but not in ways that Germany planned. No longer did the military look on the rocket as an alternative to siege guns, but instead as a potent battlefield weapon against tanks, airplanes, and ships. An even more ominous possibility became apparent on August 5, 1945, when the explosion of an atomic bomb over Hiroshima annihilated an entire city.

The German rocket development team, led by Wernher von Braun, made their way to the American forces in May 1945 and surrendered. Although the Allies competed intensely for rocket spoils, the U.S. seized the lion's share, gaining in addition to the V-2's research engineers all of Germany's research documents and hundreds of tons of rocket parts. The Soviet Union captured the Mittelwerk factory at Nordhousen and its lower-level production engineers. Just as V-2s would soon be flying over the desert of New Mexico, they would also be launched over the steppes of Russia as both countries strove to absorb the new weapon's technology.

Earlier and quite independently, the American Army had begun work on establishing a land range that would permit safe testing, launching, monitoring,

and recovery of long range rockets. After reviewing a number of sites, the Army selected a large area around White Sands National Monument in New Mexico in late 1944. The site's isolation, topography, and dry, cloudless climate were nearly ideal. In February 1945, the Army ordered the consolidation of the existing military ranges, national parks, and private lands within the site's boundaries.[13] By this time Germany's defeat was imminent, but few military planners realized that war with Japan would also end soon. Most were preparing for a lengthy and costly conflict that might be shortened by the use of rockets. The Corps of Engineers began construction at White Sands in late June 1945, and V-2 materiel arrived a month later. On a remote site of the proving ground an apparently unrelated test took place the same month: the July 16th explosion of the world's first atomic bomb at Trinity Site.

The concentrated impetus to develop rockets abruptly ended on August 14th with Japan's surrender. The American rocket program continued, perhaps neglected in the jubilation and disorder of sudden peace and demobilization. But within a year, the Army's large rocket program became one without a clear purpose. This attitude towards large rockets was expressed in an Army memorandum of June 1947 that assessed the future of a rocket such as the V-2.[14] It noted the following drawbacks of the V-2: 1) while its accuracy (within 1% of range) was good by artillery standards, at 200 miles the rocket could be off target by as much as two miles; 2) its payload was small, less than one-tenth that of a bomber, making the rocket's inaccuracy intolerable; and 3) the rocket itself was extremely expensive. The memorandum concluded

that the only suitable use for large rockets was for the delivery of atomic weapons. But the 1947 atomic bomb was massive, requiring a rocket eight to ten times larger than a V-2. With exclusive possession of the bomb and with existing aircraft able to deliver it, the Army saw no reason to embark on such an expensive rocketry program. The Soviet Union, faced with much the same choice, made the opposite decision and began developing massive rockets that would not only deliver atomic bombs but would eventually give it the capability to put the first man into earth orbit.

German scientists and engineers had begun arriving at Ft. Bliss, Texas, in October 1945, and by February 1946 the 124-man German rocket development team had been reunited. About 20 went on to White Sands to assist in the assembly, testing, and launching of the captured V-2s, while the balance remained at Ft. Bliss, ostensibly to develop new rockets. But the Army's interest in rockets had already waned, and the German team's hopes of developing rockets for manned space exploration appeared frustrated. Over the next four years it assisted in the launch of about sixty V-2s, hardly more than would have been launched in one or two months at Peenemunde. Not until early 1950 when the German team was transferred to Redstone Arsenal in Huntsville, Alabama to begin the development of the Redstone rocket would their hopes be revived.

Yet the V-2 program was of seminal importance to the United States. Though dwarfed by Germany's wartime effort, it initiated America's rocket program and directly foretold its space program. At the most immediate level, it

transferred the knowledge developed by years of German research to the U.S., providing America with its first direct experience in assembling, manufacturing, and launching large liquid fueled rockets.

During their years at White Sands and Ft. Bliss, the German engineers visited American manufacturers and lectured on the technical aspects of rockets. Virtually all remained in rocket engineering through the 1970s, most with the military or the National Aeronautics and Space Administration, with a few joining companies that manufactured equipment for the rocket program. And while the Germans regarded their time in New Mexico as one of forced inactivity, it was an important incubation period for ideas, particularly those dealing with staged rockets and the question of human survival in space.

Staged rockets had been postulated by theoreticians as the most feasible means of attaining high altitudes, earth orbit, and even escape velocity. In a staged rocket, two or more rockets are combined, one atop the other, and fired in sequence. With each firing the heavy mass of the previous stage's motor, tanks, and other equipment is shed, greatly reducing the overall energy needed to overcome earth's gravity. The efficiency of staging more than offsets the added weight of duplicating the rocket system in each stage.

In the late 1940s, however, the technical problems of ground launch were just being mastered. No one was sure that a second stage launch could be accomplished by remote control and with the precise timing required to realize the efficiencies of staging. The Army began to confront these technical problems in 1948 through a series of experiments known as "Project

Bumper." In the Bumper experiments the payload section of a V-2 was fitted with the WAC Corporal, a smaller liquid fueled rocket. After the V-2 was launched and had attained maximum velocity, the Corporal was fired. Eight V-2s were modified for Project Bumper, three of which were unconditional successes, demonstrating that the technical problems of staged launches could be overcome. The Bumper flight of February 24, 1949 reached an altitude of 250 miles, nearly twice that attainable by a V-2 alone. Because the Army wanted to test the maximum range of the Bumper V-2, which far exceeded the length of White Sands, several were launched across the Atlantic from an isolated point in Florida known as Cape Canaveral, inaugurating what later became the Cape Canaveral Space Center.[15]

Other Army experiments investigated the question of whether life could survive the weightlessness and radiation of space. Initial experiments began with plants and seeds, but rapidly advanced to sending animals--first a mouse, then a monkey--aloft. All the animals survived outer space apparently unharmed, although none survived reentry impact. But the experiments indicated that, properly protected, humans would not be harmed in space and thus could undertake its exploration.[16]

By a combination of such experiments, the basic concepts of the U.S. space program were developed in the V-2 launches. While enormous technical problems of space travel remained, the task was more one of executing the mechanics of rocket flight than testing theories. The large Saturn rockets that would eventually boost the Apollo into moon orbit were direct descendants of the V-2, different principally in scale and refinement.

The V-2 program also demonstrated the value of research even when its benefits could not be anticipated. Even though the Army's interest had centered on gaining experience in handling large rockets, it found that the V-2 provided an unprecedented opportunity to explore the upper atmosphere. The first dozen or so launches did little more than provide handling experience, but later flights carried simple instruments for measuring the temperature of the upper atmosphere and determining radiation levels outside the atmosphere. In January 1947, the Army established the V-2 Upper Atmosphere Research Panel, composed of civilian scientists, to direct and select experiments to be carried in the V-2.[17] The number and sophistication of scientific experiments accelerated rapidly. "Mapping" of the upper atmosphere began, with the documentation of its different layers, their gaseous composition, and their temperature, humidity, and wind characteristics. Detailed analysis of the sun was also undertaken, with special equipment sent above earth's atmosphere to take direct solar measurements. Such experiments enormously enriched scientific understanding of the earth and solar system.

Notes

1. Wernher Von Braun and Frederick I. Ordway III, The Rocket's Red Glare (Garden City, NY: Anchor Press/Doubleday, 1976), p. 124.

2. Walter A. McDougall, ...The Heavens and the Earth: A Political History of the Space Age (New York: Basic Books, Inc., 1985), pp. 35-37.

3. Willy Ley, Rockets, Missiles, and Men in Space (New York: The Viking Press, 1968), pp. 23-31.

4. Frederick I. Ordway III and Mitchell R. Sharpe, The Rocket Team (New York: Thomas Y. Crowell, Publishers, 1976), p. 12.

5. Von Braun and Ordway, Rocket's Red Glare, p. 134.

6. Ley, Rockets, Missiles, p. 108.

7. Ibid., p. 148.

8. Ordway and Sharpe, Rocket Team, p. 25 and Von Braun and Ordway, Rocket's Red Glare, p. 143.

9. Ordway and Sharpe, Rocket Team, p. 28.

10. Von Braun and Ordway, Rocket's Red Glare, p. 148.

11. Gregory P. Kennedy, Vengeance Weapon 2: The V-2 Guided Weapon (Washington, D.C.: Smithsonian Institution Press, 1983), p. 24.

12. Ibid., pp. 26 and 27.

13. Eunice Brown et al, White Sands History: Range Buildings and Early Missile Testing (White Sands Public Affairs Office, partial reproduction of a 1959 historical report, no date), p. 16.

14. Wernher Von Braun and Frederick I. Ordway III, History of Rocketry and Space Travel (third rev. ed.: New York: Thomas Y. Crowell Co., 1975), p. 122. The memo was entitled "Operational Requirements for Guided Missiles."

15. Brown, White Sands, pp. 89-95 and Herbert Karsch, interview of January 1976.

16. Brown, White Sands, pp. 83-89.

17. Von Braun and Ordway, History of Rocketry, p. 123.

Chapter 2

WHITE SANDS HEADQUARTERS

Background

The Headquarters area (also called the cantonment area in reports of the period) at the early White Sands Proving Ground served as the center of all rocket development and test operations except static firing and launching. It contained housing for troops and officers assigned to White Sands, administration and related operations buildings, and facilities for assembling rockets. Eventually Headquarters area became a small town, housing civilians as well as military personnel, with a church, school, and hospital, all bearing the name "White Sands."

The order establishing the Proving Ground in 1945 envisioned it as a temporary facility, probably to be deactivated following victory over Japan.[1] Early structures reflected this impermanent vision, and consisted of portable quarters made of plywood and hangars and other buildings scavanged from nearby military installations. Not until September 1948 did the Army upgrade the status of White Sands to a permanent facility.[2] A fairly extensive reconstruction followed, with more substantial buildings replacing temporary buildings and quarters.

Structures

A site plan for Headquarters was prepared in Washington, D.C. during April and May 1945.[3] The Corps of Engineers received the plans in its District

Office in Albuquerque, New Mexico, in mid-June, and construction began on June 25, 1945.[4]

Headquarters was sited south of the White Sands-El Paso highway in the southwestern corner of the Proving Grounds (see HAER drawing NM-1B, Sheet 1). One of the first construction activities was obtaining an adequate supply of water. The Corps drilled a half-dozen shallow wells south and east of the Headquarters area to provide drinking water until more reliable deep wells could be sunk. Water for mixing concrete and other construction was pumped from several abandoned mines in the mountains that had by then flooded.[5]

The Headquarters area was divided into quadrants, each holding specific operations that could be expanded outward from the center. The northeast quadrant was used for troop quarters and administration; the southeast for warehouses, some industrial, maintenance, and supply buildings, and a motor pool; the southwest for missile assembly; and the northwest for officers and civilian quarters.[6]

A large number of Dallas hutments--small portable houses, each 16 feet square and made of plywood--were erected in the northeast quadrant for the troops. Each hutment housed three men.[7] A number of portable Civilian Conservation Corps buildings, obtained from Sandia Air Base near Albuquerque and re-erected at White Sands, served as office and administration buildings.[8] From Fort Bliss, lumber was obtained from several old cavalry buildings dismantled for the purpose.[9] In the northwest quadrant, several large barracks

were erected, framing a parade ground.[10] The barracks housed both officer personnel and the 40 German scientists stationed at White Sands.

A huge 130 by 160 foot Quonset-type steel hangar building was also brought from Sandia and used to store and assemble the large inventory of V-2 parts that had arrived at White Sands in late July 1945. Designated Missile Assembly Building 1, it housed the first assembly line for the V-2 (see HAER drawing NM-1B, Sheet 2).[11]

By February 1946 a second assembly building was under construction.[12] Completed by April and called the "Mill Building," it was a three-bay, rectangular steel structure 120 feet wide and 180 feet long.[13] This building became the primary assembly site for the V-2 (see HAER drawing NM-1B, Sheet 2).[14] Its center bay, which housed the main assembly line, was high enough to provide clerestory lighting over the work area and accommodate a traveling crane that ran its length. The crane brought equipment and rocket components to a carriage that held the V-2. The carriage traveled down the assembly line on a rail track embedded in the floor. On either side of the central bay lower lean-to bays provided space for sub-assemblies and offices.[15]

V-2 assembly began by lining the rocket's two half-cylindrical mid-section shells with rock wool to insulate the rocket's super-cold propellants (see HAER drawing NM-1B, Sheet 3). The top (alcohol) tank was fastened in place on one of the mid-section shells and the bottom (oxygen) tank fitted beneath it. Once the tanks were assembled, the other mid-section shell was bolted over the tanks, completing the central portion of the rocket.

The rocket's lower portion, made up of the motor and turbine-driven propellant pump, was assembled separately. But before installation, the rocket motor was "flow" tested to ensure proper operation. The motor, although simple in design, required exacting precision in its manufacture and assembly. Its injection system had a total of 2,160 oxygen orifices and 1,224 alcohol orifices; very small errors in their calibration could make an enormous difference in the proportion and mixing of the two propellants, critically affecting rocket performance. One V-2, for example, reached an altitude of only 63 miles, while another nearly identical in weight and burn time flew to 116 miles. The difference in performance was ascribed to improper calibration of the injection system.[16]

Flow testing of the rocket motor occurred in an outdoor scaffold-like structure called the Propulsion Unit Calibration Stand, which was located southwest of the Mill Building. The motor was calibrated using water rather than propellants, drawn from two water tanks, one supplying each of the motor's propellants. Water was pumped through the motor at an operating pressure of approximately 266 pounds per square inch, allowing calculation of the motor's performance characteristics from the quantity and duration of flow in each propellant system.[17]

Because a large volume of water passed through the motor at high pressure, a small concrete blockhouse was erected in July 1946 next to the Calibration Stand to protect test personnel and instruments. Referred to as the "Von Braun Blockhouse," it had two slit windows facing the stand.

After calibration, the rocket motor and its turbine pump were installed at the base of the oxygen tank and covered with the rocket's tail housing to complete its lower section.

Guidance equipment and on-board experiments were housed in the top section of the rocket, with the guidance equipment attached directly over the alcohol tank. Experiments were installed in lieu of explosives in the rocket's nose cone, thereby completing the rocket.

Once assembled, the rocket was weighed and hung from a balance to determine its center of gravity. These measurements permitted calculation of its fuel requirements and the gyroscope settings necessary to obtain a particular trajectory. The rocket was then placed on the German-made Meillerwagen and towed by truck either to Launch Complex 33 for launching or to the 100,000 pound static test stand for static firing.

Present Remains

The expansion and reconstruction of the Headquarters area over the past 40 years has left only three facilities known to be directly related to the history of the V-2 rocket. Two of these are Missile Assembly Building 1 (Building 1538) and the "Mill Building" (Building 1558), both of which are in good condition but now used for other purposes (see HAER photographs NM-1B-56 through NM-1B-59). The third survivor is the Von Braun Blockhouse (Building 1592) formerly associated with the Propulsion Unit photographs (NM-1B-60 and NM-1B-61). The stand itself has been demolished, leaving only its footings,

but the concrete blockhouse, currently used for storage, is little changed from its original appearance.

Notes

1. Eunice Brown et al, White Sands History: Range Buildings and Early Missile Testing (partial reproduction of 1959 historical report, White Sands Public Affairs Office, no date), p. 20.

2. Ibid., p. 22.

3. Ibid., p. 20.

4. Ibid., p. 20; apparently just drilling of wells.

5. Ibid., p. 21.

6. Story of White Sands and Brown, White Sands, p. 20.

7. Herbert Karsch (personal interview of January 31, 1986).

8. Brown, White Sands, p. 20.

9. Ordway and Sharpe, Rocket Team, p. 345.

10. Ibid. photograph "White Sands" between pp. 366 and 367; and Karsch, interview.

11. White Sands, and Karsch interview. According to Von Braun (as reported in Ordway and Sharpe, Rocket Team, p. 346) there was a "Building H," "...a huge wooden airplane hangar to be used for assembling V-2s" in which some German scientists were housed upon first arriving at White Sands. This description does not appear reliable: the early photographs of the period show no building that fits Von Braun's description and Von Braun was stationed at Ft. Bliss, not at White Sands and thus it may have been second-hand. Herbert Karsch's recollection in 1986 (interview) is that the German's were housed in a wooden CCC building.

12. Milton W. Rosen, The Viking Rocket Story (New York: Harper and Bros., 1958), p. 38.

13. Story of White Sands and Karsch, interview.

14. Gift Motion Pictures, Paramount News (Vol. 6, No. 23), November 16, 1946.

15. U.S. Army Signal Corps, V-2 Rocket: Assembly and Launching (Film Bulletin No. 219, 1947). Also Karsch, interview.

16. General Electric, Final Report: Project Hermes V-2 Missile Program (unpublished report prepared by Leo D. White, Field Test Director, Schenectady, NY: September 1952), p. 21.

17. Information on flow testing from Karsch, interview.

Chapter 3

LAUNCH COMPLEX 33

Background

Construction of Launch Complex 33 began on June 25, 1945. At first it consisted of no more than a large concrete blockhouse to protect personnel, and one concrete slab from which rockets could be launched. But the Army intended the complex to be the center of rocket launch operations and designed it to be easily expanded from its simple beginnings. Before the end of 1945, an additional launch pad was built for the V-2. Over the next seven years the launch complex was to be continually expanded to provide ever more sophisticated facilities for fueling and launching and to accommodate new rockets. By the end of the V-2 program in 1952, Launch Complex 33 contained no less than six launch pads, one of which was an integrated testing and launching facility served by the nation's first rocket gantry crane (see HAER drawings NM-1B, Sheets 2 through 6).

In 1944 the U.S. Army let two contracts for the development of liquid fueled rockets. One, with the Jet Propulsion Laboratory of the California Institute of Technology, was for the WAC Corporal, a small, simple liquid fueled rocket that was the first developed by the U.S.[1] The other contract, with the General Electric Company (GE), sought the development of a much larger rocket.[2] The GE contract, signed in November, was spurred by Germany's deployment of the V-2 in September, and was soon expanded to include study of the German rocket.[3] The subsequent GE involvement in reviewing secret

intelligence reports and aiding the Army in retrieving V-2s after Germany's surrender led to the program receiving the code name "Project Hermes."

The first rocket launch at Launch Complex 33 (and also the first launch at White Sands) took place on September 26, 1945.[4] The rocket was a solid fuel device called Tiny Tim that had been developed earlier by the Navy for use from airplanes against stationary enemy targets. The California Institute of Technology (CIT) was investigating the suitability of the Tiny Tim as a booster for the WAC Corporal. The Tiny Tim looked like an airborne torpedo; ten feet long and almost twelve inches in diameter, it burned for one second with a 30,000 pound thrust.[5] Tests of it alone continued for several months, in parallel with tests of the Corporal.

The Corporal also measured about twelve inches in diameter, but was 16 feet long and burned for 50 seconds with a thrust of 1,500 pounds. Carrying an instrument payload of no more than 25 pounds, it would reach an altitude of 100,000 feet.[6] Aided by the Tiny Tim booster, the Corporal ultimately attained an altitude of over 200,000 feet. Launch tests of partially fueled Corporals began on October 1, 1945, five days after the first Tiny Tim launch. Launches of the WAC Corporal and its modified versions continued at the complex through the early 1950s. Simple and inexpensive, the Corporal eventually became a mainstay of upper atmosphere research.

The first V-2 was launched on April 16, 1946.[7] A total of 64 V-2s were launched at Launch Complex 33, the last taking place in September 1952. Three additional V-2s, part of an experiment called Project Bumper, were

launched at Cape Canaveral, Florida in 1949. As part of its Project Hermes contract, GE was responsible for all but the final five launches, which were conducted by Army personnel.[8]

The procedures for preparing a V-2 for launch consisted of transporting the rocket to the launch complex and fueling and testing it immediately before flight. The first launch was essentially a replication of the wartime launches that German troops had conducted with mobile equipment in the field. Later, sophisticated equipment at the launch complex would make prelaunch preparation much safer and easier, but would barely alter the procedure.[9]

Once the V-2 was deemed ready to launch, it was towed to the launch complex on a German trailer called the Meilerwagen, which also elevated the rocket to a vertical position. There were three functional parts to the Meilerwagen: chassis, lift frame, and hydraulic lift. The chassis consisted of a steel frame mounted on trailer wheels. The lift frame cradled the V-2 and was attached at one end to the chassis by a pair of trunnion hinges. Once the Meilerwagen was properly positioned at the launch pad, the lift frame and rocket were elevated to a vertical position by the hydraulic lift system. Two girdles, one at the rocket's nose and one just above its fins, held the V-2 tightly to the lift frame. Access to the raised rocket was provided by ladder rungs welded to one girder of the lift frame and by temporary platforms that were hung from the frame. Another piece of German equipment, the Magirus ladder, a three section telescoping ladder that extended to 56 feet, was also used to gain access to the V-2's hatches.

When elevated, the rocket was placed on a low portable steel "launch table." Lugs on the table engaged brackets on the Meilerwagen before the rocket was raised to ensure proper alignment. Once raised, a weight-bearing gear wheel in the table allowed the rocket to be rotated, aiming it at its target. The table also incorporated a blast deflector, a mast for electrical wiring, and fittings for liquid propellant hoses.

In place on its launch table, the rocket was carefully checked and tested to ensure that all systems were operating. Upon completion of the tests, the rocket was fueled and prepared for launch. Approximately 1,530 gallons of alcohol and 13,200 pounds of liquid oxygen were pumped into the rocket's tanks. The secondary fuels of hydrogen peroxide and sodium permanganate (which powered the turbine pump) and compressed air (which forced these fuels into the pump) were also added during the fueling process. Under ideal circumstances, launch took place within one hour of fueling so the extremely cold liquid oxygen would not freeze servo motors and valves. If launch was delayed beyond this period, hot air would be forced through the rocket to warm its components.

The launch procedure included a final test of the rocket motor. The fuel lines were opened without activating the turbine pump, allowing the propellants (which ignited on contact) to flow into the combustion chamber by gravity. This produced approximately 16,000 pounds of thrust, too little to move the rocket, but enough to check that its motor functioned properly. Once the turbine was activated, fuel flow increased, thrust jumped to 52,000 pounds, and the rocket became airborne almost immediately.

Launch preparations were somewhat changed by the construction of the gantry crane, which provided much improved access to the rocket. This eliminated the use of the Magirus ladder and the platforms on the Meilerwagen to service and fuel the V-2. But the Meilerwagen remained in use throughout the program to move and lift the rocket (it was also used to transport American rockets) and all V-2 launches took place from the German-made launch table.

Structures

Launch Complex 33 was located at the southern end of the newly established Proving Ground, providing a flight range of nearly its full 121 mile length. The site selected was flat open desert 6-1/2 miles east of the offices and residences of the Headquarters area, sufficiently distant to pose no threat in case of a rocket explosion (see HAER drawings NM-1B, Sheets 1 through 6).

Construction of Launch Complex 33 began on June 25, 1945, with earth moving equipment clearing, grading, and compacting a rectangular area 1,500 feet by 1,025 feet.[10] The long axis of the clearing ran north-south along the axis of the Proving Ground itself. Within this cleared area, the Army constructed a 22-foot wide service road around the perimeter of a roughly square core area measuring 550 feet by 600 feet.

On July 10, 1945, construction began on the Army Blockhouse at the south edge of the area encompassed by the service road (see HAER drawing NM-1B, Sheet 5).[11] The Blockhouse was designed to provide personnel protection from the largest rocket then known--the German V-2, which dug a

crater 30 feet deep on impact. The walls of the Blockhouse were made of reinforced concrete 10 feet thick and surrounded a work space 20 feet wide, 40 feet deep, and 9 feet high. The roof was a pyramid of reinforced concrete, 27 feet thick at its apex. The long side of the Blockhouse faced north toward the launch area and was pierced by two heavily armored slit windows, each 6 inches high and 36 inches wide. Entrance was from the south side through a steel door buffered by a massive interior concrete wall. An at-grade concrete slab, 15 feet by 50 feet, was poured outside the Blockhouse adjacent to the south entrance.

About 980 feet directly north of the Blockhouse, just outside the area encompassed by the service road, the Army constructed a 70 foot square concrete launch platform for the WAC Corporal (see HAER drawing NM-1B, Sheet 4). The Corporal consisted of little more than two propellant tanks and a motor; it had no internal guidance system and had to be aimed at the time of launch. For this purpose, a 102 foot steel tower was built on its launch pad. The tower was triangular in plan, with vertical guide rails on each outside corner. The Corporal slid along one of the guide rails upon being launched, gaining enough velocity before reaching the rail's end to maintain a stable flight.[12] Launches were controlled by electric cables routed through an underground conduit that linked the Blockhouse to the launch platform.

A railroad track was also constructed, running north-south just east of both the Blockhouse and the Corporal launch platform. At the end nearest the launch platform it was paralleled for about 400 feet by a second railroad

track. Although constructed to test a rail-mounted German V-2 rocket launcher, there is no record of such tests and it is doubtful that any were ever conducted.[13]

In July 1945, only weeks after construction began, the need to expand the launch facility was made obvious by the arrival of 300 railroad box cars filled with V-2 components.[14] Additional construction plans, completed in September, provided for the first V-2 launch platform and two observation towers.[15] The V-2 platform was located 30 feet west of the Corporal launch platform and, like the Corporal platform, was a simple reinforced concrete slab (see HAER drawing NM-1B, Sheet 5). Slightly smaller than the Corporal platform, it measured 54 feet by 58 feet 6 inches and had no tower, since the V-2's internal guidance system made this feature unnecessary. Underground cable in conduit lined the V-2 platform to the Blockhouse.

Two observation towers were also proposed in the September plans. One, designated Tower No. 1, stood 20 feet behind the Blockhouse (away from the launch area), and consisted of a roofed and partially enclosed platform mounted on a square steel tower about 40 feet high. Partially shielded by the Blockhouse and about 500 feet from the launch platform, it may have been used for direct viewing as well as camera recordation of launches. The second tower, No. 2, was sited in the plans just 30 feet west of the V-2 launch pad. This tower is not evident in any photographs and, while its foundations were poured, the tower itself may never have been erected and its intended use is now uncertain.

Three months later, in December 1945, the Army completed plans for the most sophisticated facility that would be built at Launch Complex 33.[16] It was a combined test/launch facility consisting of a rocket platform and below-ground blast pit that could be used for 20,000 pound thrust static tests or for launches, and a gantry crane that could be moved into place over a rocket (see HAER drawings NM-1B, Sheet 6). Construction began in early 1946 with the excavation of the blast pit. It was 30 feet deep and opened on its east side to a V-shaped, flared incline that rose upwards to the level of the desert floor over a distance of 95 feet (see HAER photographs NM-1B-21 and 23). The pit's walls were made of reinforced concrete two feet thick and its rear wall was curved to deflect the exhaust out the open east side. The curved wall was armored with two-foot wide overlapping steel plates, varying from 1/4 to 3/4 inches thick. The platform over the pit, from which rockets were fired, had an opening 7 feet by 7 feet to allow exhaust gases to pass into the pit and be diverted out across the desert. A sprinkler system helped quench the rocket blast by directing water into the pit during tests and launches.

A movable gantry crane was the other principal feature of the new test/launch facility. The gantry moved on two parallel rails, spaced 27 feet apart, that straddled the rocket platform and extended about 550 feet north (see HAER photograph NM-1B-14). It consisted of two open steel towers, each 60 feet tall and mounted on two pairs of rail wheels. Along the length of each tower, work platforms were provided at several levels that could be

swung down, nearly encircling a rocket. The platforms were reached by stairs and ladders (see HAER photographs NM-1B-15, 16, 18, 20, 22, and 26). At the top, the two towers were joined by a steel truss with an integral platform. A 15-ton chain hoist mounted on the truss lifted tools and instruments to the work platforms, and could even raise some smaller rockets to a vertical position. The gantry's had an internal clearance of 16 feet wide by 54 feet high (see HAER photograph NM-1B-17), sufficient to accommodate the largest rockets of the period, including the V-2. For rockets too heavy for the crane to lift, such as the V-2, the gantry was trundled into position after the rocket had been elevated by other equipment.

The gantry provided much improved access to the hatches and payload sections of a rocket, allowing more sensitive adjustments to the guidance systems and permitting more sophisticated experiments to be carried. Immediately before launch the gantry was pulled back a safe distance. Drive units in the base of the gantry moved the entire structure at a slow pace (see HAER photographs NM-1B-28, 29, and 30).

The gantry was put in service by June 1946 and the rocket platform and its blast pit were completed later that year.

Tradition attributes much of the design of the new test/launch facility to Wernher Von Braun and some of the other Germans who had begun arriving in the U.S. in October 1945.[17] This seems likely because the Army still had no experience with large rockets. Surviving plans, however, like all construction plans for White Sands, were nominally prepared by the Albuquerque

District of the Corps of Engineers. The gantry has recently been commemorated as the "Von Braun V-2 Gantry Crane" (see HAER photograph No. NM-1B-31).

While the gantry crane was used exensively for V-2 launches, as indicated by the commemoration, no other part of the test/launch facility was ever used for a V-2 launch.[18] The static testing of V-2s took place at the 100,000 pound static test stand several miles away, and launches were conducted exclusively from at-grade concrete slabs. The rocket platform above the blast pit was used frequently for launching American rockets, however, including a version of the Corporal that could be launched without a guide tower. The first large rocket to use the rocket platform was the Navy's Viking, first launched on May 3, 1949.[19] Smaller than the V-2, the Viking was bolted to the platform and static tested during final prelaunch preparations. After a successful test, it would be unbolted, refueled, and immediately launched.[20]

It may have been the Army's intention to use the test/launch facility for V-2 launches. For some reason it was not used for the V-2s, however, and the Army had to install a diagonal track to move the gantry crane back and forth to the first V-2 launch pad. The diagonal track was installed by the fall of 1946 and ran from the north end of the original track to the V-2 pad.[21] About this time, the Army enlarged the V-2 pad, pouring concrete to connect it on the east with the Corporal launch pad and on the south with the service road. The pad was also extended 58 feet west, which necessitated removing all remains of observation Tower No. 2. As part of the same project, the Army widened the service road in this area and paved it with concrete.

But using the gantry crane for V-2 launches required shifting it from the original to the diagonal track. To eliminate this procedure, in January 1947 the Army completed plans for a second V-2 launch pad that laid on axis with the gantry's original north-south track.[22] Located south of the test/launch facility, the second pad was reached by a southern extension of the gantry track. The trackage for the extension was obtained by reinstalling the track used to reach the first V-2 pad. The second V-2 pad, like the first, was a simple at-grade concrete slab. The remainder of the V-2 launches took place from this pad.[23]

The January 1947 plans also provided for a supplementary launch pad and two additions to the Blockhouse.[24] The supplementary pad, for small rockets (those that did not require the gantry crane), was adjacent to the second V-2 pad. The additions to the Blockhouse were of reinforced concrete and provided space for communication equipment and an air compressor.[25] The larger addition, for the communication equipment, measured 39 by 30 feet and was attached to the south side of the Blockhouse (see HAER photographs NM-1B-2, 3, and 7). Containing three equipment rooms, it was entered through two portals, one in its south wall and the other in its west wall. The communication room addition necessitated the removal of observation Tower No. 1 and obliterated all traces of its foundations. The second addition, measuring 20 feet by 13 feet 6 inches, housed an air compressor and was attached to the west side of the Blockhouse.

At this time a viewing port was cut into the Blockhouse to allow observation of the new V-2 launch pad.[26] The port measured 60 by 13 inches, and was

cut through the east wall at a slight angle to face the new pad. The early 1947 construction also resulted in the removal of the two sets of railroad tracks installed when Launch Complex 33 was first built.

Starting in 1948 an experimental series of V-2 launches necessitated a major modification of the gantry crane. The experiment, called "Project Bumper," entailed placing a Corporal rocket in the payload section of a V-2 and launching it after the V-2 was in flight. The combined rockets stood slightly over 60 feet tall, exceeding the gantry's height clearance of 54 feet. To accommodate the Bumper launches, platform extensions were added on the south side of the gantry, allowing it to service the combined rockets by being maneuvered next to rather than over them. The platforms were cantilevered directly out from the main structural frame of the gantry (see HAER photograph NM-1B-19).

Experimentation and test demands led to other changes at Launch Complex 33.[27] Eventually an additional launch platform would be constructed to the east, outside the perimeter road, for the Hermes rocket, and a wide strip of concrete would be poured inside the perimeter road, extending from the south to the north road, to provide launching facilities for a number of smaller rockets.

Present remains

The launch complex is remarkably unchanged from its active period (see HAER drawings NM-1B, Sheets 1 through 6). While no longer in use, it is still virtually intact. The Blockhouse is in good condition and is still

occasionally used as a monitoring facility for tests at other launch sites. The configuration of the Blockhouse has been unchanged since the 1947 modifications except that a second compressor room was added to the west side of the first compressor room addition. In place by 1955, the room measures 12 feet 4 inches on each side (see HAER photographs NM-1B-1 through NM-1B-13).[28]

In 1982, the gantry crane was cleaned and painted and the launch/test facility cleaned and rehabilitated.[29] The gantry crane is in much the same condition it was in at the conclusion of the V-2 program, and retains the platform modifications built for the Bumper launches (see HAER photographs NM-1B-14 through NM-1B-31).

Notes

1. Eunice Brown et al, White Sands History: Range Buildings and Early Missile Testing (partial reproduction of a 1959 historic report, White Sands Public Affairs Office, no date), p. 47.

2. Ibid.

3. Gregory P. Kennedy, Vengeance Weapon 2: The V-2 Guided Weapon (Washington, D.C.: Smithsonian Institution Press, 1983), p. 52.

4. Brown, White Sands, p. 50.

5. Ibid.

6. Ibid., p. 52.

7. Ibid., p. 74 (renumbered p. 143) in Appendix A.

8. Ibid., pp. 149-150, gives a launch schedule of the V-2s at White Sands.

9. Kennedy, Vengeance Weapon 2, pp. 43-51.

10. Brown, White Sands, p. 20 and White Sands Proving Ground (unpublished report, authorized by G. C. Eddy, Commanding Officer. No date, but between February 1950 and February 1954). National Archives and Record Service, Record Group 156, Entry 660, Tab K, Box 1036. Also derived from drawings.

11. Brown, White Sands, p. 21.

12. Willy Ley, Rockets, Missiles, and Men in Space (New York: The Viking Press, 1958), p. 231.

13. The rail-mounted launcher is shown in the lower right corner of the photograph on page 104 of the Supplemental Material, herein.

14. The Story of White Sands (unpublished report authorized by G. W. Trichel, 30 April 1946) passim. National Archives and Records Service, Record Group 156, Entry 660, Tab K, Box 1036.

15. U.S. Corps of Engineers, Albuquerque District, Foundation Details, Launching Platform, and Observation Towers 1 & 2 (blueprint of plan drawing, September 1945).

16. Ibid., Missile Launching Platform Layout Plan (blueprint of plan drawing, December 1945).

17. Frederick I. Ordway, III and Mitchell R. Sharpe, The Rocket Team (New York: Thomas Y. Crowell, 1979), p. 346.

18. Herbert Karsch (interview). While it is clear that the V-2 was not launched from the blast pit, there is little evidence to indicate why this was so. If not intended for the V-2, there appears to be little reason for the Army to have built it in 1946. Karsch believes it was always intended for the Viking, but this seems unlikely, principally because the Viking was just being developed in 1946 and would not be ready for launch until 1949.

    Clyde Tombaugh (interview in February 1986) recalls early plans for a never-to-be-built rocket that was to be twice the length of the V-2, yet half its diameter, and suggests that it was for this rocket that the blast pit was intended. This seems unlikely because such a tall rocket would have been completely unserviceable by the gantry crane.

    One other interviewee, Tom Starkweather (interview in February 1986) suggests that the blast pit was intended solely as a test facility, perhaps for the Corporal. This leaves unexplained why the Army would have left so unplanned the problem of getting the gantry crane to each V-2.

19. Ley, Rockets, Missiles, p. 251.

20. Milton W. Rosen, The Viking Rocket Story (New York: Harper and Bros., 1958), p. 78.

21. U.S. Corps of Engineers, Missile Launching Platform (December 1945), revision notes indicate date between 6/27/46 and 10/21/46.

22. U.S. Corps of Engineers, Albuquerque District, Additional Launching Stations: Location Plans (January 1947).

23. Karsch (interview).

24. U.S. Corps of Engineers, Missile Launching Platform (December 1945).

25. U.S. Corps of Engineers, Albuquerque District, Communications Room Addition (January 1947).

26. U.S. Corps of Engineers, Albuquerque District, Existing Control Building (January 1947).

27. White Sands Proving Ground, Army Launching Area No. 1 (blueprint of plan drawing, no date).

28. White Sands Proving Ground, Army Blockhouse (blueprint of plan, July 1, 1955).

29. White Sands Missile Range, Facilities Engineering Directorate, Gantry Crane Preservation and Chain Link Fence (blueprint of drawings, June 1982).

Chapter 4

RANGE INSTRUMENTATION

Background

The means for aerial tracking were virtually non-existent for the first rocket flights at White Sands, but they rapidly became one of the more important adjuncts to every launch. Early flights were only visually observed and rockets were recovered by teams scouring the desert in jeeps.[1] Even when the spent rockets were found, they were so pulverized by their high speed impact that little meaningful information could be extracted from them. Yet improving the performance and reliability of subsequent flights depended upon careful analysis of each rocket's performance, and this could only be gained by gathering data on the rocket's flight characteristics. Furthermore, many on-board rocket experiments required both predetermining and recording the rocket's exact flight trajectory.

To aid in tracking the V-2 flights, German Askania cinetheodolites, captured in Europe, were shipped to White Sands. A cinetheodolite combined a surveyor's theodolite (a device that measures horizontal and vertical angles from a fixed point) with a camera. The camera took photographs that indicated an in-flight rocket's exact angle above the horizon and angle down range as seen from the cinetheodolite's station. Several cinetheodolites along the flight course, each simultaneously taking photographs, could together provide data for plotting an accurate flight trajectory. The Army installed eight Askania cinetheodolites along the length of the range by the Spring of 1948, as well as several more specialized Mitchell theodolites.[2]

Other tracking and monitoring means included radar, radio Doppler analysis, radio telemetry, and photographs from telescopic tracking cameras.

Radar functioned differently from optical instruments in that one radar unit could instantaneously indicate the general trajectory of a rocket. This ability, combined with radar's greater range, made it an important range safety instrument even though it was not as accurate as optical instruments. If radar indicated that a rocket would leave the range, a signal was sent to destroy the rocket in flight.[3]

One of the more sophisticated systems developed at White Sands, called DOVAP (Doppler Velocity and Position), took advantage of the fact that the frequency of a moving signal appears to shift when perceived from a stationary point (the "Doppler effect"). The set frequency of a socket-mounted beacon signal would be recorded as lower by stations behind the rocket and higher by stations before it, with the extent of frequency shift indicating the rocket's speed. A network of down-range receivers could gather enough data to permit extremely accurate calculation of the rocket's velocity and position.[4]

White Sands also monitored the rocket's internal operations through telemetry sensors that radioed readings to ground stations. Transmitted data included turbine propellant pump speed, storage tank temperatures, combustion chamber pressure and temperature, and gyroscope and control vane operations. Further, many experiments carried aloft by the V-2 depended upon radio telemetry, which frequently provided the only means to retrieve information from instruments that could not survive the rocket's impact upon landing.

A major, but less visible aspect of instrumentation was the analysis of data. For example, triangulation of the rocket's position from cinetheodolites required extensive mathematical and geometric analyses. Improvements in tracking analysis methods at White Sands constituted a major step in America's rocket program. Not only did they enable the conversion of raw data into a meaningful trajectory plot, they also contributed to a better understanding of the mechanics of sub-orbital and orbital flight, eventually enabling the extremely accurate calculation of space vehicle and ballistic missile trajectories.[5].

The Army's Signal Corps Engineering Laboratory was responsible for most of the range instrumentation and data analysis. First detailed to White Sands on a temporary basis in the Spring of 1946, the Signal Corps grew significantly in size and became an indispensable and permanent part of the proving ground's early operations.[6]

Structures and Present Remains

No instrumentation remains from the V-2 era at White Sands. Early tracking instruments were simply mounted on a vehicle and parked on a relatively level place down range. Even when they became more sophisticated, the instruments continued to require little more than a precisely located level concrete pad on which to rest. This allowed flexibility of movement for measuring the different aspects of a rocket's flight and for accommodating the flights of different rockets. While most instruments were housed in nothing more substantial than a temporary structure or a trailer, by the

mid-1950s some types of optical equipment were so sophisticated and massive that small observatory-like structures were built to shelter them.

The proving ground's main radar station was stationary due to radar's long range and ability to track from only one point. Because range safety depended upon radar, the station also became a main communication point for all tracking instruments and range activities. The station was located three miles south of Launch Complex 33 to provide a perspective on a rocket's northward flight. Called "Range Control," it occupied a large permanent building known as Station C. In the late 1950s, however, Range Control was relocated to a new station just east of the Headquarters Area from which all range functions were coordinated, and the Army demolished Station C.[7]

Notes

1. Milton W. Rosen, The Viking Rocket Story (New York: Harper and Bros., 1958), p. 38.

2. Report of 13 May 1948 Flight, "Bumper Project," unpublished manuscript in the National Archives, Record Group 156, Entry 660, Tab K, Box 1036.

3. Eunice Brown, et al, White Sands History: Range Buildings and Early Missile Testing (partial reproduction of a 1959 historical report: White Sands Public Affairs Office, no date), p. 44.

4. Ibid., pp. 43-44.

5. Herbert Karsch (interview by Michael C. Quinn, January 1986).

6. Brown, White Sands History, p. 26.

7. Ibid., p. 25.

Chapter 5

100,000 POUND STATIC TEST FACILITY

Background

Test firing was critical to White Sands' V-2 program because the rockets were assembled from cannibalized parts. Despite the Army's best efforts, it had captured no operational V-2s in Europe. German field units, facing defeat, launched all operational V-2s under the direct supervision of the SS.[1] Although as many as 2,000 V-2s in various stages of assembly or repair were left in Germany at the close of the war, the retreating Germans sabotaged everything they could, and the V-2 parts that arrived at White Sands in July 1945 had to be completely refurbished and tested.[2]

The 100,000 Pound Static Test Facility, which held a rocket stationary during a full thrust firing of its motors, provided one means of conducting such tests. The V-2 developed 56,600 pounds of thrust, so the facility's test stand was designed with a safety margin that brought its design capacity to 100,000 pounds.[3] The first ignition of a fully assembled V-2 at White Sands took place in the 100K facility on March 15, 1946, slightly more than a month before the first V-2 was launched.[4]

Although alternative means of testing were also developed, such as flow testing rocket motors with pressurized water prior to V-2 assembly, the 100K facility provided the only means of static firing the V-2 and the only opportunity for investigating its motor's performance under controlled conditions.

No plans or construction records of the 100K facility survive, but secondary histories attribute its design to the German scientists.[5] Completed in early 1946, the facility included a test stand, small machine shop, water storage tank, and blockhouse, the latter providing a safe place for test observation, monitoring, and control.

After assembly, the unfueled V-2 was loaded on a Meillerwagen, transported to the test stand, and elevated to a vertical position. Monitoring equipment, linked to the control and instrumentation rooms through underground cables, was attached to the V-2 and the rocket was fueled from tank trailers. During test firing, instruments monitored the pressure and temperature in all tanks and the combustion chamber, as well as turbo pump speed, vibration, acceleration, and thrust. High speed still and motion picture cameras recorded the sequence of events during the test.[6]

Structures

The site for the 100K test facility was selected for its isolation (see HAER drawings NM-1B, Sheets 1 and 2). Located in the foothills of the Organ Mountains on a slope that faced northeast, the facility stood one and one-half miles south of Headquarters area, far enough away from the installation's residential and administration facilities to pose no threat in the event of an explosion. The facility included a motor test stand, blockhouse, water tank, and a small shop building.

The motor test stand had a reinforced concrete platform that held the rocket carriage and a reinforced concrete base that served as an anchor and exhaust diverter. The base was embedded in the side of a hill and surrounded on three sides by earth. The fourth side, facing northeast, opened to the desert. A circular hole in the platform channeled the rocket exhaust, which from the V-2 reached a velocity of approximately 4,500 miles per hour and a temperature of 3,600 degrees farenheit, directly against the curved back wall of the diverter and out across the desert.[7] The diverter was lined with steel plates to protect its concrete walls from the force of the blast.

The steel plate protection failed during the first motor firing on March 15, 1946. During that 57-second test the rocket blast heated the plates red hot, ripped them from their anchors, and blew them away, starting brush fires as far as 250 yards from the stand.[8]

Above the test stand's base stood a rocket carriage made of two steel pylons 50 feet in height and joined at the top by a steel cross beam. Two fastening attachments on each pylon held girdles that encircled the V-2 during the test firing, withstanding and measuring the thrust generated. The steel carriage was fitted at three levels with hinged work platforms that when lowered in place provided direct access to the rocket. The platforms were reached by an open ladder attached to the back side of each carriage pylon, and the steel cross beam held a five-ton chain winch for hoisting equipment to the work platforms.

A 15 by 40 foot reinforced concrete blockhouse was erected southwest of the test stand. Built of reinforced concrete walls 18 inches thick, it contained

both a control and an instrumentation room. The control room housed the firing control panel, television monitors, and air pressure controls and gauges. Two slit windows, 4 by 24 inches, provided a view of the test stand. The instrumentation room housed equipment that measured such performance parameters as pressure, temperature, vibration, acceleration, and event sequence. Test instruments included Baldwin load cells for measuring thrust, an Esterline Angus 20 channel sequence recorder, oscillographs, Wiancko carrier systems, and an eight channel Consolidated System D amplifier. Eighty-six separate data channels transmitted information between the instrumentation room and the test stand in 12 underground conduits.[9]

Immediately northwest of the blockhouse stood a machine shop, housed in a light metal building measuring 20 by 24 feet, that contained work benches and machine tools for on-site maintenance and repair work. A 100,000 gallon tank located southwest and approximately 200 feet uphill from the test stand provided up to 900 gallons of water per minute for quenching flames in the exhaust diverter.

Modifications and Present Remains

The Army built the 100K test stand specifically for the V-2 and used it exclusively for that rocket from 1946 through 1949. The need to test other rockets led to later modifications of the test stand, most consisting of a change in the means of fastening rockets of smaller dimensions to the thrust attachments of the steel carriage. The first such change occurred in 1950

to allow testing of the Air Force's Bomark missile.[10] In 1951, the stand was modified to hold the Corporal missile, then being produced by the Firestone Tire and Rubber Company.[11]

The most significant modification occurred in 1956 when an additional carriage was installed, providing an entirely new testing capability. It attached directly to the original steel pylons of the test stand and cantilevered over the exhaust diverter. The carriage, or outrigger as it was called in contemporary reports, held only rocket motors rather than complete rockets. It used the stand's foundation and its instrumentation, but was limited to tests that did not exceed 20,000 pounds of thrust. The carriage had the added feature of being able to rotate the motor from a vertical to a horizontal position, simulating different angles of flight.[12]

Other changes to the test stand included increasing the number of work platforms to four, providing a catwalk on the top cross beam, installing safety hoops on the open access ladders, and adding several concrete extensions to the stand's concrete base. The first extension consisted of pushing the base walls farther out the side of the hill to the northwest. With the addition of the new motor carriage in 1956, wing platforms were also added to both sides of the base to provide additional work space.

The 100K static test facility was abandoned in the 1960s, and the entire facility stripped of most salvageable equipment and steel. Only the concrete platform and base remain at the test stand; the steel carriage has been removed (see HAER photographs NM-1B-35, 36, 37, 38). The blockhouse is

now empty (see HAER photographs NM-1B-33, 39). The metal building that once housed the machine shop has been removed, leaving only a concrete slab (see HAER photograph NM-1B-34). The concrete water tank, located uphill of the test stand, is still intact.

Notes

1. Gregory P. Kennedy, Vengeance Weapon 2: The V-2 Guided Weapon (Washington, D.C.: Smithsonian Institution Press, 1983), p. 52.

2. Eunice Brown et al, White Sands History: Range Buildings and Early Missile Testing (partial reproduction of a 1959 historical report, White Sands Public Affairs Office, no date), p. 59.

3. Kennedy, Vengeance Weapon, p. 78.

4. Brown, White Sands, p. 83.

5. Ibid., p. 37. While the Army had planned and constructed a launch pad for the V-2 by the time the first German scientists arrived in October 1945, it had not provided a test stand. It seems likely that the Army simply knew too little about rockets in general and the V-2 in particular to design one, so deferred the task until the experienced Germans arrived.

6. White Sands Proving Ground, Electro-Mechanical Laboratories, 100,000-Pound Rocket Static Test Facility at White Sands Proving Ground (Special Report, 1958), passim.

7. Kennedy, Vengeance Weapon, p. 78.

8. Brown, White Sands, p. 74.

9. White Sands Proving Ground, 100,000-Pound Facility, passim.

10. Ibid., p. 4.

11. Ibid.

12. Ibid., p. 1.

Chapter 6

500,000 POUND STATIC TEST FACILITY

Background

Despite the extensive technical experience of the Germans and the growing sophistication of American scientists, building an efficient rocket motor still remained a product of trial and error. Designing the motor's propellant injectors was especially troublesome. Their placement, configuration, number, and orifice size were critical to achieving the correct proportion and proper mix of the motor's fuel and oxidizer; earlier German development of the V-2's injector cup alone had taken hundreds of meticulous tests of different injector configurations.[1]

When the German scientists accepted contracts with the Army after Germany's defeat, it was with the hope of continuing to develop rockets and ultimately achieving manned space flight. The slow years at White Sands and Fort Bliss, from 1946 through early 1950, gave them little reason to believe that this hope would be realized.[2] With few exceptions, the Army launched the rebuilt V-2s at an unhurried pace while awaiting construction of the smaller nuclear bombs that large rockets seemed most suited to deliver.

In 1946, the German scientists sought to prompt the Army into developing a major new rocket by designing a rocket motor that would develop 300,000 pounds thrust.[3] Their drawings, coupled with descriptions of what the rocket could achieve, were compelling. To take the design from the drafting board

to reality, however, required hundreds of test firings of the rocket motor, so in 1948 the Army began construction of a 500,000 pound static test facility.[4]

Like the 100K facility, the 500K facility was designed and built to provide a wide margin of safety for the large motor it would test. Plans for the motor were eventually scrapped, but not before the Army was well into building what would later be called the "White Elephant at White Sands." Construction of the 500K facility stretched to two years, and some features of the original design were never built. In the year after its completion in 1950, the 500K facility was used principally for a number of long duration tests of the V-2's graphite control vanes.[6]

In 1951, the facility was altered, scaling it down for tests of a smaller motor for the Army's new Redstone rocket, a direct successor of the V-2.[7] Outwardly only slightly larger than the V-2, the Redstone incorporated some significant improvements, especially the mounting of the motor in a movable gimbal that allowed the rocket to be guided by adjusting the direction of the motor. This made the use of control vanes, which caused enormous drag, unnecessary. The Redstone motor was tested frequently at the 500K facility between February 1953 and February 1955.[8]

Structures

The 500K static test facility, located several miles directly south of the Headquarters area (see HAER drawings NM-1B, Sheets 1 and 2), was a huge concrete structure built into unfaulted granite strata at the base of the

Organ Mountains (HAER photographs NM-1B-40, 41, 42).[9] Its steel motor carriage inclined at a 60 degree angle, and since the carriage held only a motor, the test facility contained integral storage tanks and pumps for supplying the motor's liquid propellants. Immediately behind and above the motor carriage were two separate pump houses, each 30 feet by 40 feet, which pumped, respectively, the huge volumes of fuel and oxidizer needed for such a large rocket motor (see HAER photograph NM-1B-43). Above the pump houses were two 15,000 gallon storage tanks, one for each of the two liquid propellants. The tanks were housed in separate "barricade" structures that could catch and divert, through external concrete spillways, the propellants in the event of a leak (see HAER photographs NM-1B-46, 47). Pipes 24 inches in diameter transported the propellants to the pump houses and then to the motor stand. A 100,000 gallon water tank located uphill from the test facility provided water for cooling the metal-plated concrete exhaust diverter at the foot of the motor carriage.

A 300 square foot control room, built into the side of the mountain, was situated to one side of the main axis of the stand. For safety reasons it had no direct view of the rocket motor; instead, it overlooked movable mirrors that provided a reflected view of test activities (see HAER photograph NM-1B-51). The controls and monitoring instruments housed in the control room were generally similar to those at the 100,000 pound static test facility. A round pillbox located on the opposite side of the 500K facility provided access, via an underground tunnel, to the control room (see HAER photographs NM-1B-49, 55).[10]

In 1951-52, the facility was altered to accommodate the Redstone rocket motor.[11] The most visible change was the installation of a vertical 60 foot steel motor carriage to replace the original angled one. The new carriage incorporated work platforms, an access stair, and an elevator (see HAER photographs NM-1B-50, 52, 53). Major changes were also made in the pump houses. The massive pumps, no longer needed for the smaller Redstone motors, were removed. One pump house was converted to a machine shop, the other to a storage area. In one of the large barricade structures the liquid oxygen tank was removed and the space outfitted with a compressor and tanks for gas and air. A new, more advanced vacuum tank installed adjacent to the barricade replaced the former liquid oxygen tank (see HAER photographs NM-1B-47, 48).

At the conclusion of the Redstone tests in the mid-1950s, the 500K static test facility was used for several more years to test a number of other, later motors.

Present Remains

The 500K static test facility is now abandoned but still virtually intact, its appearance little changed from the 1951-52 modification. The most telling aspect of the facility's use is the large cavity that rocket motor exhaust has burned into the granite substrate of the mountain.

Notes

1. Frederick I. Ordway III and Mitchell R. Sharpe. The Rocket Team. New York: Thomas Y. Corwell, 1976, p. 33.

2. Ibid., p. 361.

3. Ibid., p. 350.

4. White Sands Proving Ground, Electro-Mechanical Laboratories, 500,000-Pound Rocket Static Test Facility at White Sands Proving Ground (unpublished special report, February 1957), p. 2.

5. Ordway, Rocket Team, p. 350.

6. White Sands, 500,000-Pound, p. 2.

7. Ibid., and Willy Ley, Rockets, Missiles, and Men in Space. (New York: The Viking Press, 1968), p. 305.

8. White Sands, 500,000-Pound, p. 3.

9. Ibid., p. 10.

10. Ibid., passim and Albuquerque District, U.S. Corps of Engineers, White Sands Proving Ground, Motor Testing Facilities (includes "Location Plan" and "Isometric View" and others, April 1947). Also see White Sands Proving Ground 500,000 LB Static Test Stand (includes "Isometric" and elevations, February 1952 through January 1953).

11. White Sands, 500,000-Pound, passim.

Appendix

THE LIQUID FUELED ROCKET MOTOR

The liquid fueled motor forms the basis of the modern rocket. Explicitly theorized by the Russian Tsiolkovsky in the late nineteenth century, liquid fueled rockets are a relatively recent concept. By contrast, solid fueled rockets were known and used for centuries, beginning with the Chinese invention of gunpowder. A solid fueled rocket, in its simplest form, consists of an explosive packed into a cylinder. The explosive is a mixture of dry chemicals that, when ignited, react violently, releasing energy and hot gases. When such a reaction takes place in an open-ended cylinder, its force is directed through the open end, thrusting the cylinder in the opposite direction in accordance with the third law of thermodynamics.

While a liquid fueled rocket produces thrust in a similar way, it uses chemicals that are so volatile they cannot be mixed without exploding. The chemicals (actually a fuel and an oxidizer) are kept separate and are mixed in the rocket motor only at the moment of combustion, producing a controlled explosion. But keeping the fuel and oxidizer apart also requires a means of pumping them from their storage tanks to the rocket motor, thus ruling out solid fuels. Gases require too large a storage space. The V-2's fuel was ethyl alcohol and its oxidizer pure super-cooled oxygen, both liquids that when combined produced far more energy for their weight than any solid fuel of the time. The Apollo moon launches were later propelled by a lighter and even more powerful mixture of liquid hydrogen and liquid oxygen.

In addition to being more powerful, liquid fueled rockets are more controllable. Because their propellants are mixed by being injected into a combustion chamber, control can be achieved by regulating the rate of flow, thus achieving longer burns and more gentle acceleration than solid fueled rockets. The V-2 burn was nearly a full minute in duration.

While Tsiolkovsky and other theoreticians pointed out many of these advantages, enormous technical difficulties had to be overcome to build a liquid fueled rocket, including problems associated with producing and handling propellants, obtaining the proper propellant mix for an efficient burn, finding metals to withstand the heat of combustion, guiding the rocket's flight, and coping with the aerodynamics of supersonic speeds.

In terms of the production and handling of the rocket's propellants, ethyl alcohol presented few problems (other than it was constantly pilfered by troops) because it was readily available and easily stored. But liquid oxygen, while available, had not previously been produced on the scale needed for large rockets. A system also had to be developed that could pump the V-2's 12,200 pounds of liquid oxygen and 9,200 pounds of alcohol from its storage tanks to its combustion chamber within the span of the rocket's 57-second burn. Further, the propellants had to be injected into the chamber with sufficient force to overcome the pressure generated by combustion and still achieve a combustible mix. The problems of handling the oxygen were compounded by its corrosiveness, its extremely low temperature (minus 300 degrees F.) which froze motors and valves, and its tendency to spontaneously ignite most organic substances.

In smaller rockets, liquid propellants were forced into the combustion chamber with compressed air, but this method was impractical for the V-2 since it would require such massive air tanks that the rocket could never fly. Instead the Germans developed a 460 horsepower turbine propellant pump that could withstand the corrosive effects of liquid oxygen. Oils burn in pure oxygen, so the pump used the liquid oxygen itself as a lubricant. Driven by superheated steam made by mixing the rocket's secondary fuels of hydrogen peroxide and sodium permangantate, the pump duplicated a small liquid fueled rocket by forcing the two chemicals into its mixing chamber with its own small supply of compressed air.

Mixing the rocket's primary fuels thoroughly and in the proper ratio to obtain a complete burn was also a surprisingly difficult matter. In fact, the Germans had found it to be unsolvable by mathematical modeling, and they performed hundreds of trial-and-error tests to learn the optimum arrangement, size, and number of propellant injecting devices. Their V-2 injector design had actually been perfected for a much smaller rocket that used only one cup-shaped injector. Rather than repeat the arduous testing required to develop a new injector system for the V-2, the Germans simply grouped 18 of the proven injector cups together.

Problems also had to be overcome in the combustion chamber itself. With combustion temperatures as high as 3,600 degrees F., the metal in the rocket's combustion chamber would melt if directly exposed. This was solved by making the chamber double-walled to provide a space through which the

alcohol fuel circulated, cooling the chamber by drilling rings of tiny holes through the chamber wall's inner side to permit a small amount of alcohol to pass through and form a protective film over the wall, absorbing heat as it vaporized, and by cutting the alcohol fuel slightly with water to reduce its burning temperature.

The German's faced even more difficult problems in developing the rocket's guidance system. Electrically driven gyroscopes had to be designed to control the four directional vanes in the rocket's tail. An integrating accelerometer, which approximated the rocket's velocity by accumulating data on the rate of its acceleration, was invented to control the rocket's range; after a pre-designated velocity was reached, the accelerometer cut off the motor. Highly accurate timing devices and a reliable, independent electrical source were also built and incorporated into the rocket's guidance system.

In initial tests of the V-2, the Germans discovered that during reentry the rocket's supersonic speed caused it to break up and explode prematurely. Overcoming this problem required the construction, in Germany, of the world's first supersonic wind tunnel for the redesign of the rocket's shell.

Immediately after the war, complete documentation of the V-2 and its launch procedure was prepared under British supervision. The constraints of secrecy and the continual redesign of the rocket had precluded the creation of such a document by Germany, but in late 1945 the British assembled a force of German rocket personnel, called the Altenwalde Versuchs Kommando (AVKO)

(Altenwalde Experimental Command) and directed the preparation of Die Fernrakete (The Long Range Rocket). This publication included measured drawings of the V-2, its components, and the German field equipment used for its launch. Although the German document is not currently available, an excellent book that includes a detailed description of the V-2 and the technical problems of its development is Gregory P. Kennedy's Vengeance Weapon 2: The V-2 Guided Missile (Washington, D.C.: The Smithsonian Institution Press, 1983).

SOURCES OF INFORMATION

A. Original Architectural Drawings.

U.S. Corps of Engineers, Albuquerque District. Unpublished drawings of construction at White Sands Proving Grounds, 1945 through the 1950s. HAER photographs of these drawings are included in the photographic documentation. See HAER photographs NM-1B-62 through NM-1B-72.

B. Bibliography (published and secondary sources).

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Welsh, Michael. A Mission in the Desert: Albuquerque District 1935-85. U.S. Government Printing Office, 1985.

C. Bibliography (unpublished and primary sources)

Brown, Eunice, et al. White Sands History: Range Buildings and Early Missile Testing. Partial reproduction of a 1959 historical report. White Sands Public Affairs Office, no date. Supplied by Building Technology, Inc., Silver Spring, Maryland.

Building Technology, Inc. Historic Properties Report: White Sands Missile Range, New Mexico and Subinstallation Utah Launch Complex, Green River, Utah. Unpublished final report prepared under National Park Serevice contract CX-001-2-0033, July 1984.

General Electric Company. Final Report: Project Hermes V-2 Missile Program. Unpublished report prepared by Leo D. White, Field Test Director. Schenectady, N.Y.: September 1952. Provided by National Aeronautics and Space Administration, History Office, Washington, D.C.

Report of 13 May 1948 Flight. "Bumper Project." Unpublished manuscript in the National Archives, Record Group 156, Entry 660, Tab K, Box 1036.

The Story of White Sands. Unpublished Report prepared under Col. G. W. Trichel. White Sands Proving Ground, New Mexico: 30 April 1946. In the National Archives, Record Group 156, Entry 660, Tab K, Box 1036.

White Sands Missile Range. Installation Environmental Impact Statement. March 1976. Portions supplied by Building Technology, Inc., Silver Spring, Maryland.

White Sands Proving Ground. Unpublished report, authorized by G. C. Eddy, Commanding General. No date, but General Eddy commanded White Sands from 1 February 1950 until 31 July 1954. In the National Archives, Record Group 156, Entry 660, Tab K, Box 1036.

White Sands Proving Ground, Electro-Mechanical Laboratories. 500,000-Pound Rocket Static Test Facility at White Sands Proving Ground. Special Report. White Sands Proving Ground, New Mexico, 1958. Supplied by Building Technology, Inc., Silver Spring, Maryland

White Sands Proving Ground, Electro-Mechanical Laboratories. 100,000-Pound Rocket Static Test Facility at White Sands Proving Ground. Special Report. White Sands Proving Ground, New Mexico, 1958. Supplied by Building Technology, Inc., Silver Spring, Maryland.

D. Historic Photographs and Movies.

The following motion pictures, located at the Motion Pictures, Sound, and Video Branch, National Archives and Records Service, Washington, D.C., contain film footage of the V-2 program at White Sands:

Gift Motion Pictures. Hitler's Secret Weapon: The V-2 Rocket at Penemunde. Film made by WGBH-TV, Boston, 1975.

Gift Motion Pictures. Paramount News. Vol. 5, No. 75. Film of May 18, 1946.

Gift Motion Pictures. Paramount News. Vol. 6, No. 23. Film of November 16, 1946.

Gift Motion Pictures. Paramount News. Vol. 9, No. 54. Film of March 15, 1950.

U.S. Army Signal Corps. V-2 Rocket: Assembly and Launching. Film Bulletin No. 219, 1947.

E. Interviews.

Karsch, Herbert. Telephone interviews in January and February 1986 conducted by Michael C. Quinn. Mr. Karsch was Technical Director and Range Safety Officer, White Sands Proving Ground, November 1946 through September 1956.

Wagner, Nathaniel. Telephone interviews in January 1986 conducted by Michael C. Quinn. Mr. Wagner worked as an engineer at White Sands, beginning in the late 1940s.

Tombaugh, Clyde. Telephone interview on February 26, 1986 conducted by Micahel C. Quinn. Mr. Tombaugh was the supervisor of the optical/photographic laboratory at White Sands and was responsible for the development of telescopic tracking cameras.

F. Major Sources of Information.

Building Technology, Inc., Silver Spring, Maryland. William Brenner of BTI managed this recordation project and supervised a comprehensive survey of White Sands; in the process his firm collected information on White Sands that includes copies of original architectural drawings, photographs, copies of articles and newsclippings, and environmental documents. This material has been forwarded, through the Historic American Building Survey/Historic American Engineering Record, to the Real Estate Branch of Headquarters, Army Materiel Command, for archival storage.

Department of Defense, Movie Film Repository, Norton Air Force Base, California. Norton Air Force Base reputedly is a Defense-wide repository for motion pictures. This resource was not consulted, but may contain information not found at the National Archives.

Department of Defense, Still Media Records Center, Bolling Air Force Base, Maryland. The Center houses the consolidated collection of all historic military photographs. Recently, however, the Center has transferred all pre-1955 Army photographs to the National Archives. As a result, this resource was not available for this research.

National Archives and Records Service, Motion Pictures, Sound, and Video Branch, National Archives and Records Service, Washington, D.C. The Center has a large collection of films and videotapes, including commercial newsreels and Army information and training movies. See Subsection D, above, for film footage applicable to the V-2.

National Archives and Records Service, Military Field Branch, Suitland, Maryland. A large number of records on the early operations of White Sands Proving Ground are contained in Record Group 156, Entry 660, Tab K. Most of the material is still classified, but one unclassified box, number 1036, contains an excellent collection of monogaphs and project reports dating from 1946.

National Archives and Records Service, Military Reference Branch, Washington, D.C. One of the most promising sources of primary documents was the discovery of an acquisition record of about 40 boxes of material on the early operations of White Sands Proving Ground. However, the Archives was unable to locate the material itself. The acquisition record is held by the Military Reference Branch and is titled "Historical Background Information: Records of the Chief of Ordinance" (job no. 68A-2853).

National Aeronautics and Space Administration, History Office, Washington, D.C. The NASA History Office has information on the formation of the space program, including a copy of General Electric's final report on Project Hermes, prepared by Leo White.

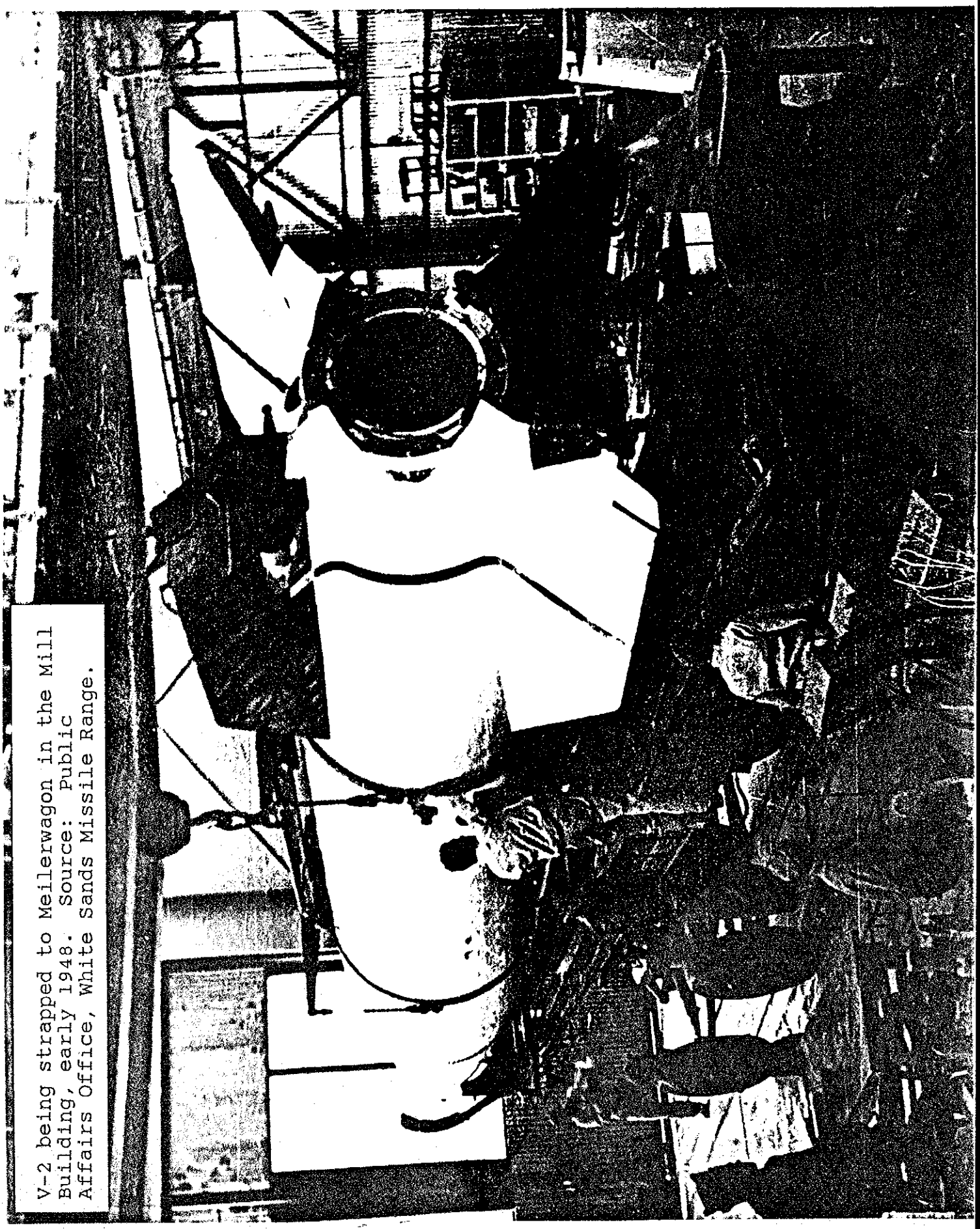
Smithsonian Institution. Washington, D.C. The Smithsonian has compiled extensive documentation on the V-2 as a result of assembling and preparing a V-2 rocket for exhibition. The documentation includes newspaper clippings, copies of drawings from Die Fernrakete, and an excellent collection of photographs.

G. Supplemental Material

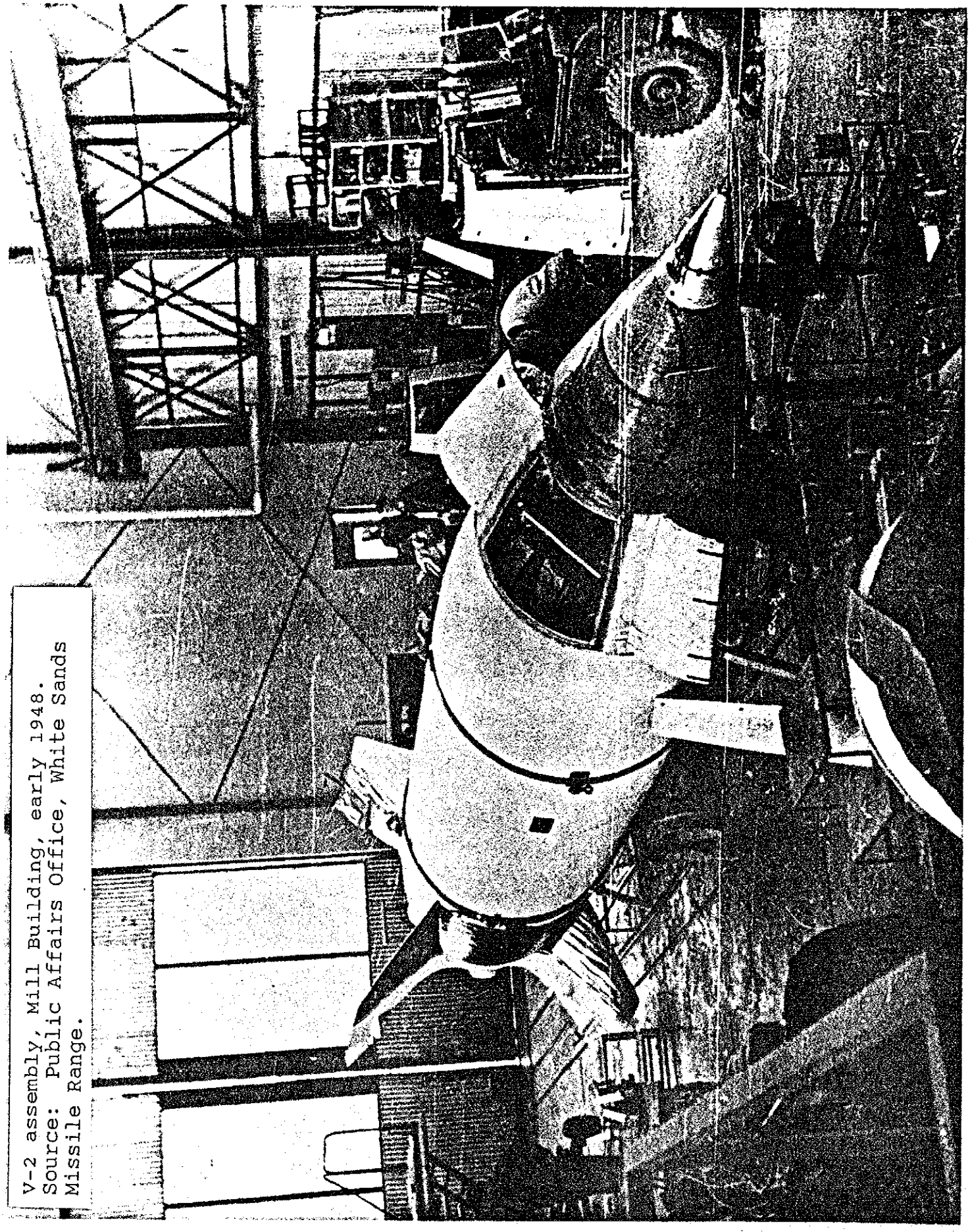
Fifty-five photographs and illustrations are included in the supplemental material that follows. Each has a caption that includes source information.

PROJECT INFORMATION

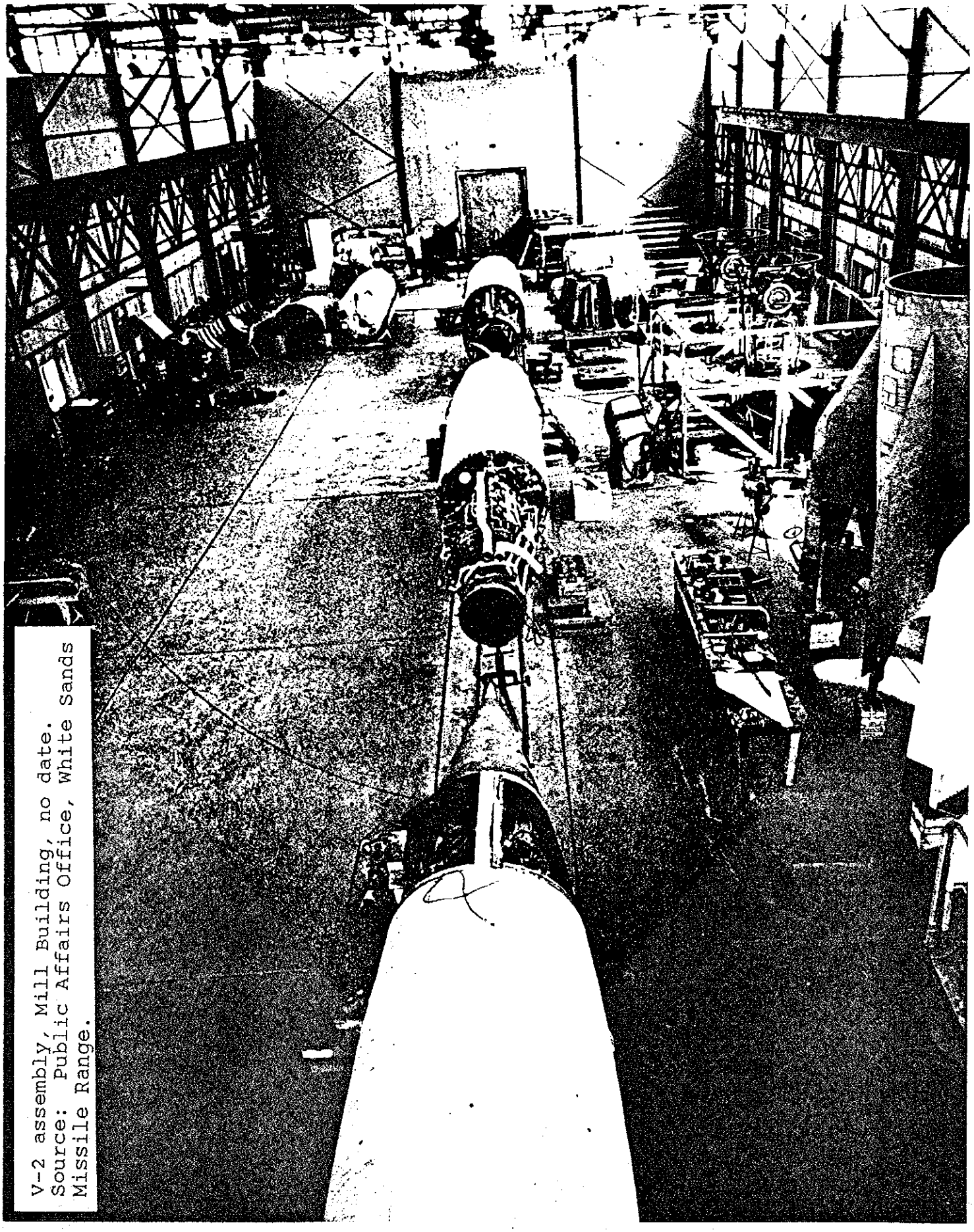
This project was part of a prgram initiated through a memorandum of agreement between the National Park Service and the U.S. Department of the Army. Stanley H. Fried, Chief, Real Estate Branch of Headquarters AMC, and Dr. Robert J. Kapsch, Chief of the Historic American Buildings Survey/ Historic American Engineering Record, were program directors. Sally Kress Tompkins of HABS/HAER was program manager, and Robie S. Lange of HABS/HAER was project manager. Under the direction of William A. Brenner, Building Technology Incorporated, Silver Spring, Maryland, acted as primary contractor, and MacDonald and Mack Partnership, Minneapolis, was a major subcontractor. This project included a survey of historic properties at White Sands Missile Range, as well as preparation of an historic properties report, and HAER documentation for Trinity Site and the McDonald Ranch. Written documentation was completed by Michael C. Quinn, and edited by William A. Brenner. Photographs were taken by Thomas Moore and George Baird of the White Sands Missile Range Photographic Laboratory, and by Dennett, Muessig, Ryan Associates, Iowa City, Iowa. Measured drawings were produced by Cheryl Stewart, Julie Perkins, and Leonard Kliwinski.



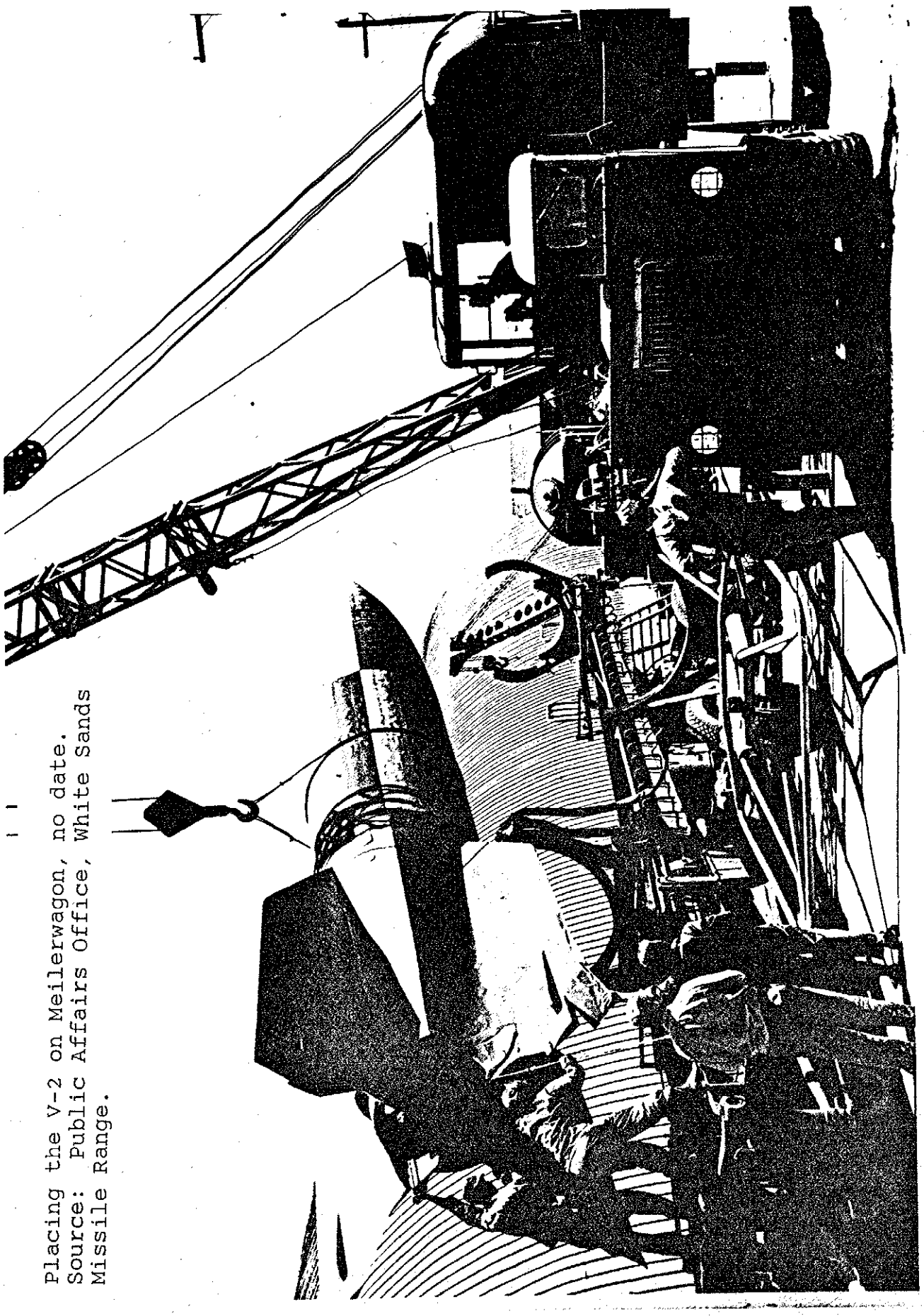
V-2 being strapped to Meilerwagon in the Mill Building, early 1948. Source: Public Affairs Office, White Sands Missile Range.



V-2 assembly, Mill Building, early 1948.
Source: Public Affairs Office, White Sands Missile Range.



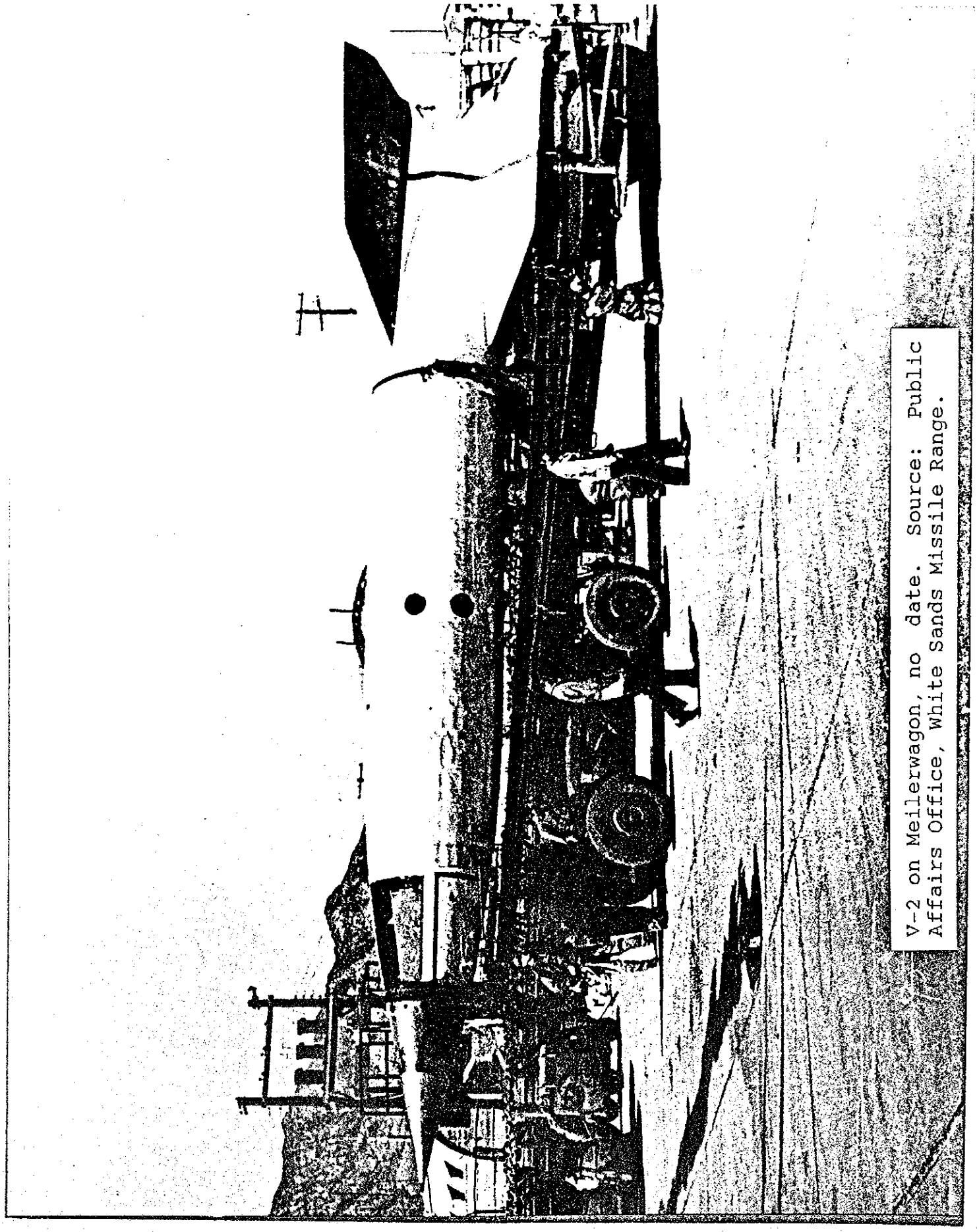
V-2 assembly, Mill Building, no date.
Source: Public Affairs Office, White Sands Missile Range.



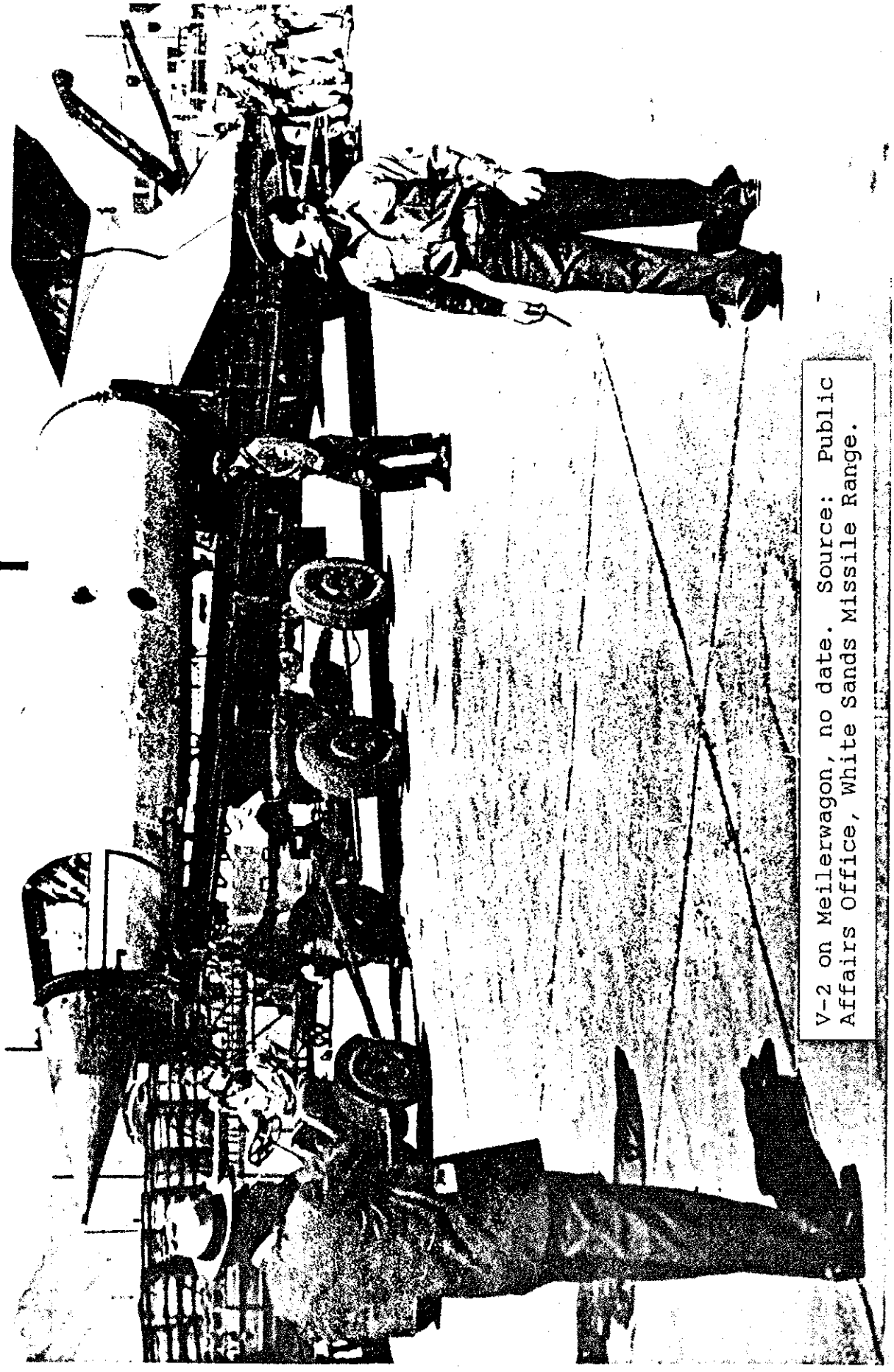
Placing the V-2 on Meilerwagon, no date.
Source: Public Affairs Office, White Sands Missile Range.

V-2 being loaded aboard trailer at Base

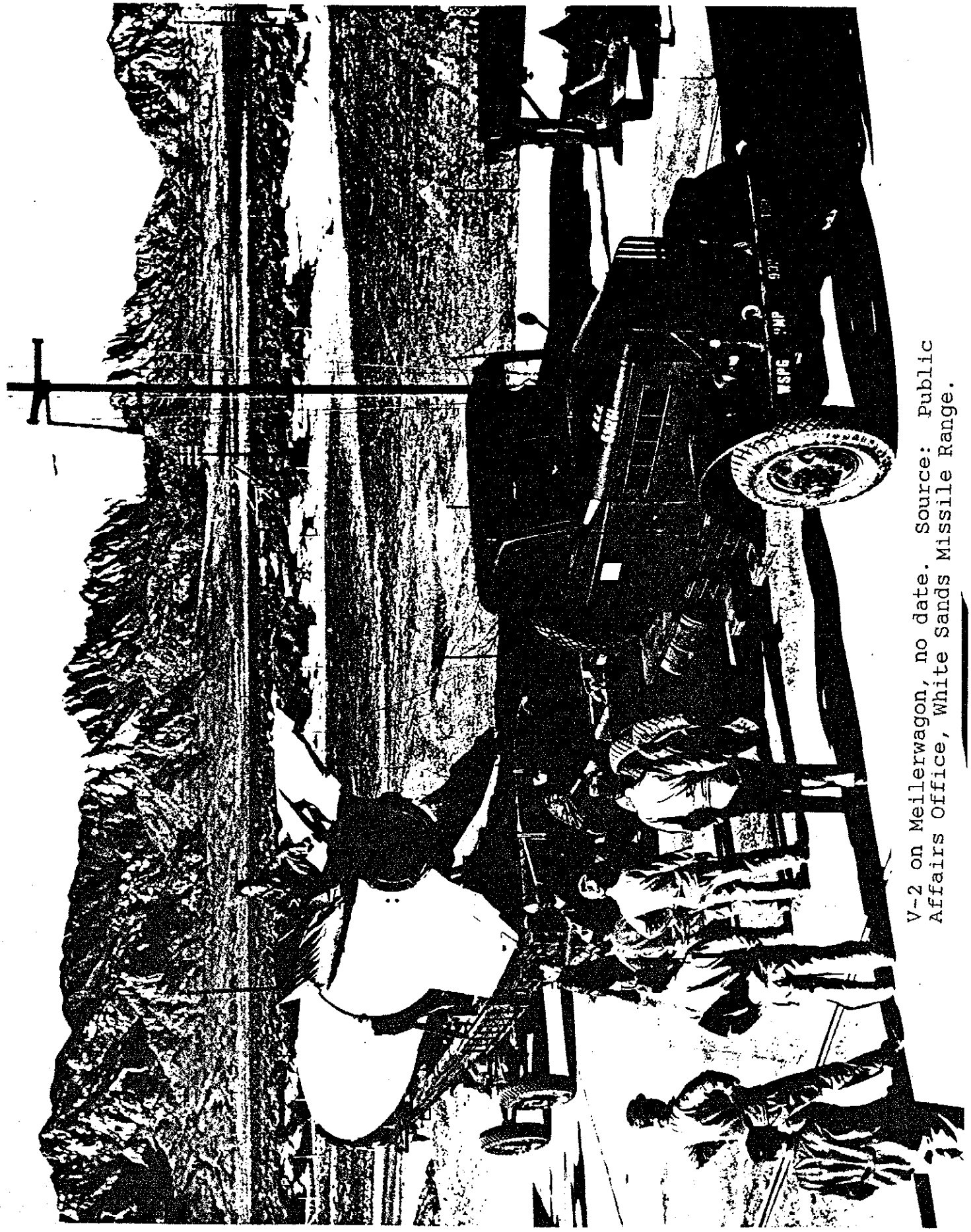
U.S. Army Ordnance Proving Ground, White Sands, N.M.



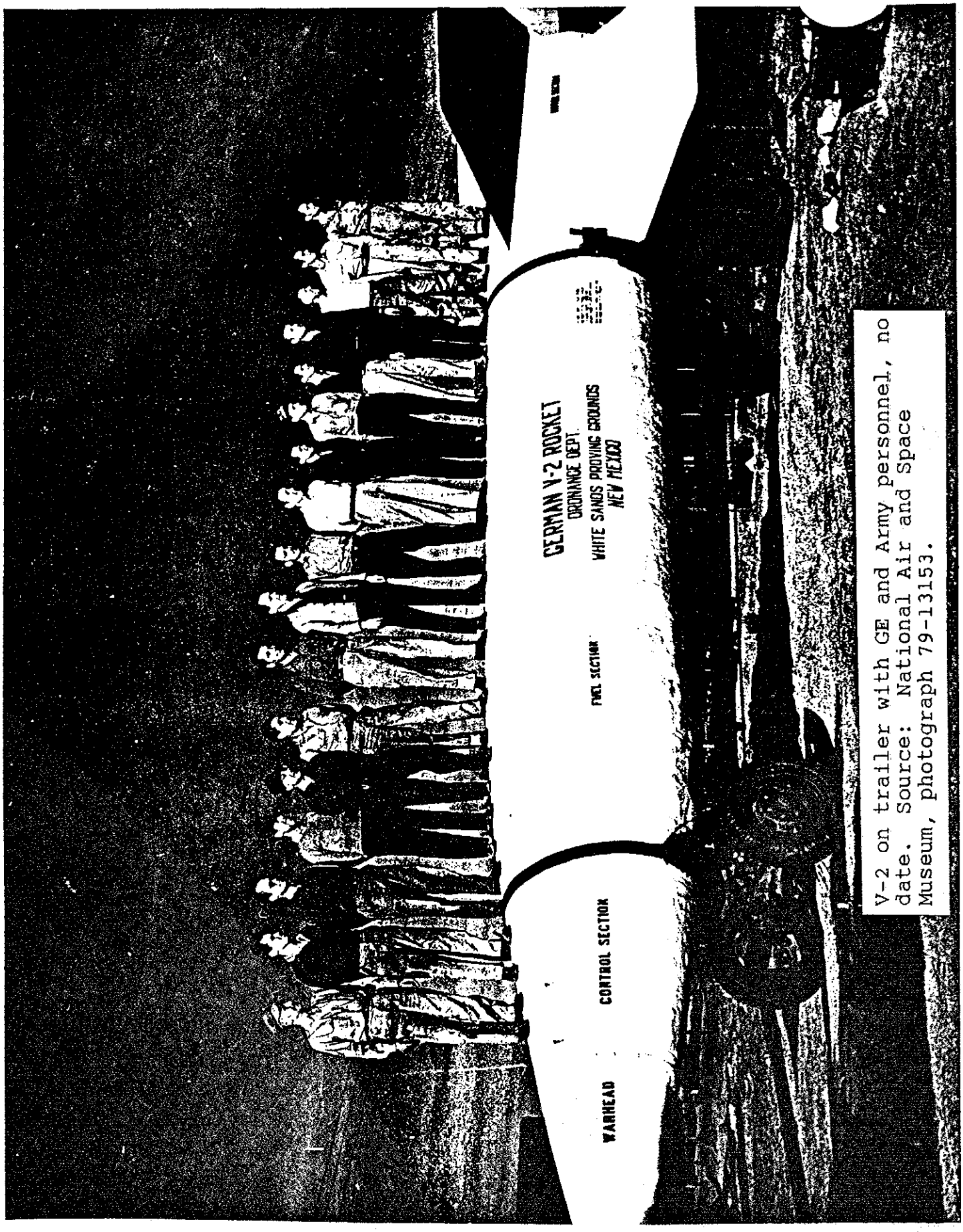
V-2 on Meilerwagon, no date. Source: Public Affairs Office, White Sands Missile Range.



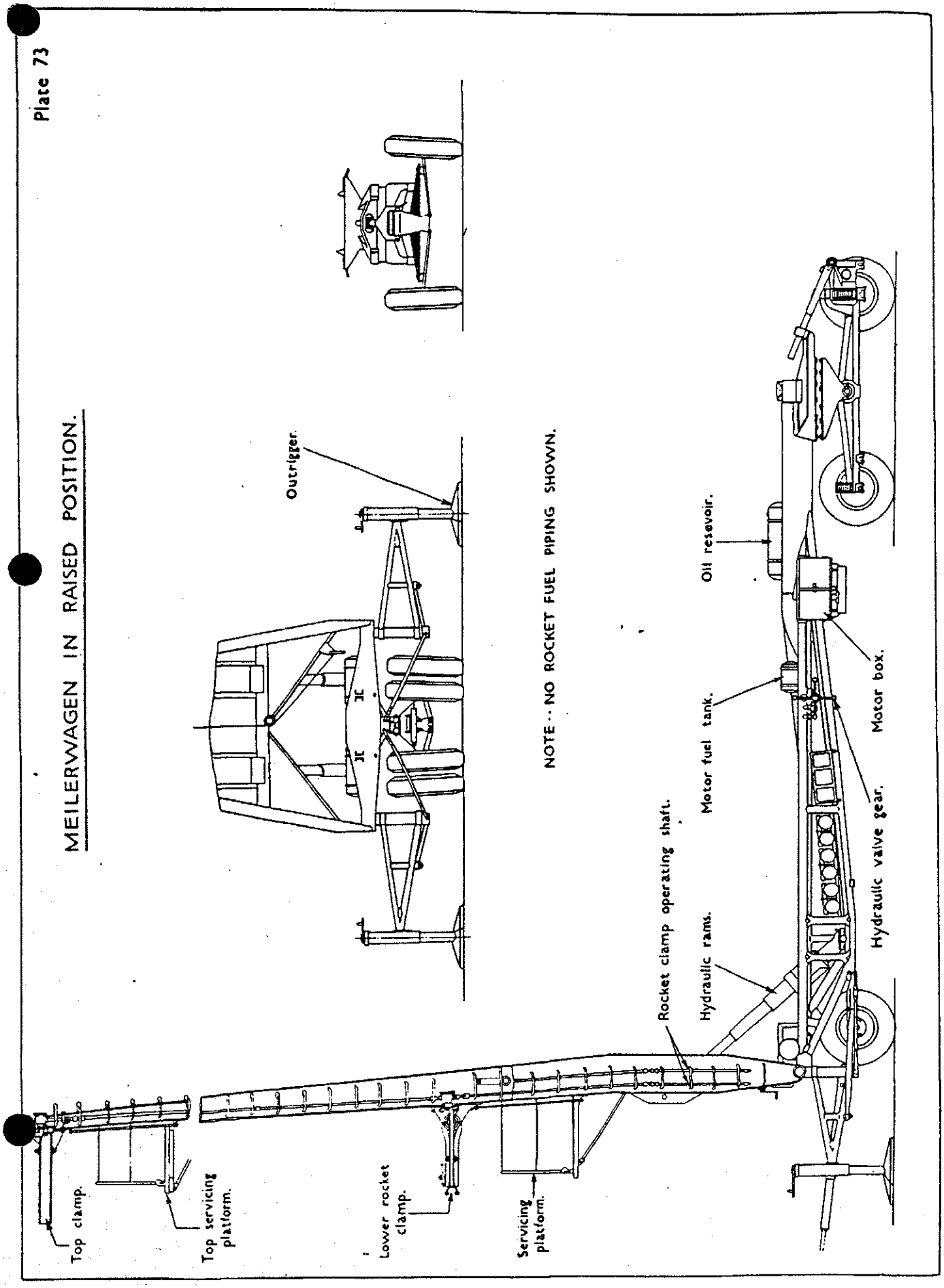
V-2 on Meilerwagon, no date. Source: Public Affairs Office, White Sands Missile Range.



V-2 on Meillerwagon, no date. Source: Public Affairs Office, White Sands Missile Range.



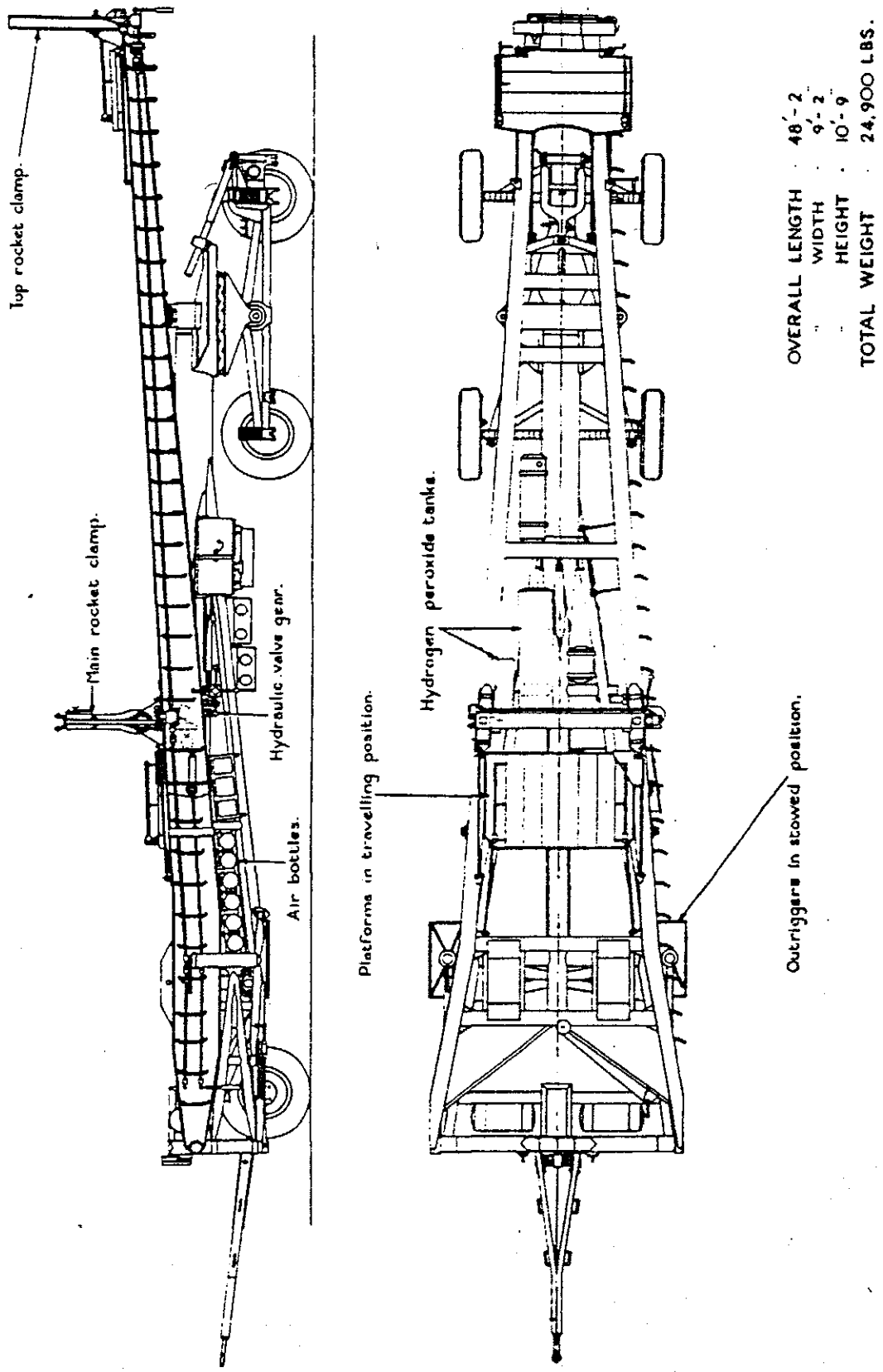
V-2 on trailer with GE and Army personnel, no date. Source: National Air and Space Museum, photograph 79-13153.



Meilerwagon schematics. Source: Great Britian War Office, Report on Operation Backfire, Ministry of Supply, London, 1946; National Air and Space Museum, photograph 79-13181.

Plate 72

MEILERWAGEN IN TRAVELLING POSITION.



Meilerwagon schematics. Source: Great Britian War Office, Report on Operation Backfire, Ministry of Supply, London, 1946; National Air and Space Museum, photograph 79-13182.

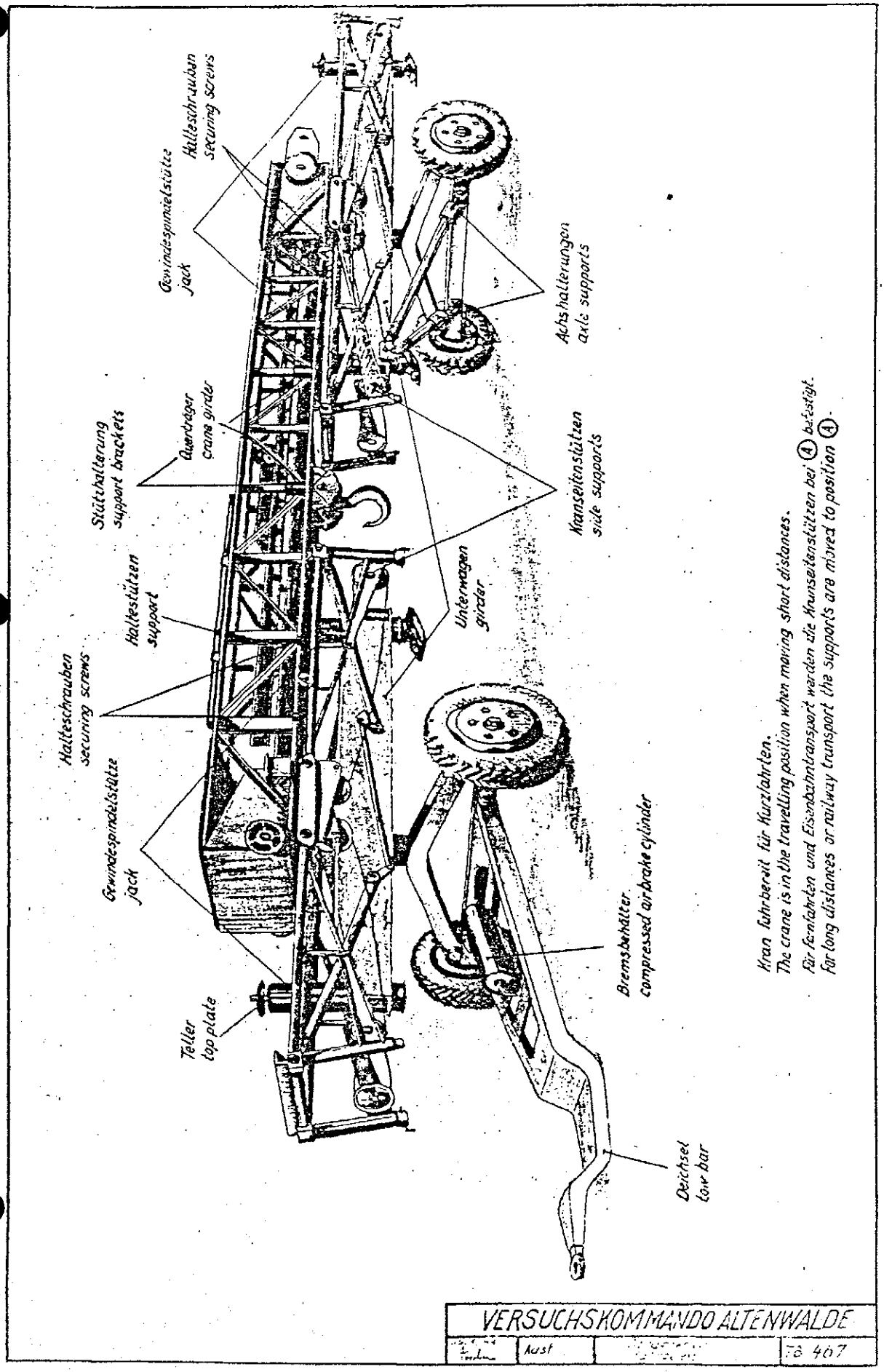


Diagram of V-2 Stabocrane, which was used by the Germans for lifting V-2 rockets in the field. Source: Altenwalde Versuchs Kommando, Die Fernrakete, 1945; National Air and Space Museum, photograph 79-13218.

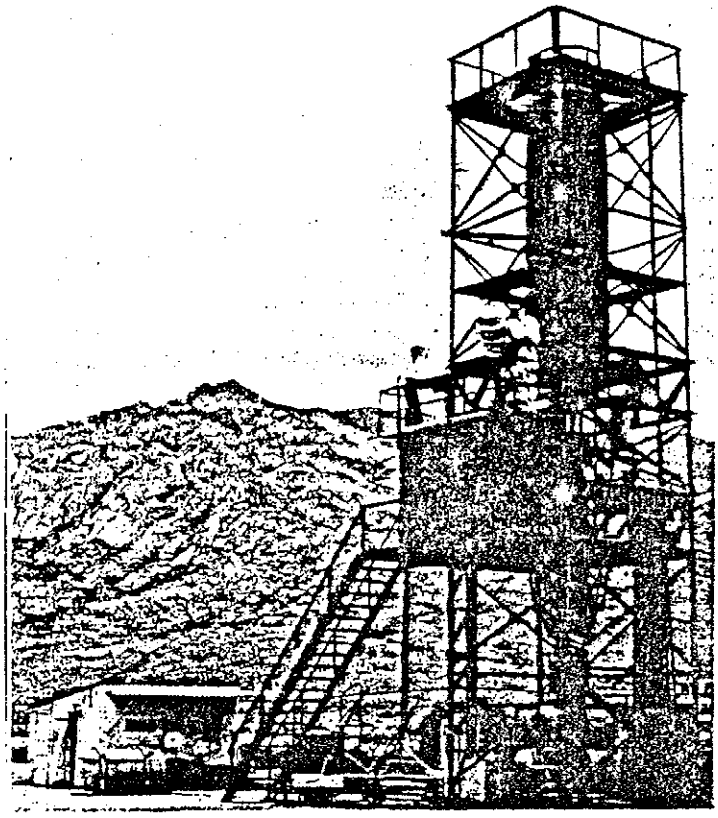
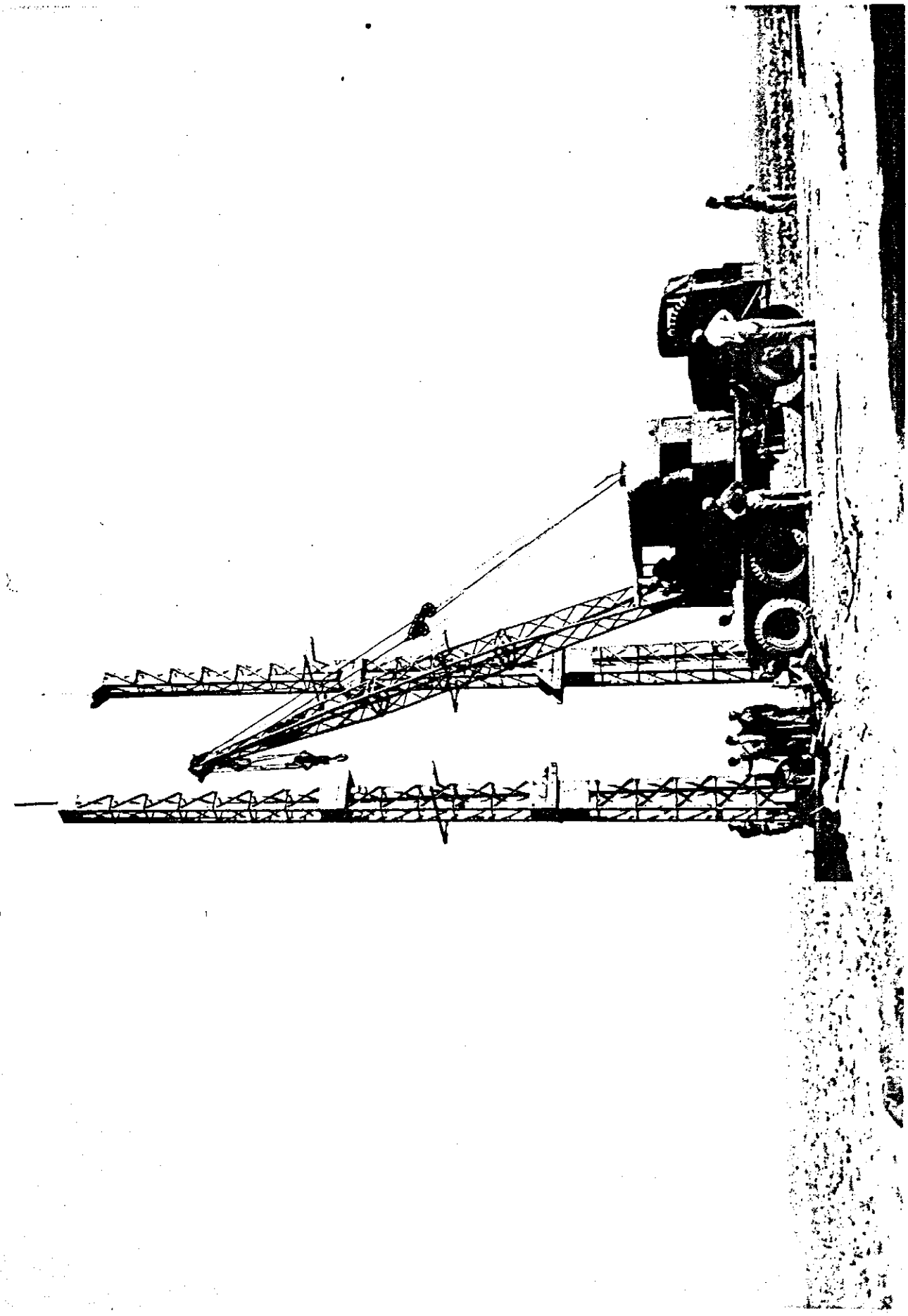
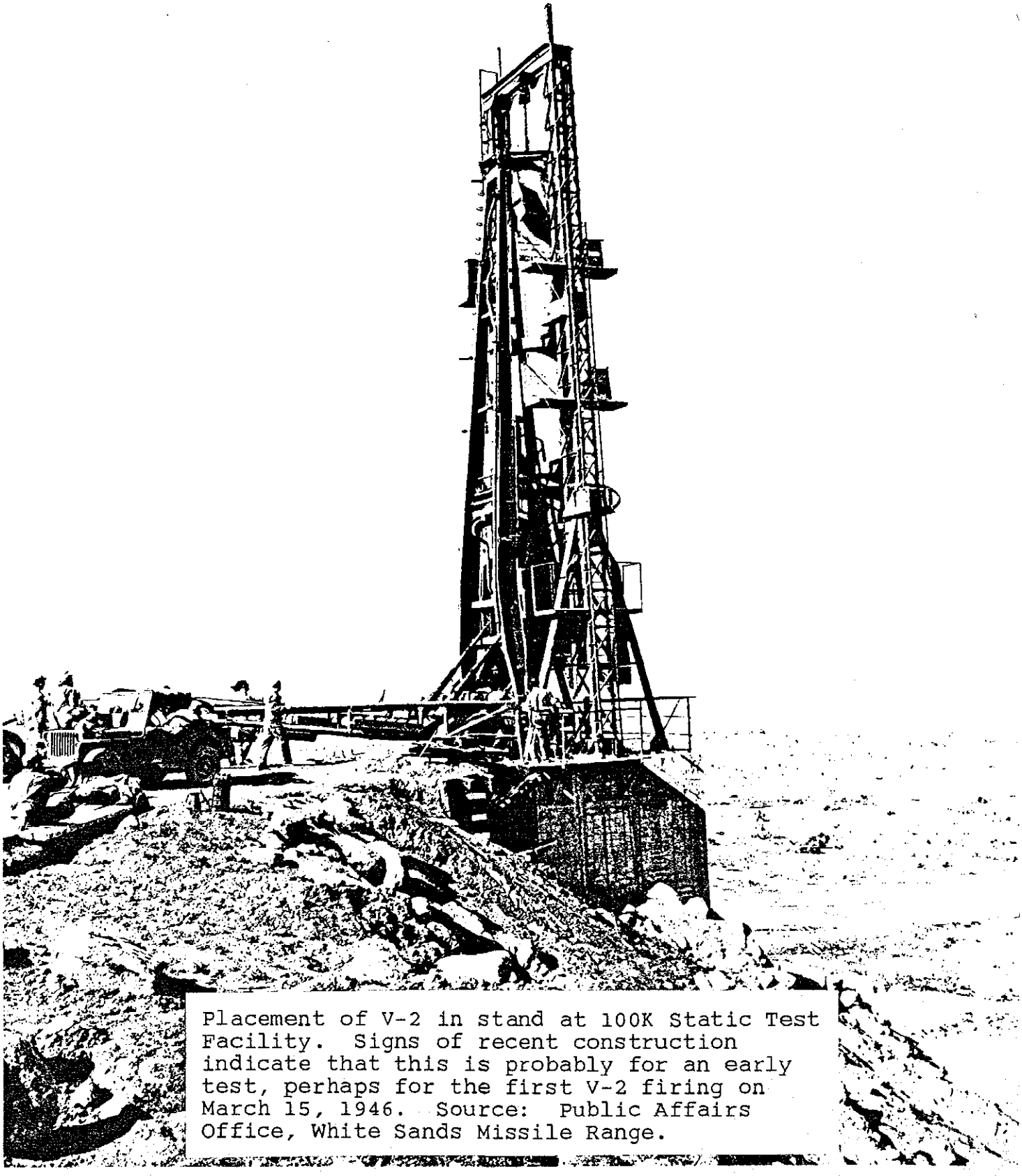


Fig. 11 Propulsion Unit Calibration Stand

Propulsion Unit Calibration Stand, view from southeast, no date. Source: General Electric Company, Final Report, Project Hermes V-2 Missile Program, 1952.

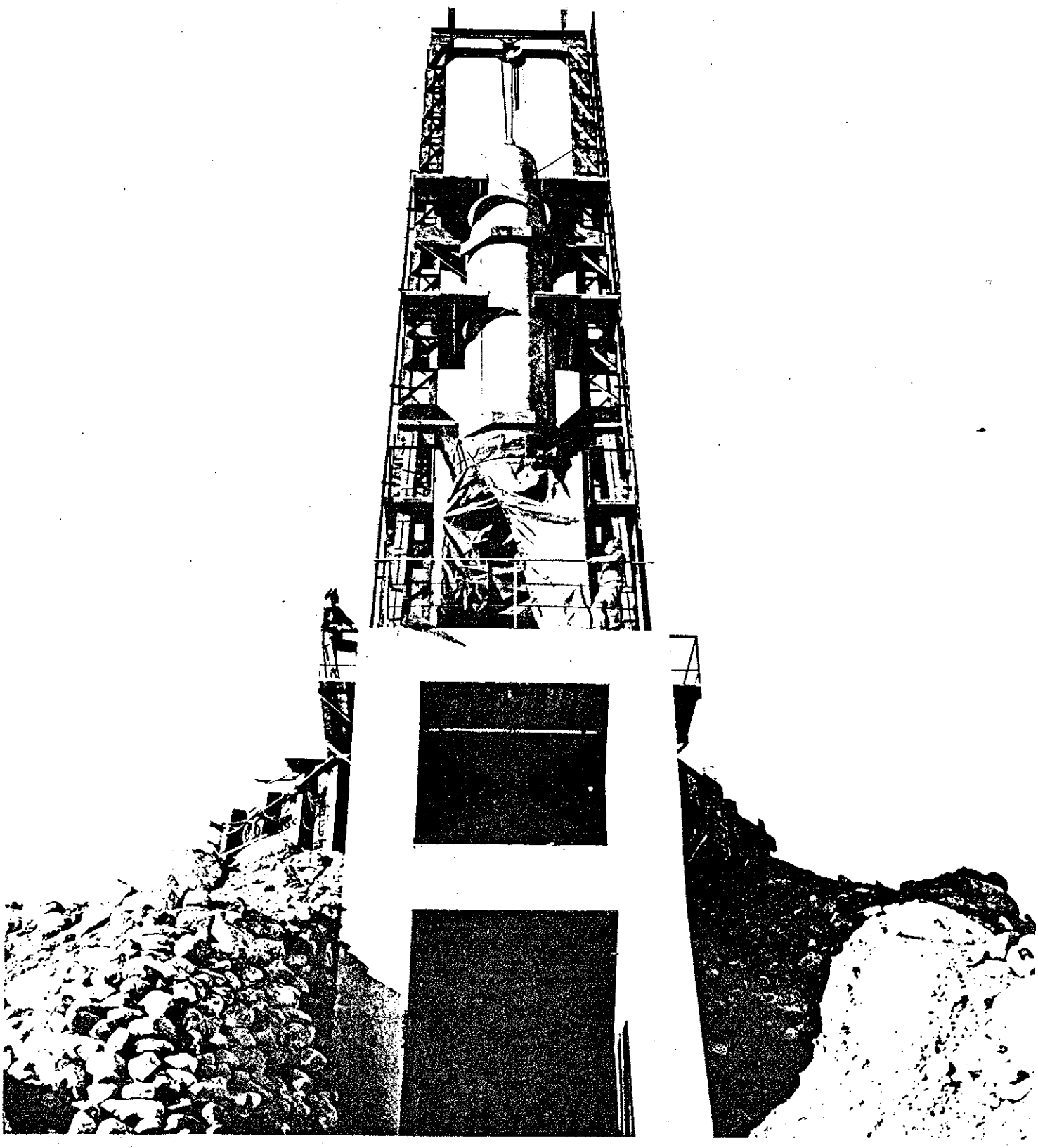


Erection of steel tower at 100K Static Test Facility, late 1945 or early 1946. Source: Public Affairs Office, White Sands Missile Range.

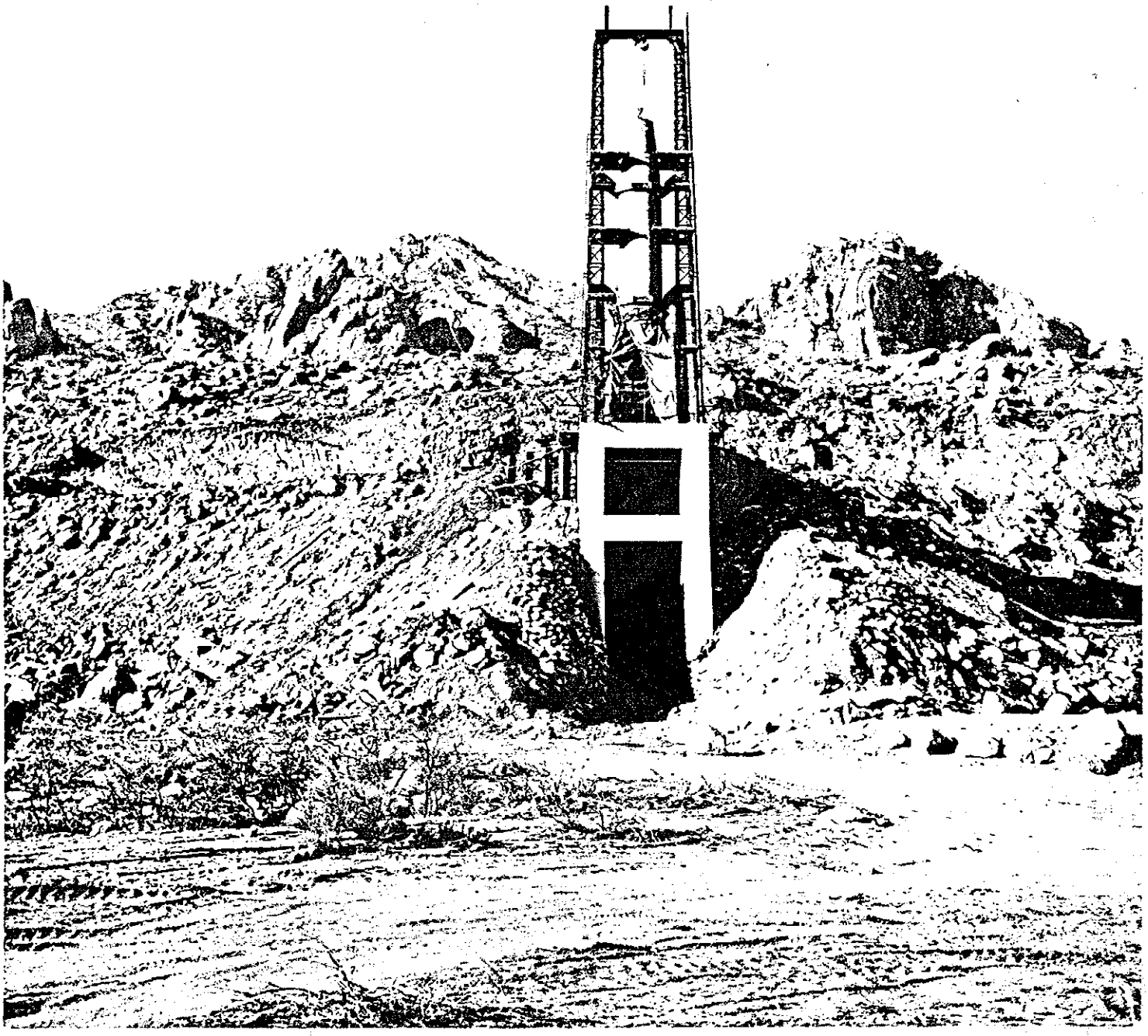


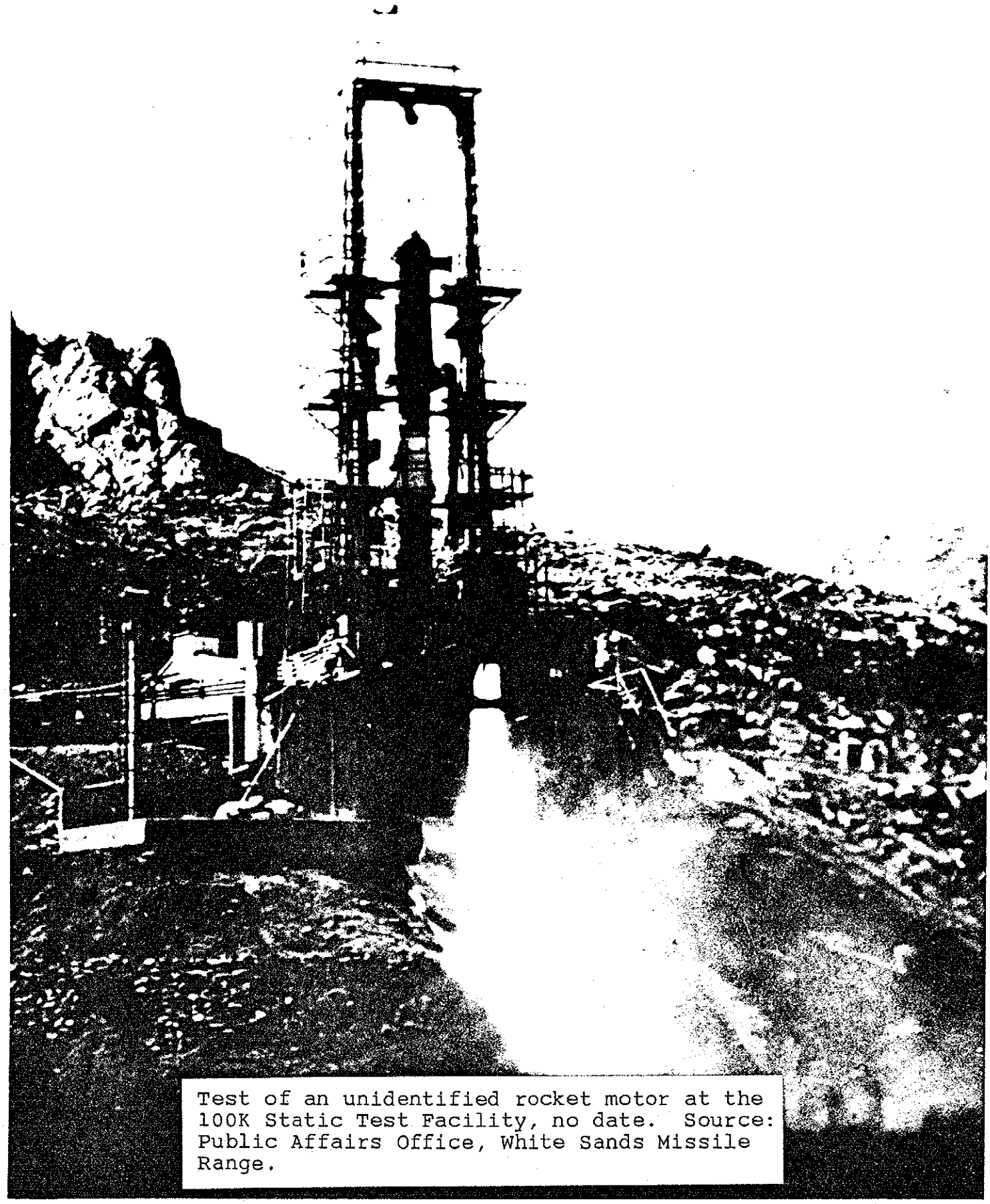
Placement of V-2 in stand at 100K Static Test Facility. Signs of recent construction indicate that this is probably for an early test, perhaps for the first V-2 firing on March 15, 1946. Source: Public Affairs Office, White Sands Missile Range.

V-2 in place at 100K Static Test Facility, perhaps March 1946. Source: Public Affairs Office, White Sands Missile Range.

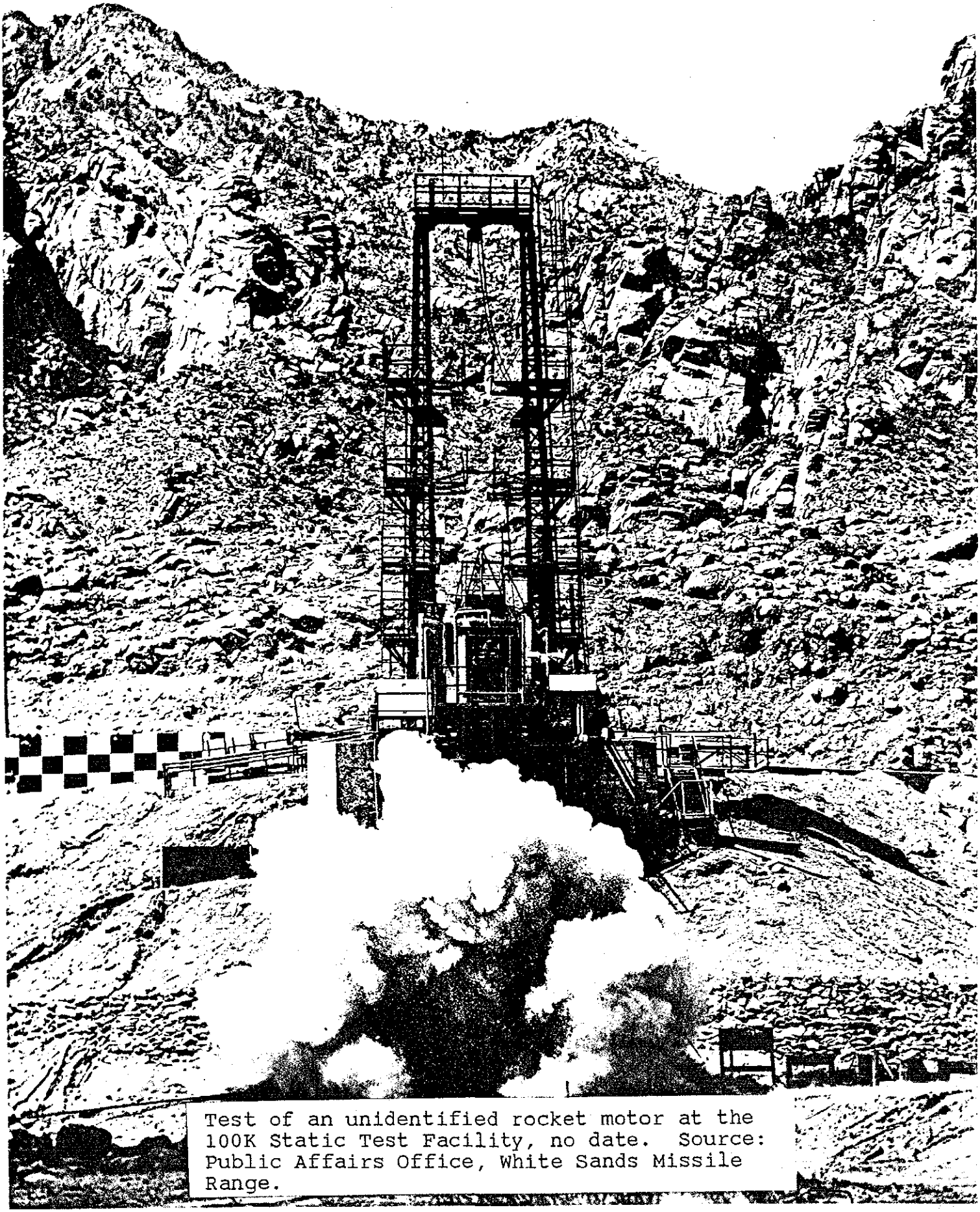


V-2 in place at 100K Static Test Facility, perhaps March 1946. Source: Public Affairs Office, White Sands Missile Range.





Test of an unidentified rocket motor at the 100K Static Test Facility, no date. Source: Public Affairs Office, White Sands Missile Range.



Test of an unidentified rocket motor at the 100K Static Test Facility, no date. Source: Public Affairs Office, White Sands Missile Range.

506 ROCKET ENCYCLOPEDIA ILLUSTRATED

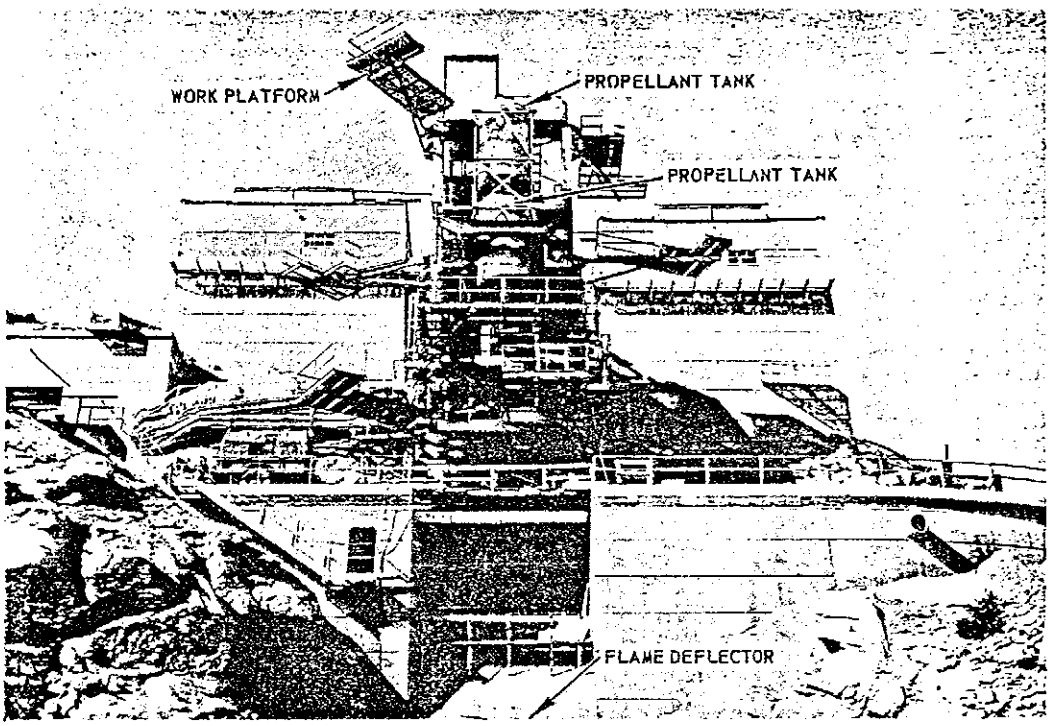
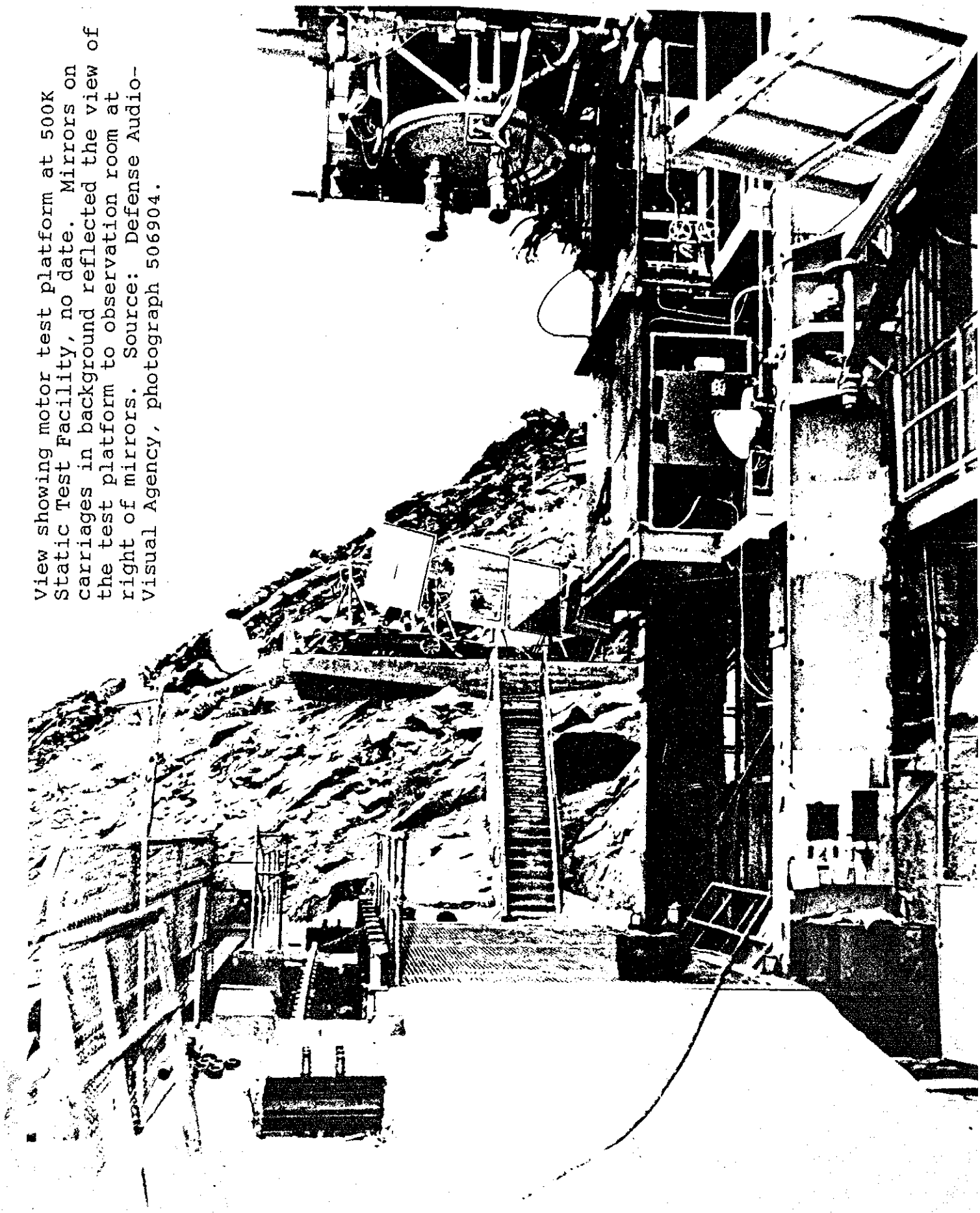
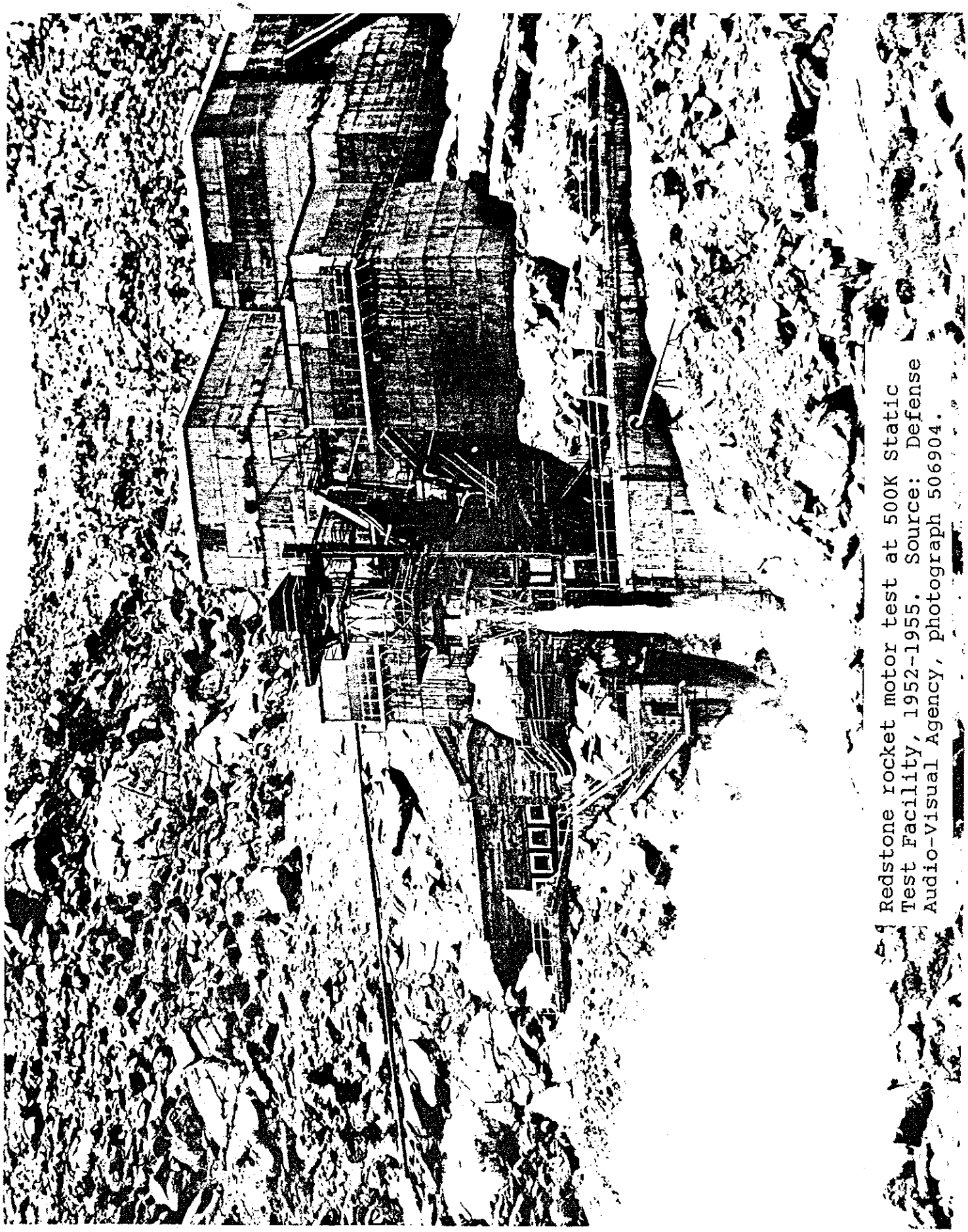


Fig. 392. 500,000 lb static test stand at White Sands Proving Ground.

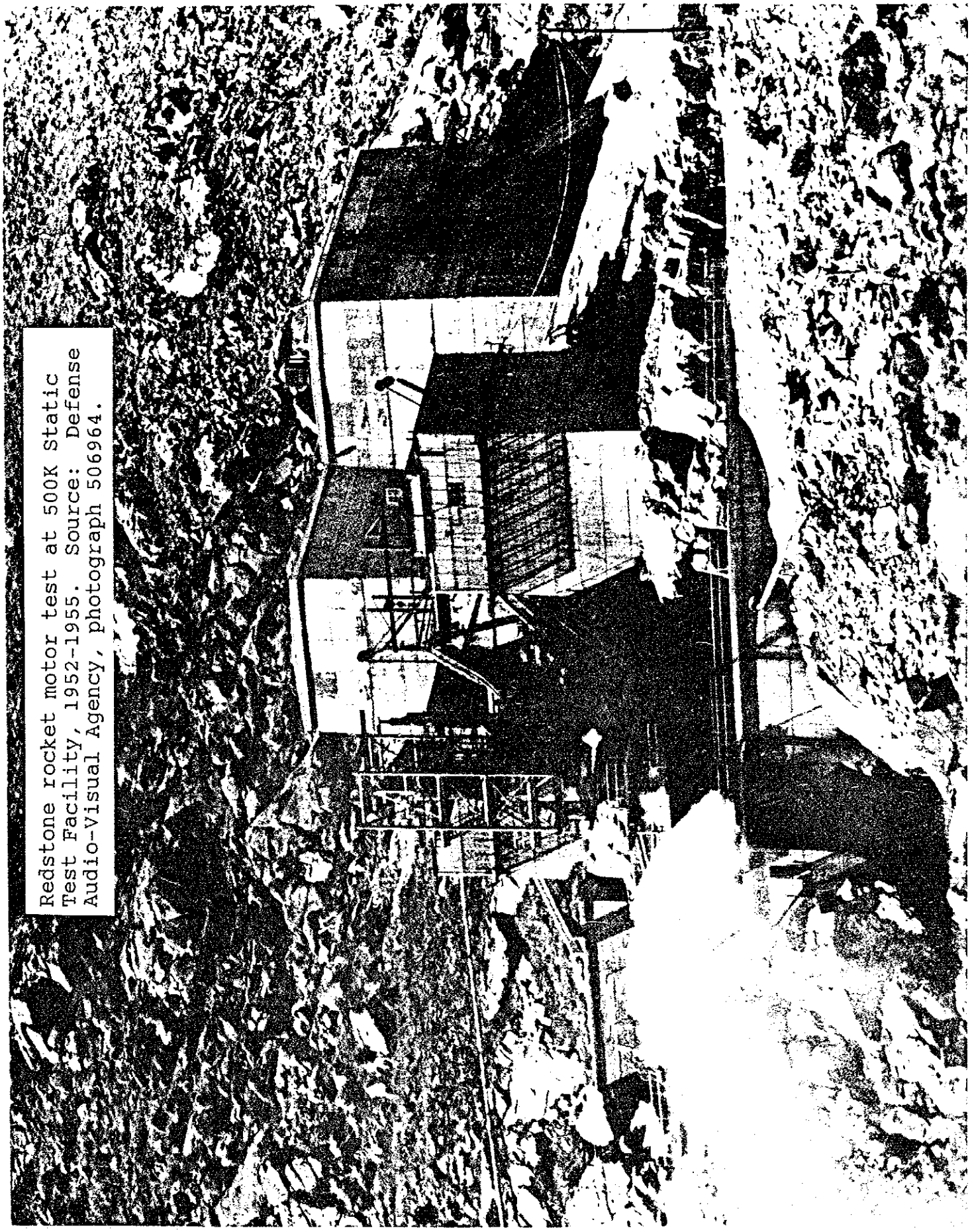
Labeled view of 500K Static Test Facility.
Source: John W. Herrick, Rocket Encyclopedia Illustrated, Aero Publishers, 1959.



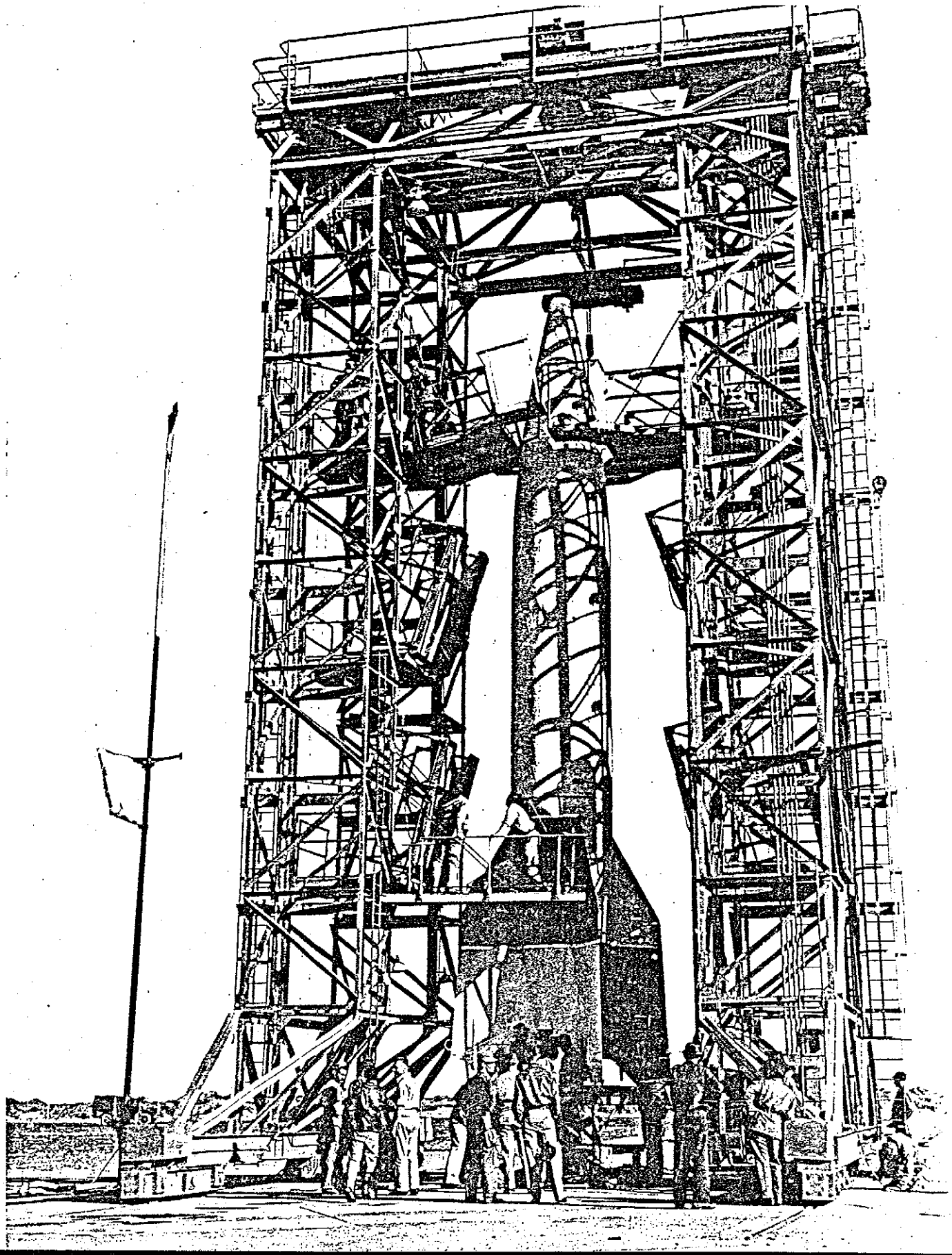
View showing motor test platform at 500K Static Test Facility, no date. Mirrors on carriages in background reflected the view of the test platform to observation room at right of mirrors. Source: Defense Audio-Visual Agency, photograph 506904.



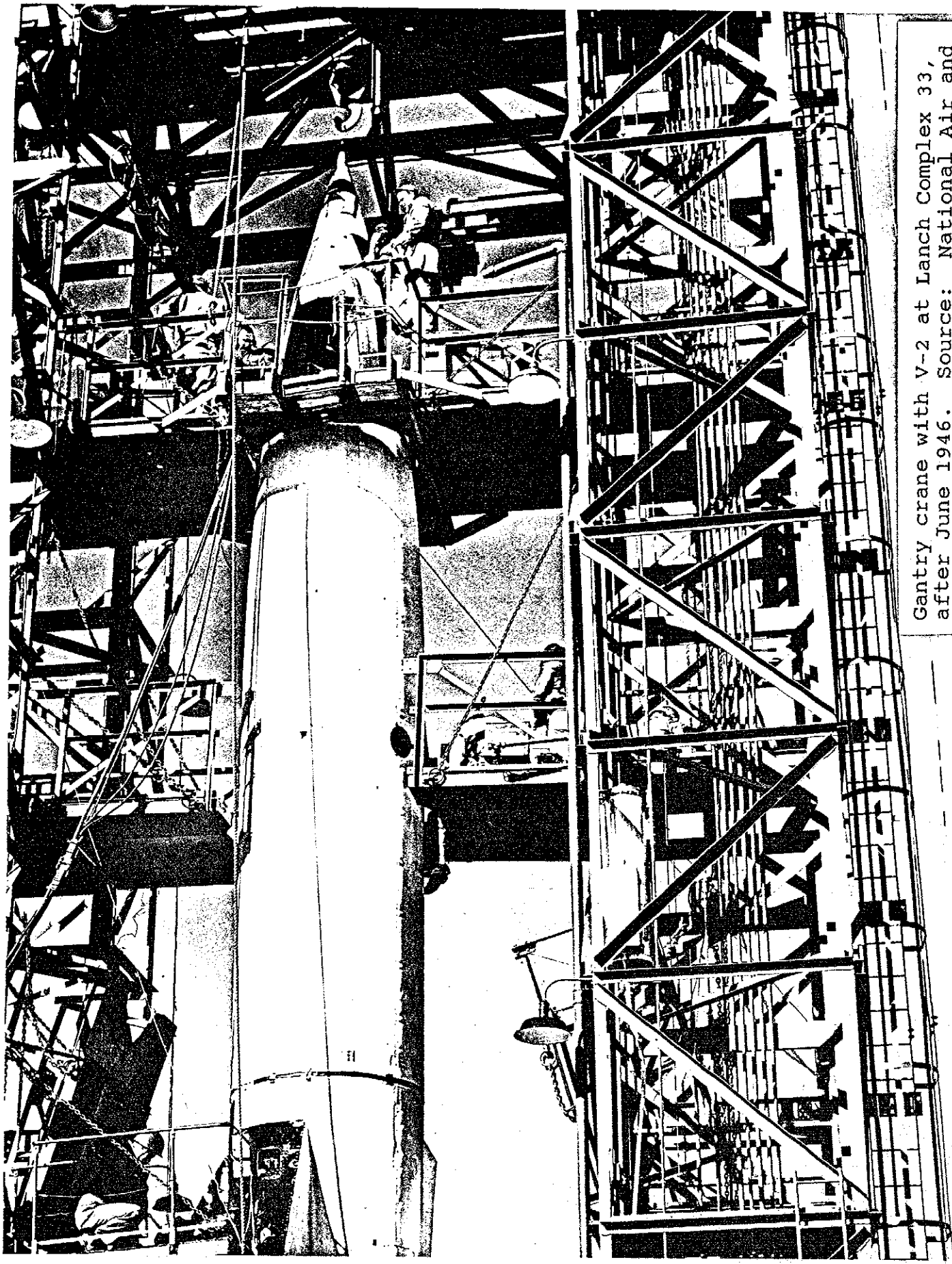
Redstone rocket motor test at 500K Static Test Facility, 1952-1955. Source: Defense Audio-Visual Agency, photograph 506904.



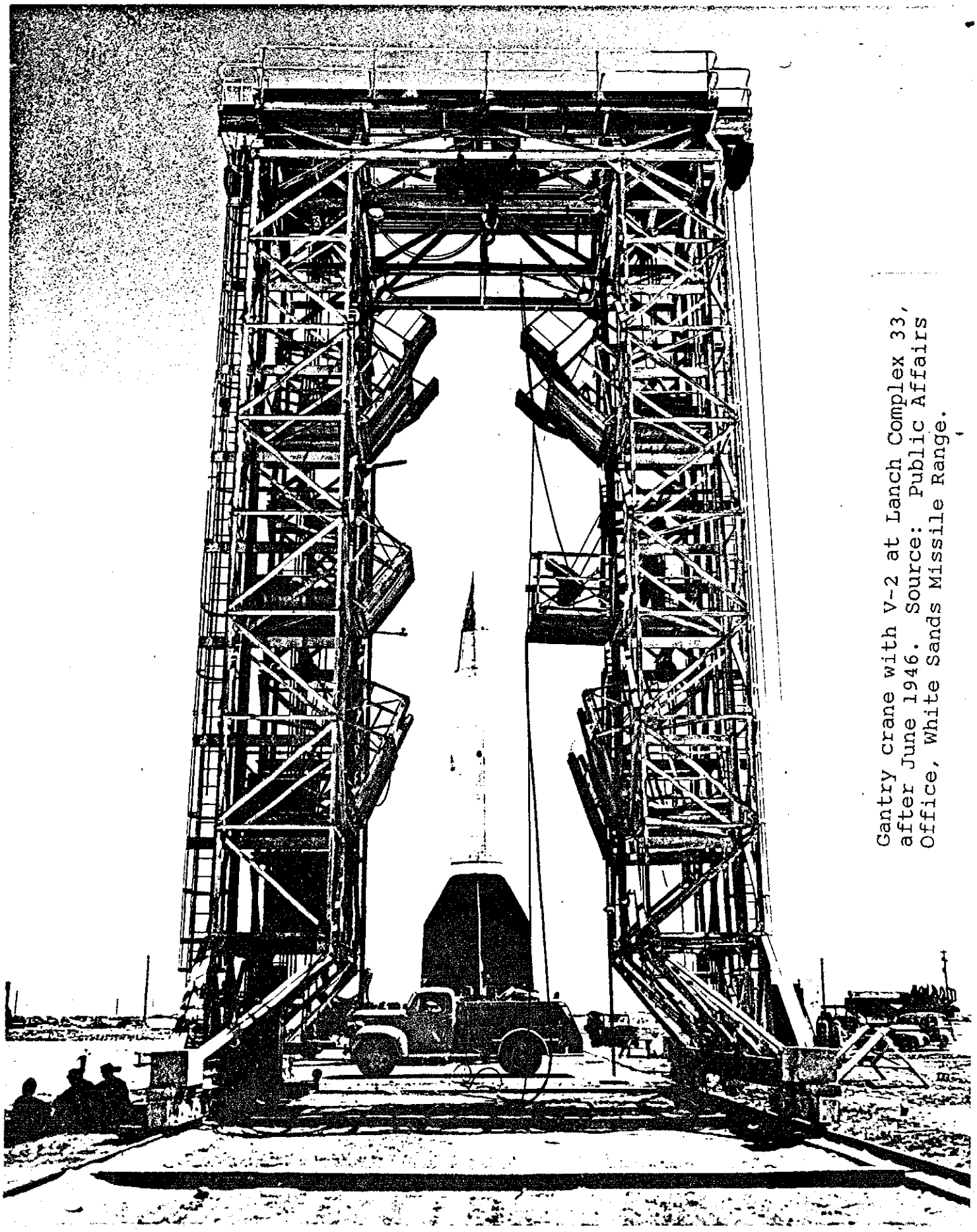
Redstone rocket motor test at 500K Static Test Facility, 1952-1955. Source: Defense Audio-Visual Agency, photograph 506964.



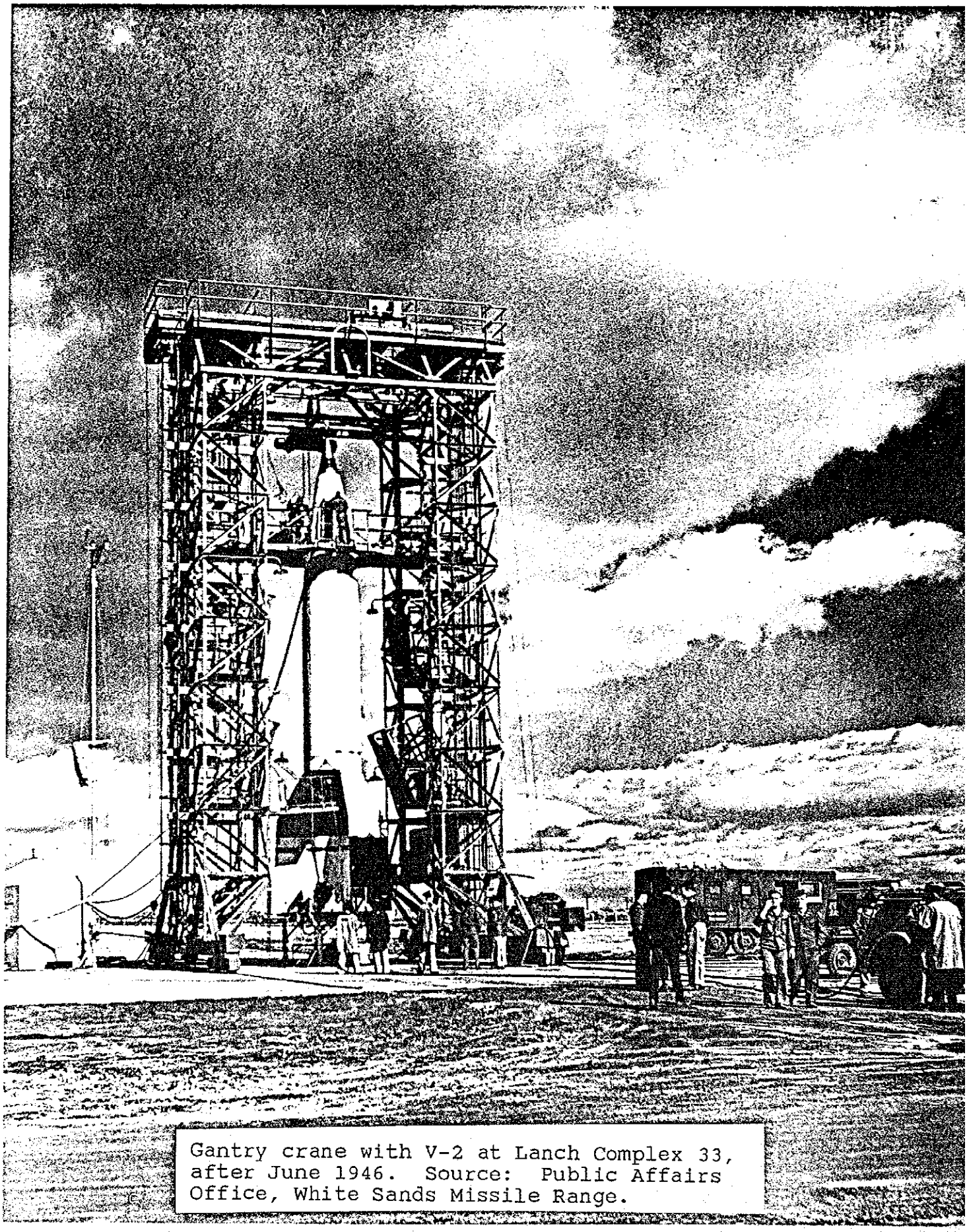
Gantry crane with V-2 at Lanch Complex 33, after June 1946. Source: National Air and Space Museum, photograph 79-1638.



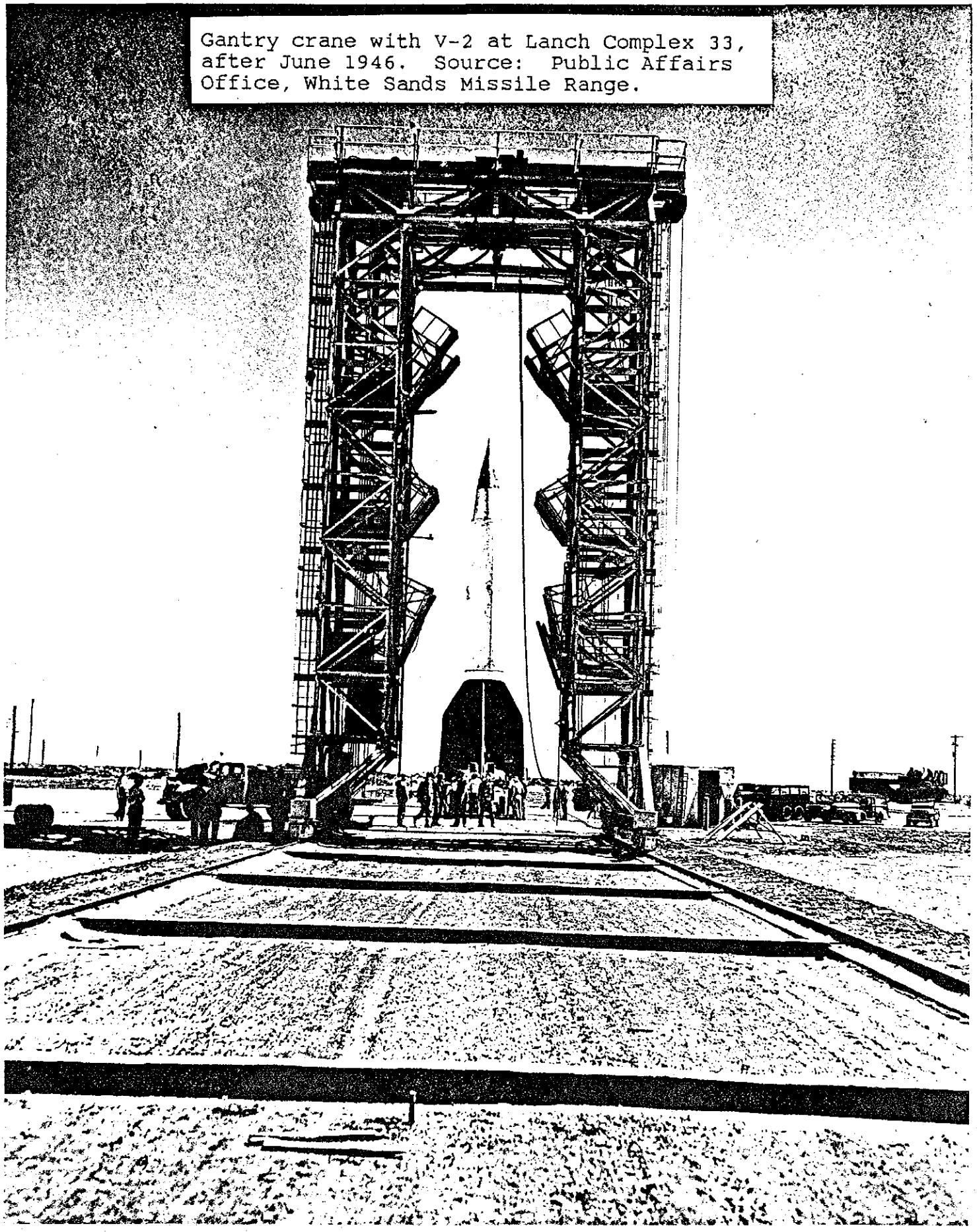
Gantry crane with V-2 at Lanch Complex 33, after June 1946. Source: National Air and Space Museum, photograph 79-1638.



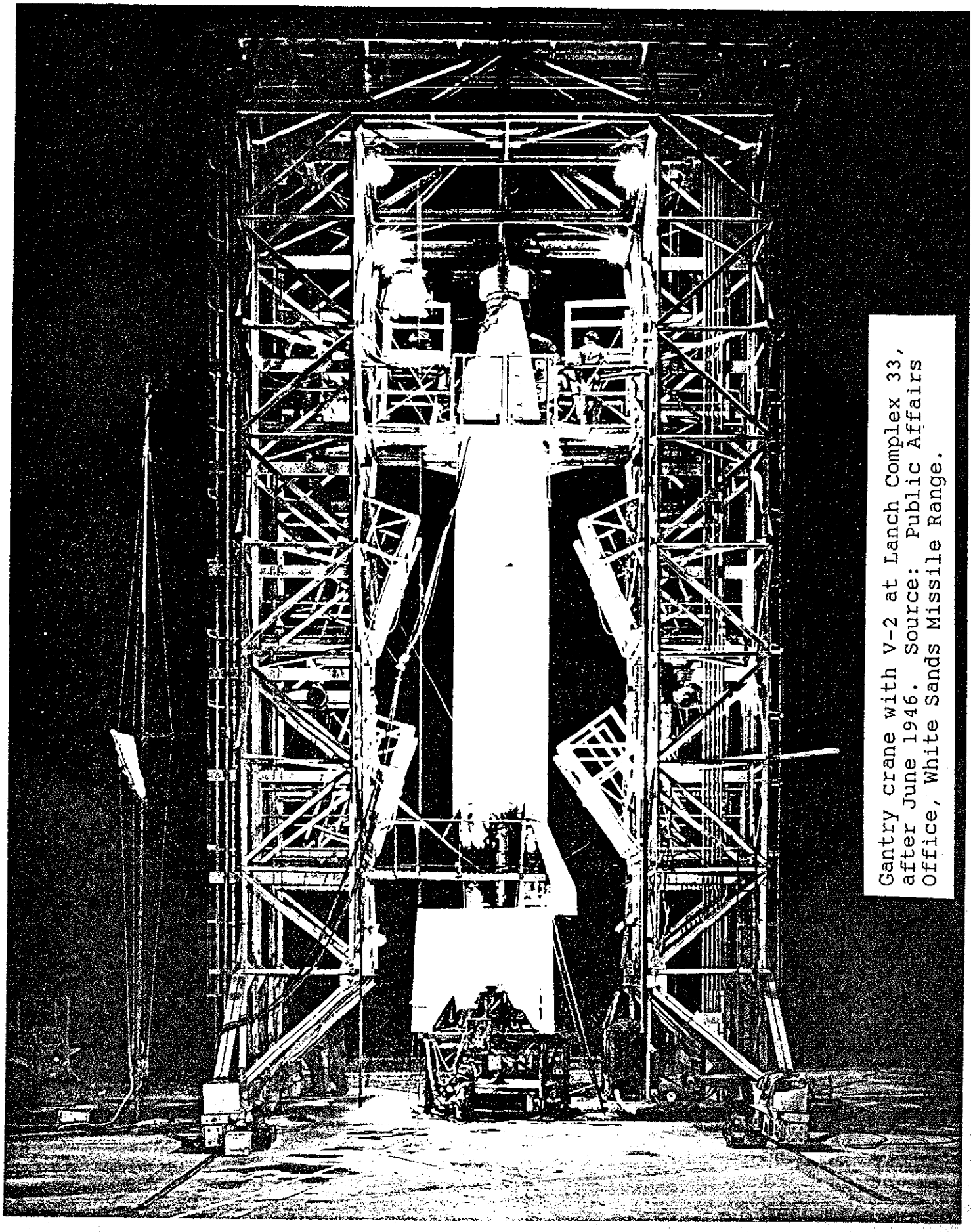
Gantry crane with V-2 at Lanch Complex 33, after June 1946. Source: Public Affairs Office, White Sands Missile Range.



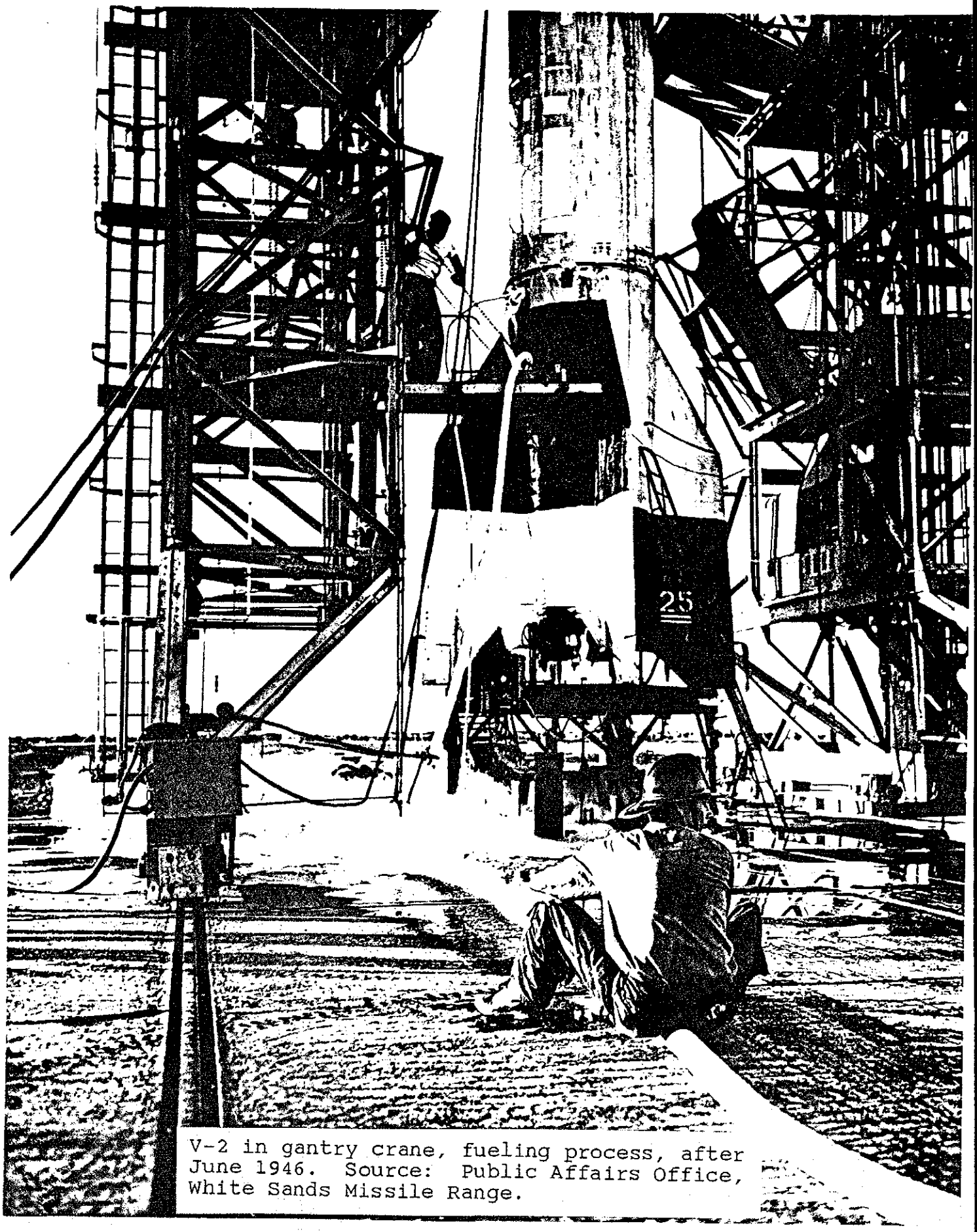
Gantry crane with V-2 at Lanch Complex 33, after June 1946. Source: Public Affairs Office, White Sands Missile Range.



Gantry crane with V-2 at Lanch Complex 33, after June 1946. Source: Public Affairs Office, White Sands Missile Range.

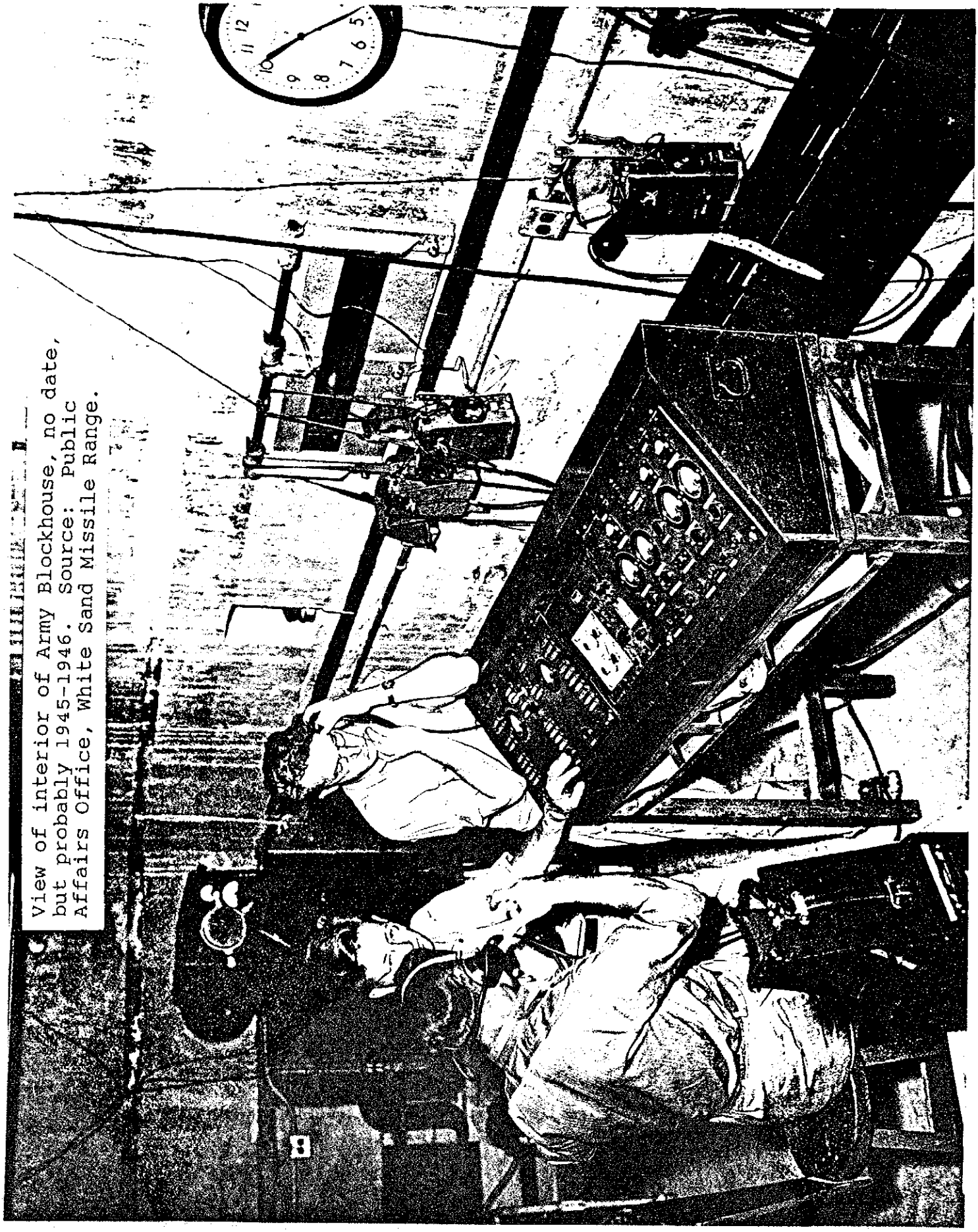


Gantry crane with V-2 at Lanch Complex 33, after June 1946. Source: Public Affairs Office, White Sands Missile Range.

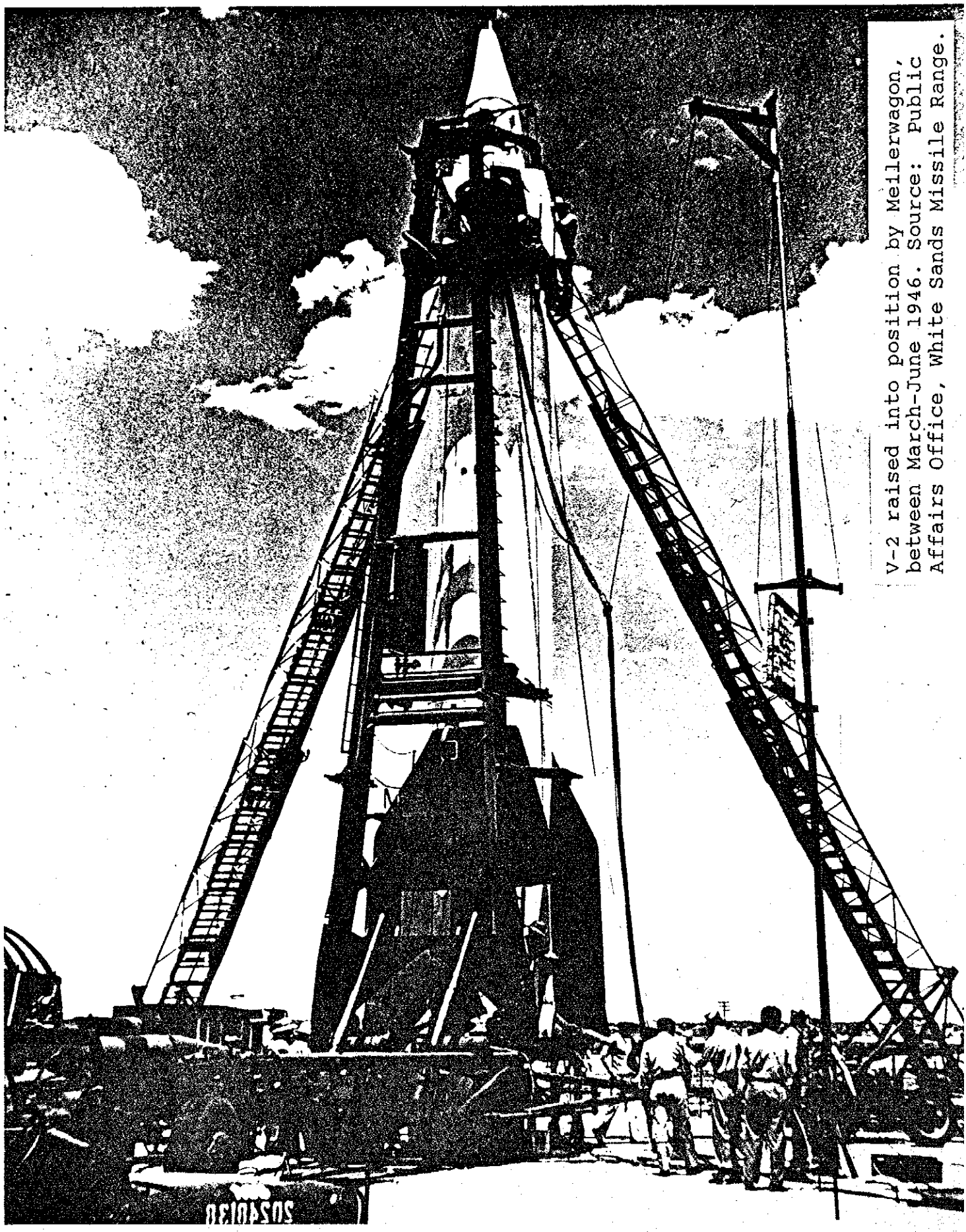


V-2 in gantry crane, fueling process, after June 1946. Source: Public Affairs Office, White Sands Missile Range.

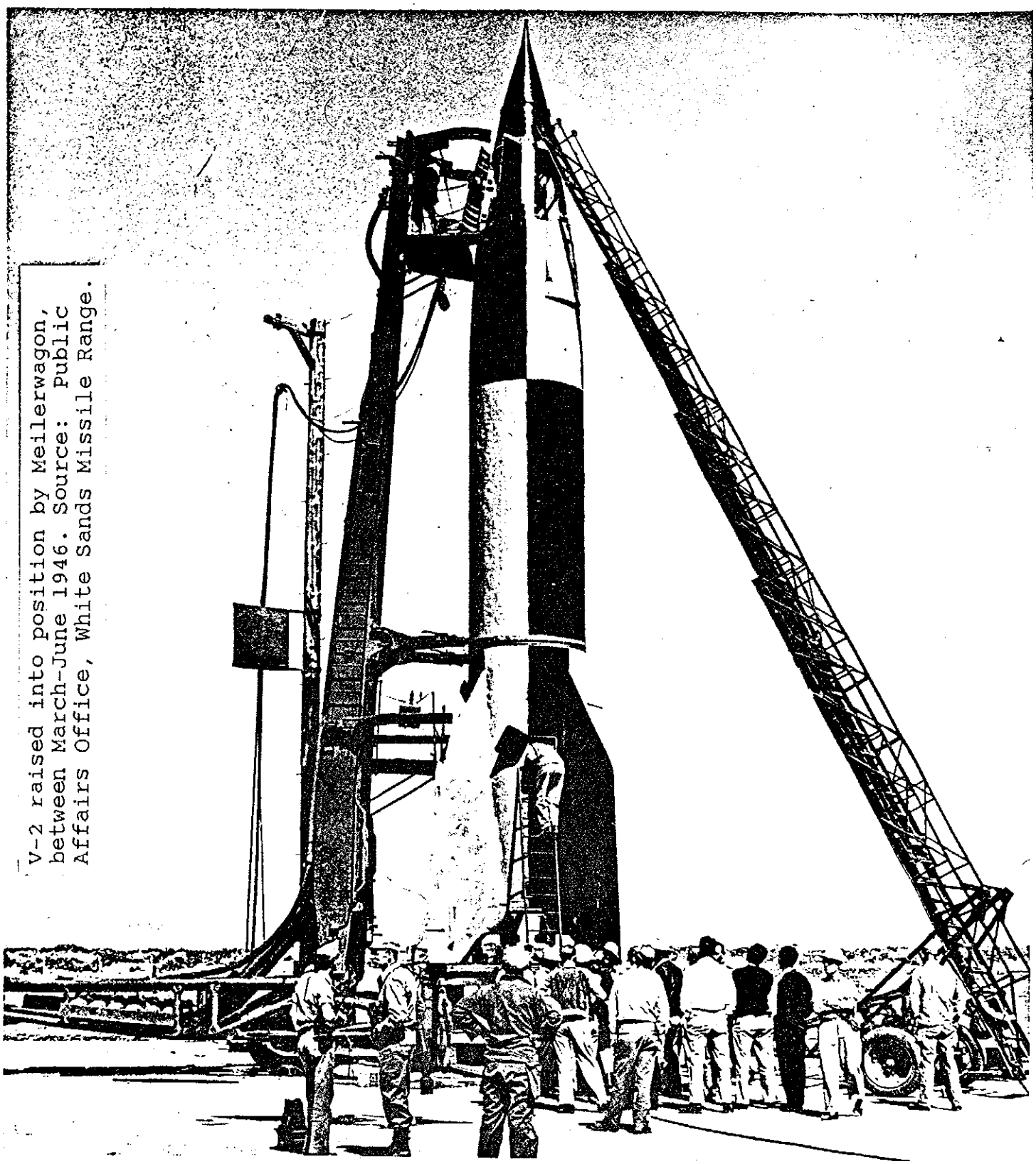
V-2 in gantry crane, fueling process, after June 1946. Source: Public Affairs Office, White Sands Missile Range.



View of interior of Army Blockhouse, no date, but probably 1945-1946. Source: Public Affairs Office, White Sand Missile Range.

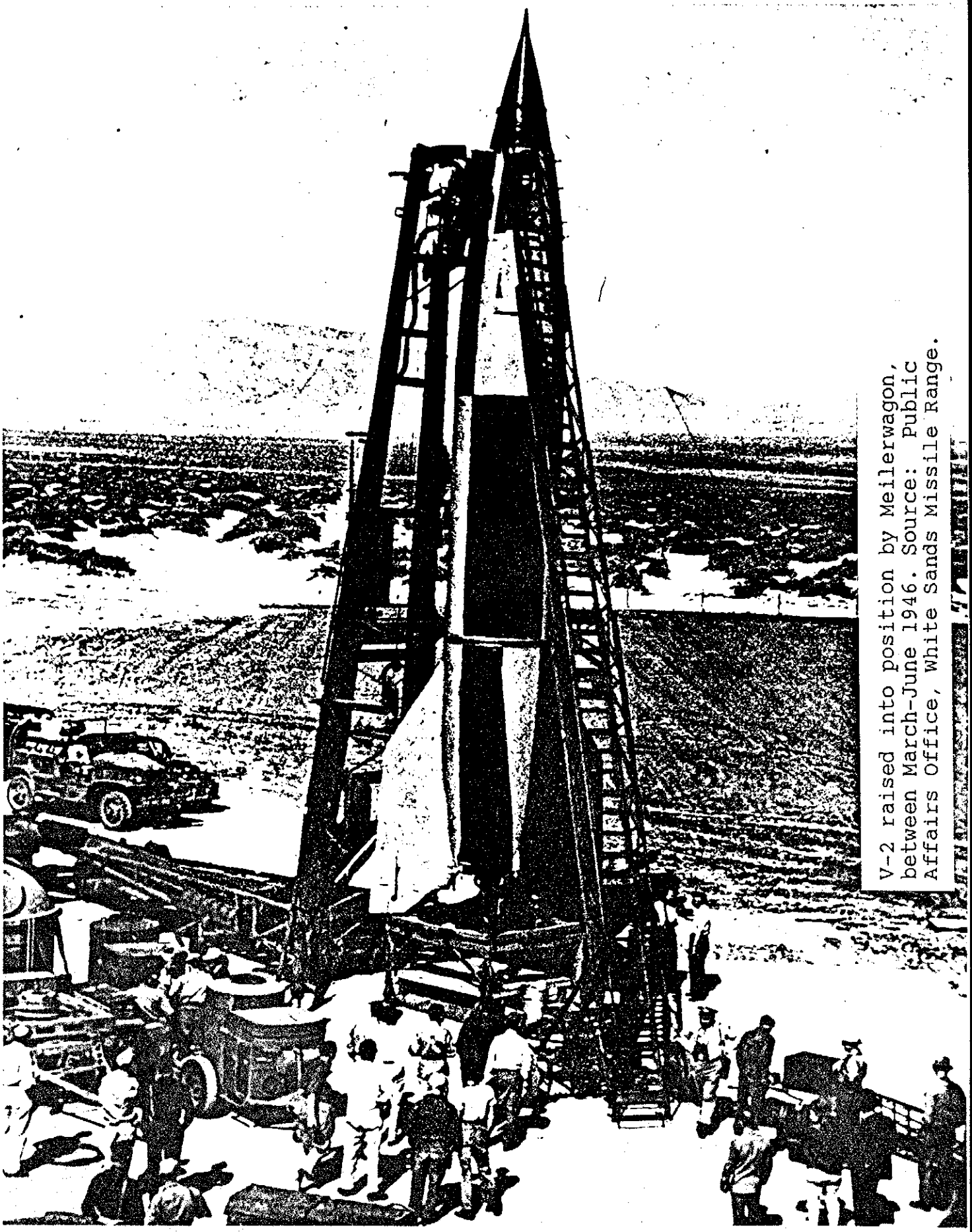


V-2 raised into position by Meilerwagon, between March-June 1946. Source: Public Affairs Office, White Sands Missile Range.

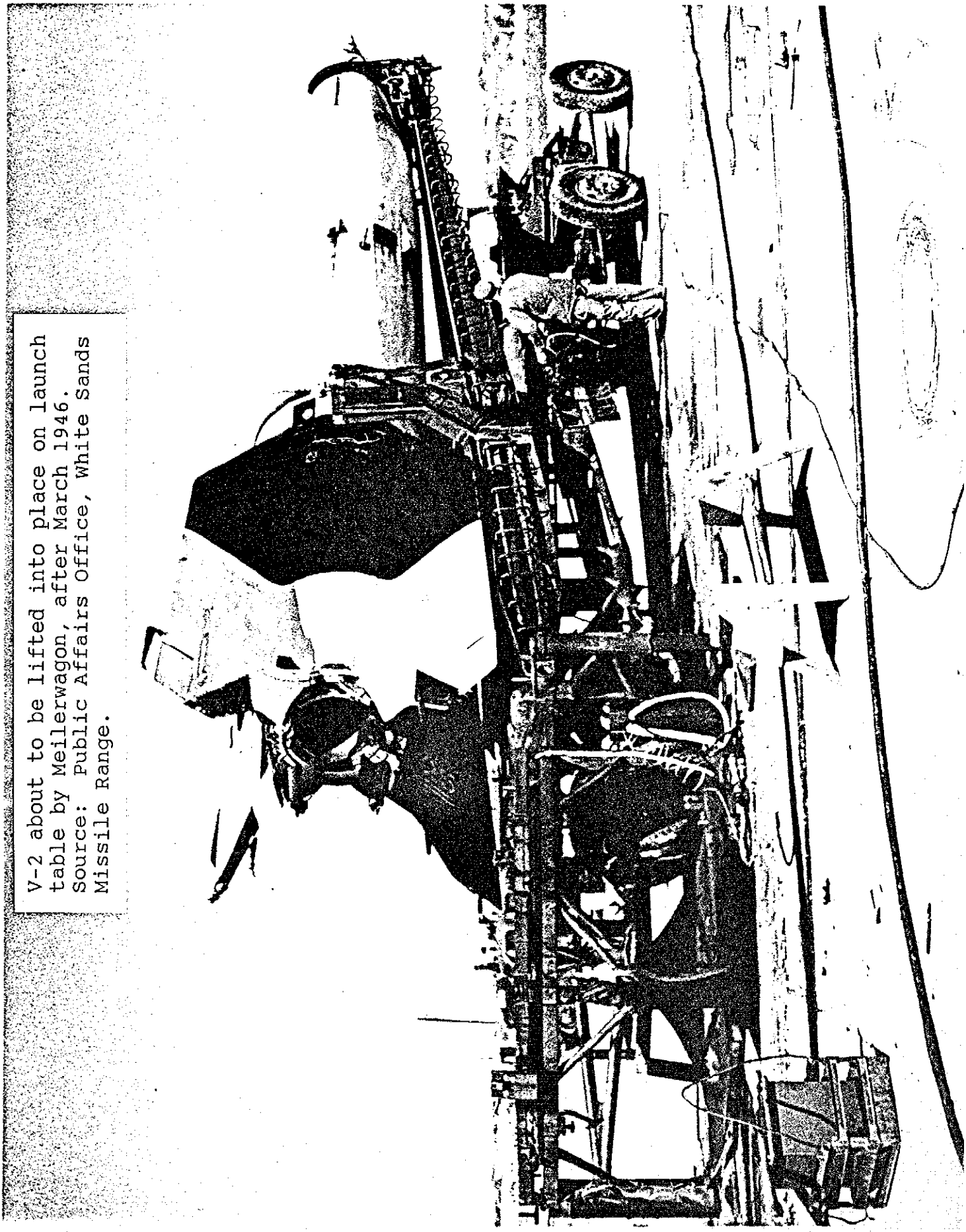


V-2 raised into position by Meilerwagon, between March-June 1946. Source: Public Affairs Office, White Sands Missile Range.

Final adjustments to delicate instruments
Used to control flight of V-2
U.S. Army Ordnance Proving Ground, White Sands, N.M.



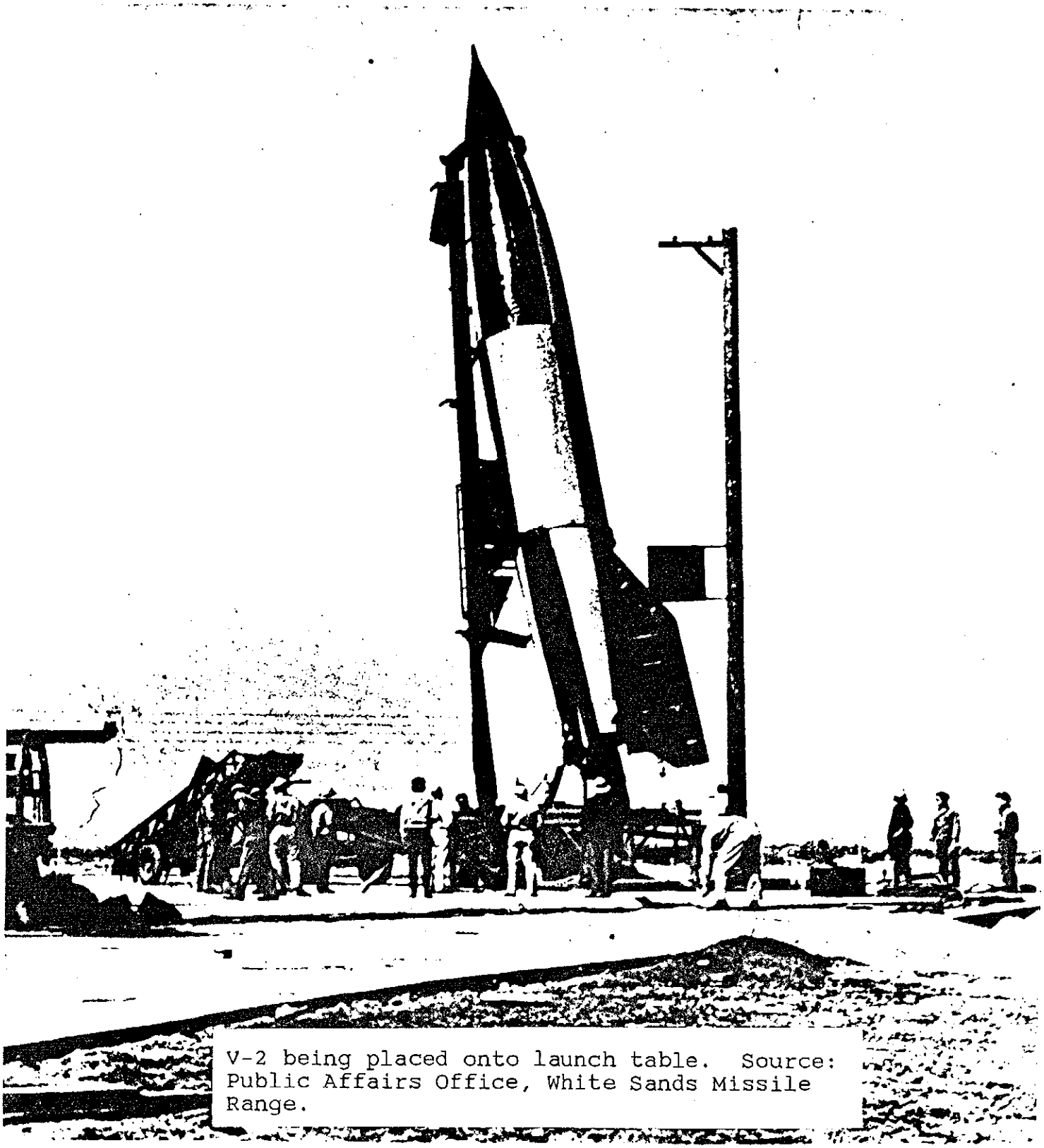
V-2 raised into position by Meilerwagon, between March-June 1946. Source: Public Affairs Office, White Sands Missile Range.



V-2 about to be lifted into place on launch table by Meilerwagon, after March 1946. Source: Public Affairs Office, White Sands Missile Range.

V-2 being placed onto launch table. Source: Public Affairs Office, White Sands Missile Range.

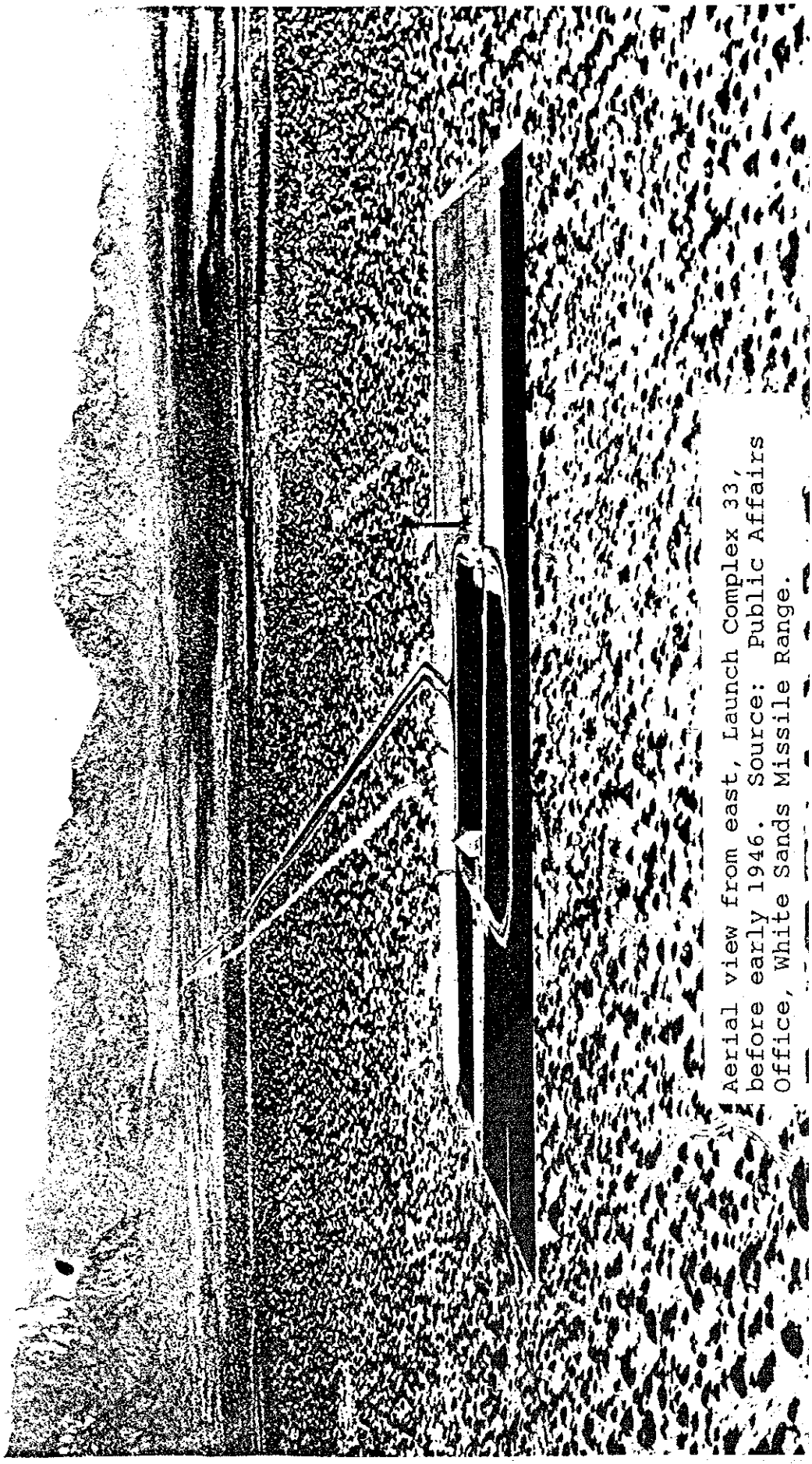
Figure 37.—V-2 being placed in position for firing, White Sands Proving Ground.



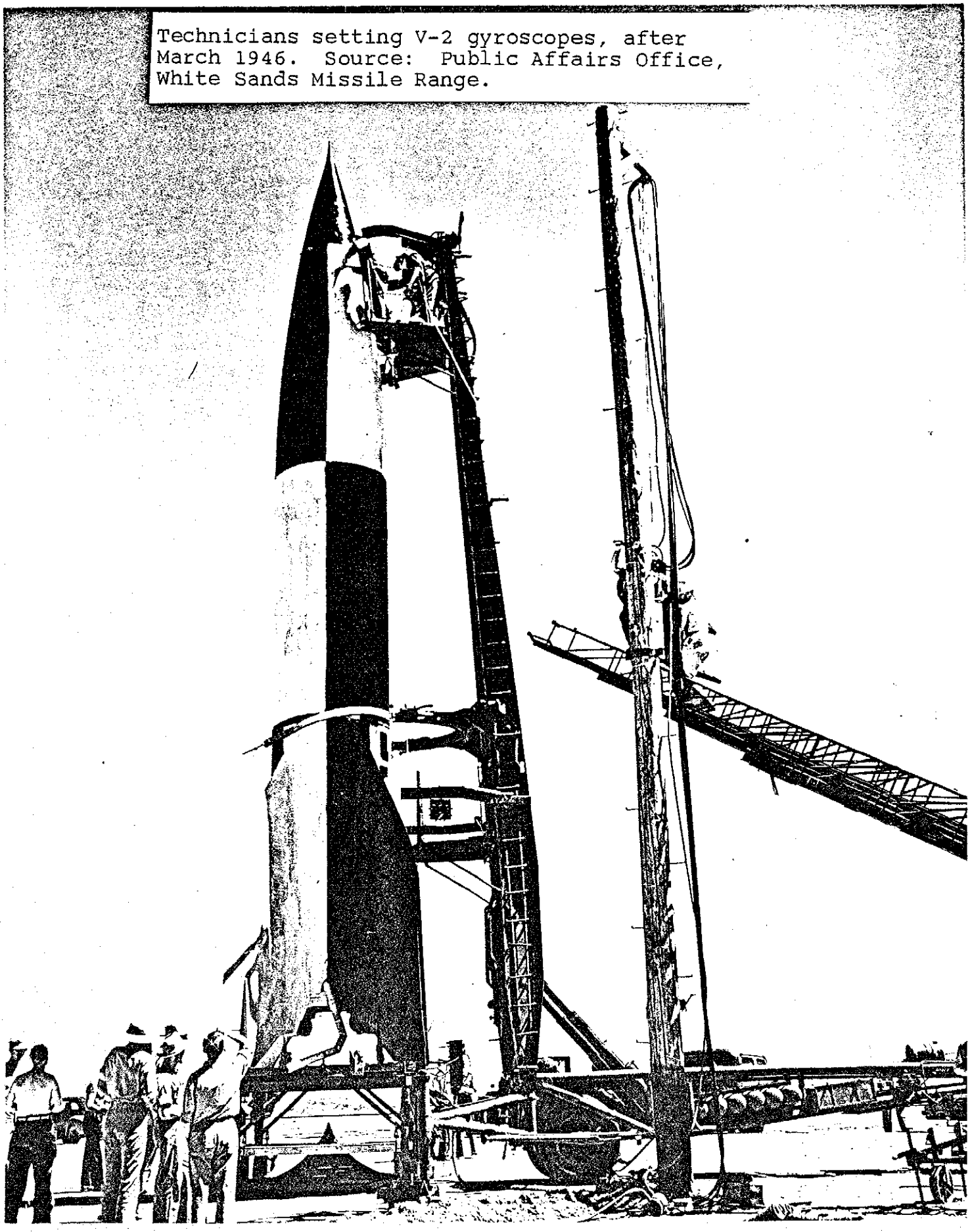
V-2 being placed onto launch table. Source: Public Affairs Office, White Sands Missile Range.

V-2 being placed in position for launching

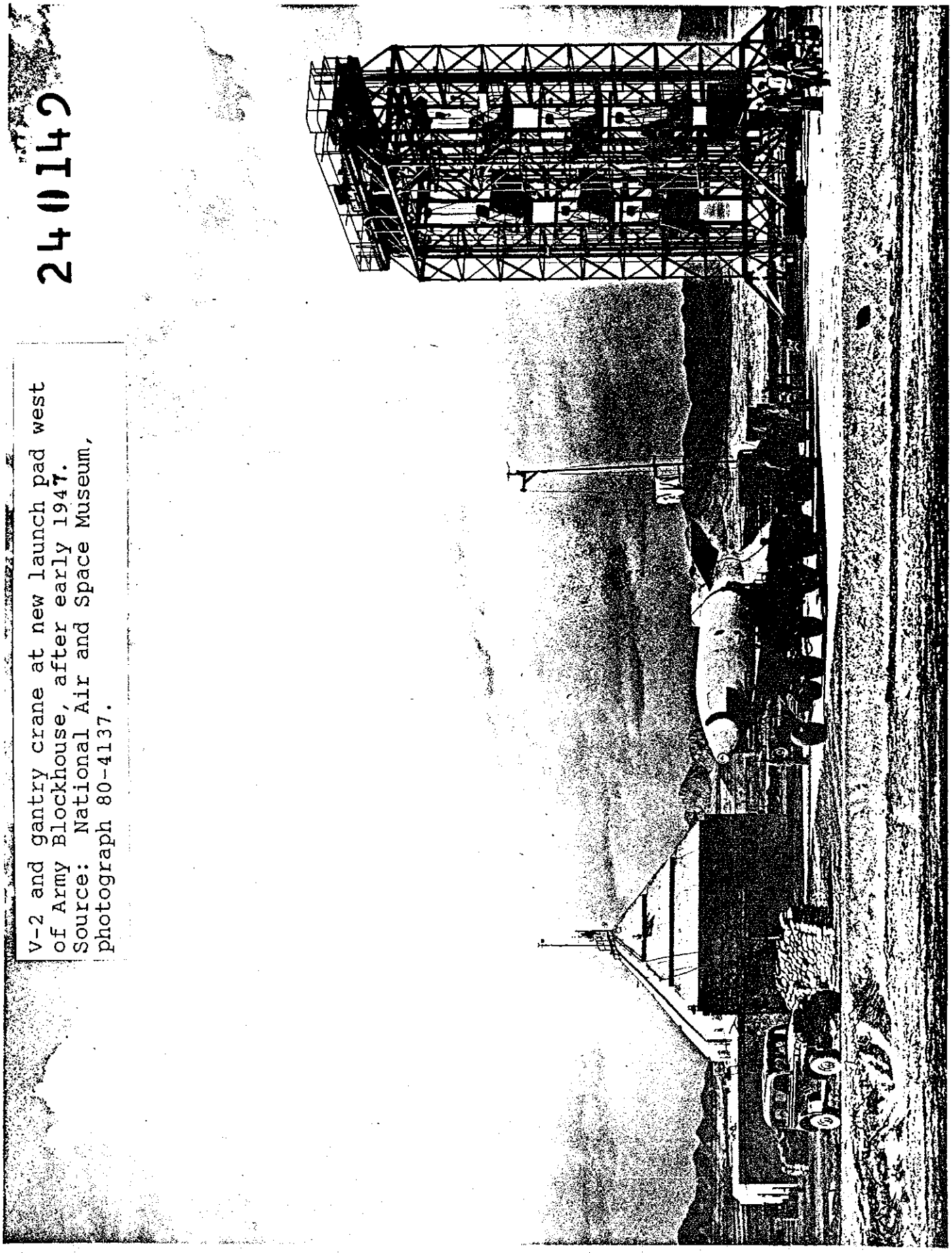
U.S. Army Ordnance Proving Ground, White Sands, N.M.



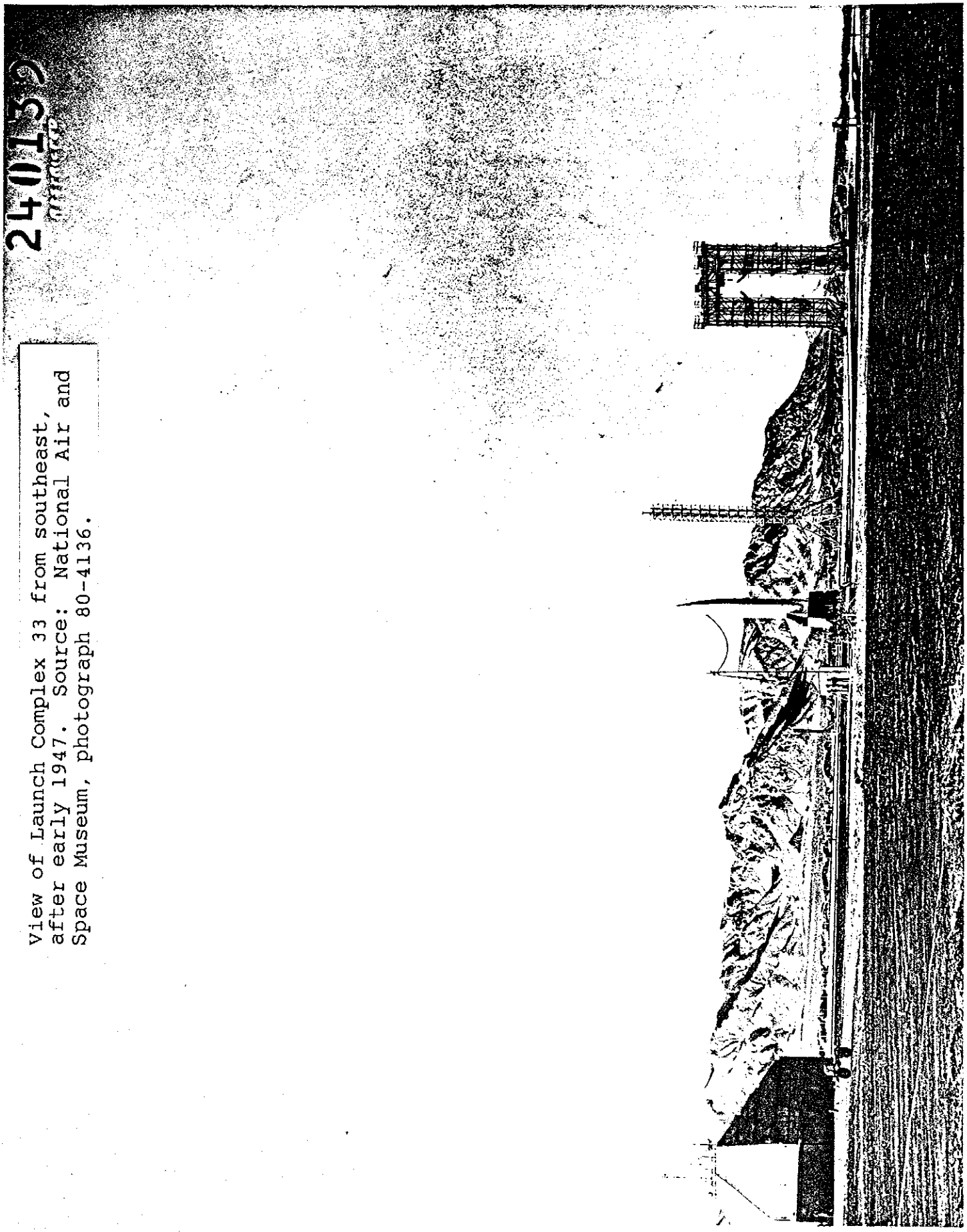
Aerial view from east, Launch Complex 33, before early 1946. Source: Public Affairs Office, White Sands Missile Range.



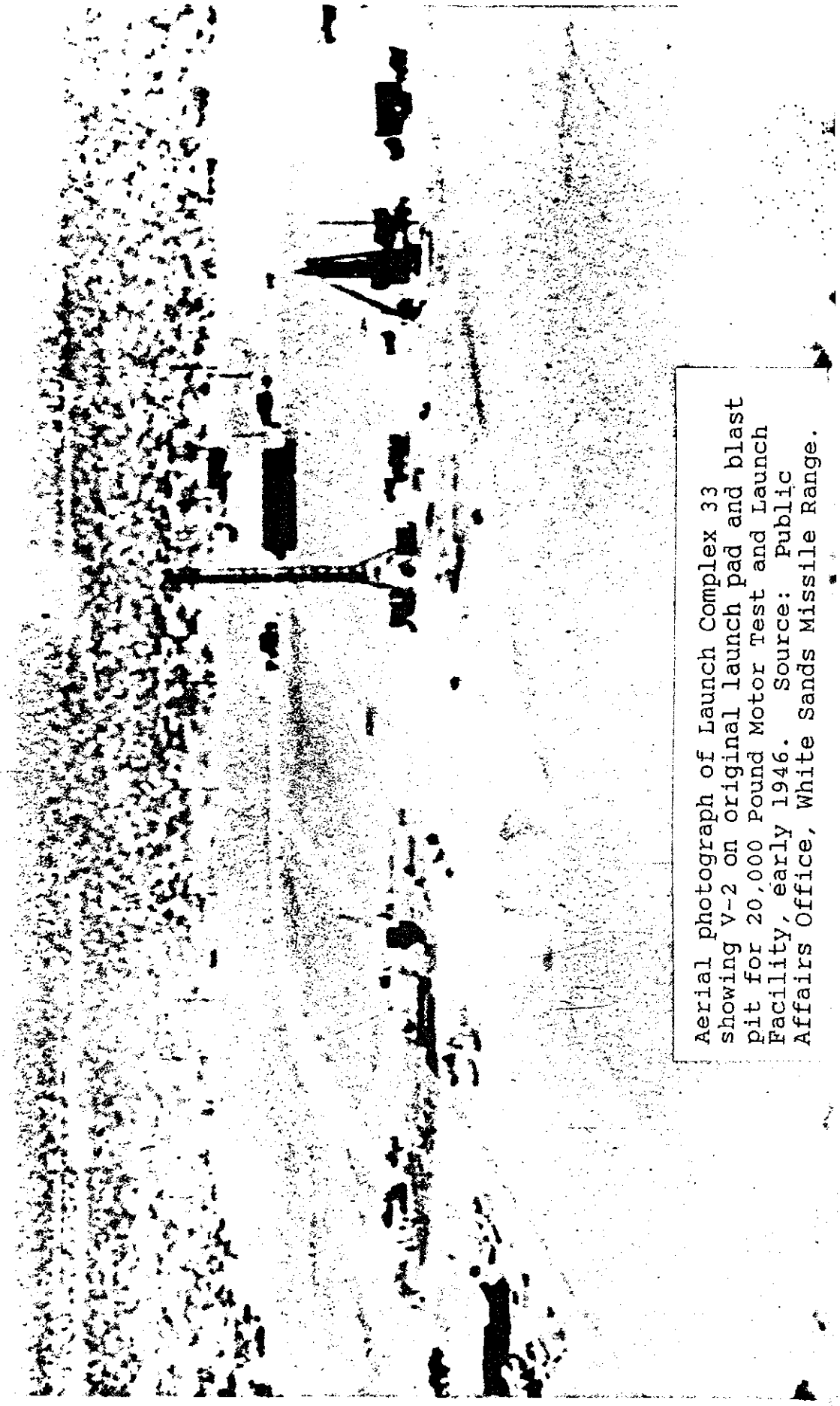
Technicians setting V-2 gyroscopes, after March 1946. Source: Public Affairs Office, White Sands Missile Range.



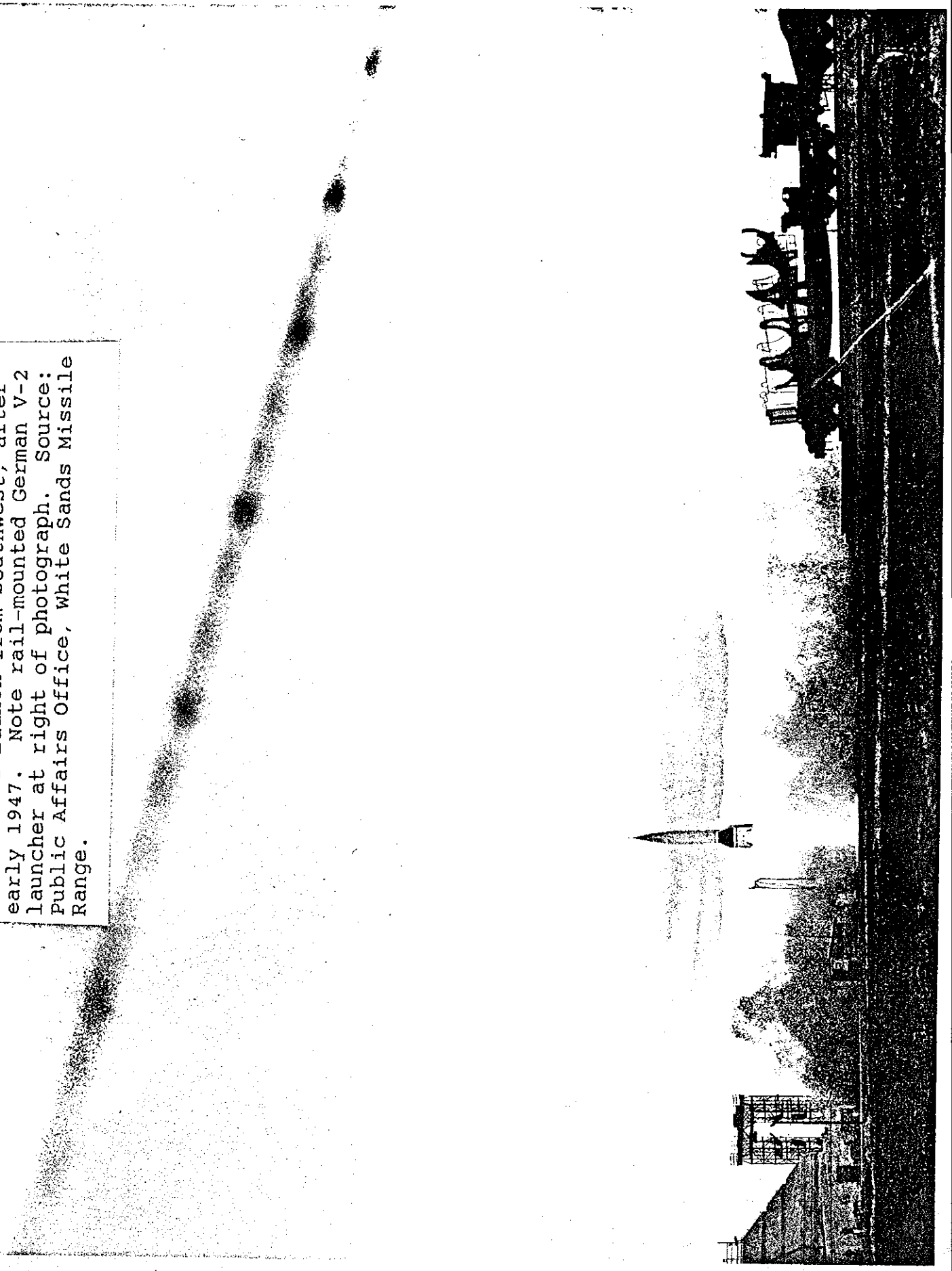
V-2 and gantry crane at new launch pad west of Army Blockhouse, after early 1947. Source: National Air and Space Museum, photograph 80-4137.



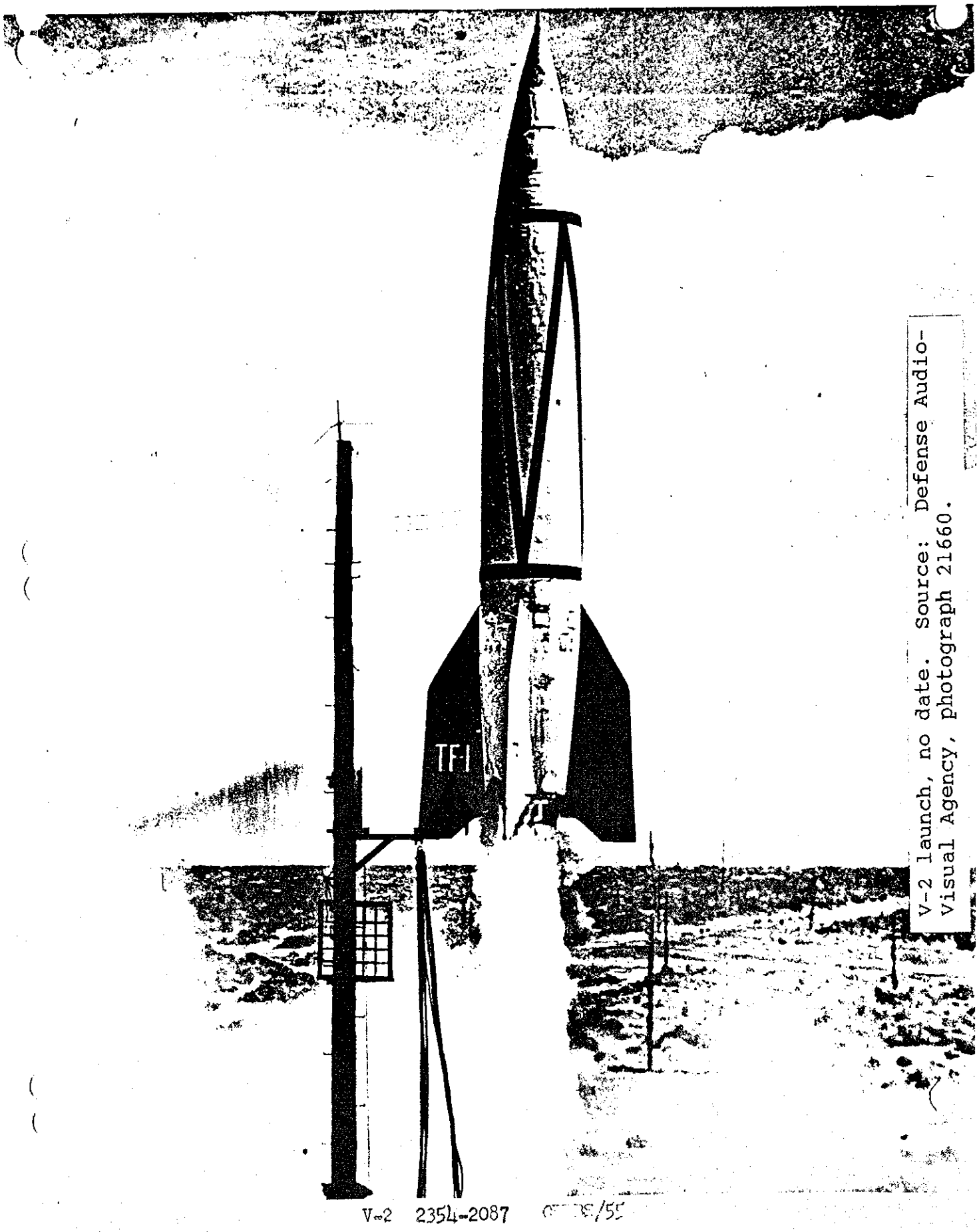
View of Launch Complex 33 from southeast, after early 1947. Source: National Air and Space Museum, photograph 80-4136.



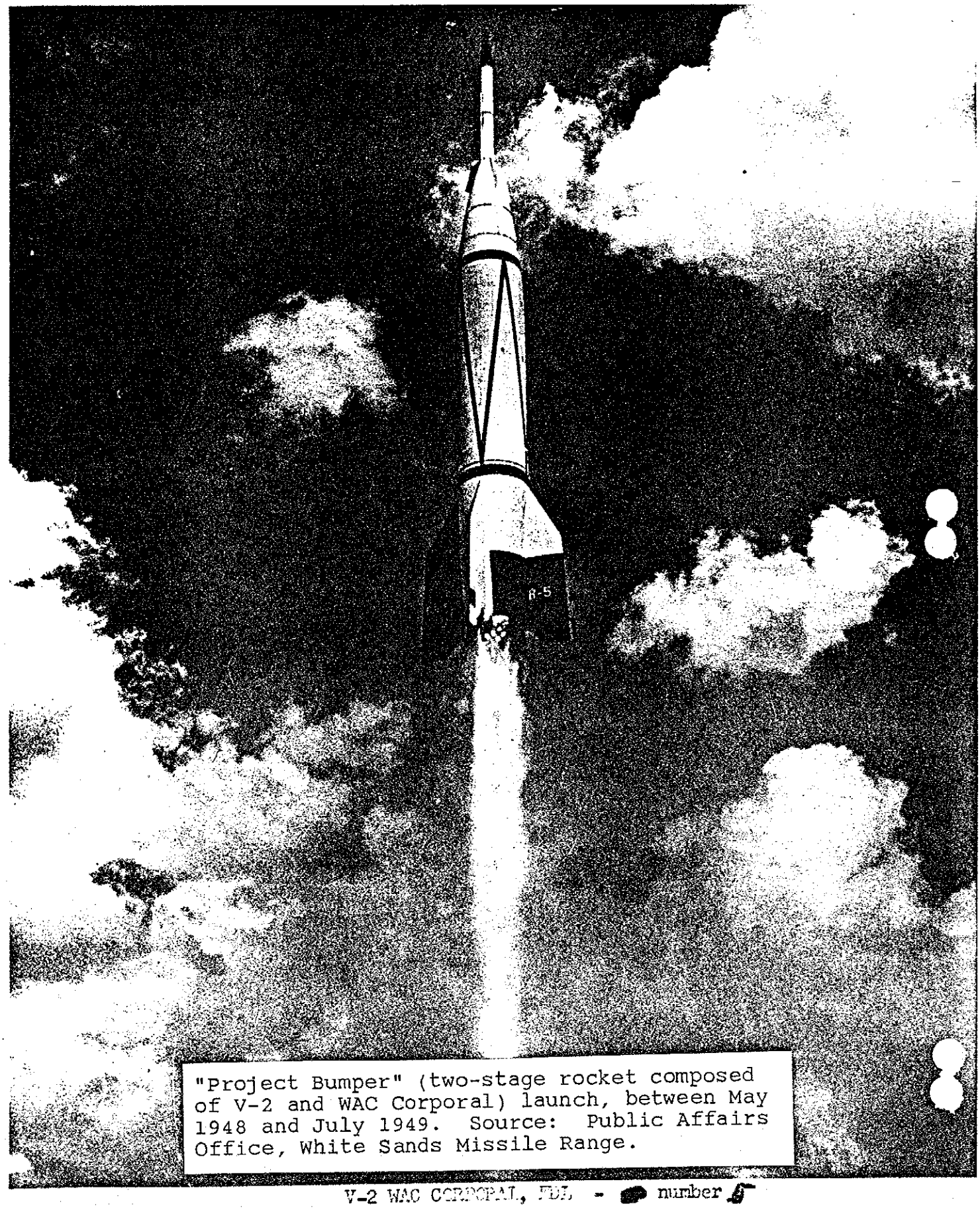
Aerial photograph of Launch Complex 33 showing V-2 on original launch pad and blast pit for 20,000 Pound Motor Test and Launch Facility, early 1946. Source: Public Affairs Office, White Sands Missile Range.



View of V-2 launch from southwest, after early 1947. Note rail-mounted German V-2 launcher at right of photograph. Source: Public Affairs Office, White Sands Missile Range.

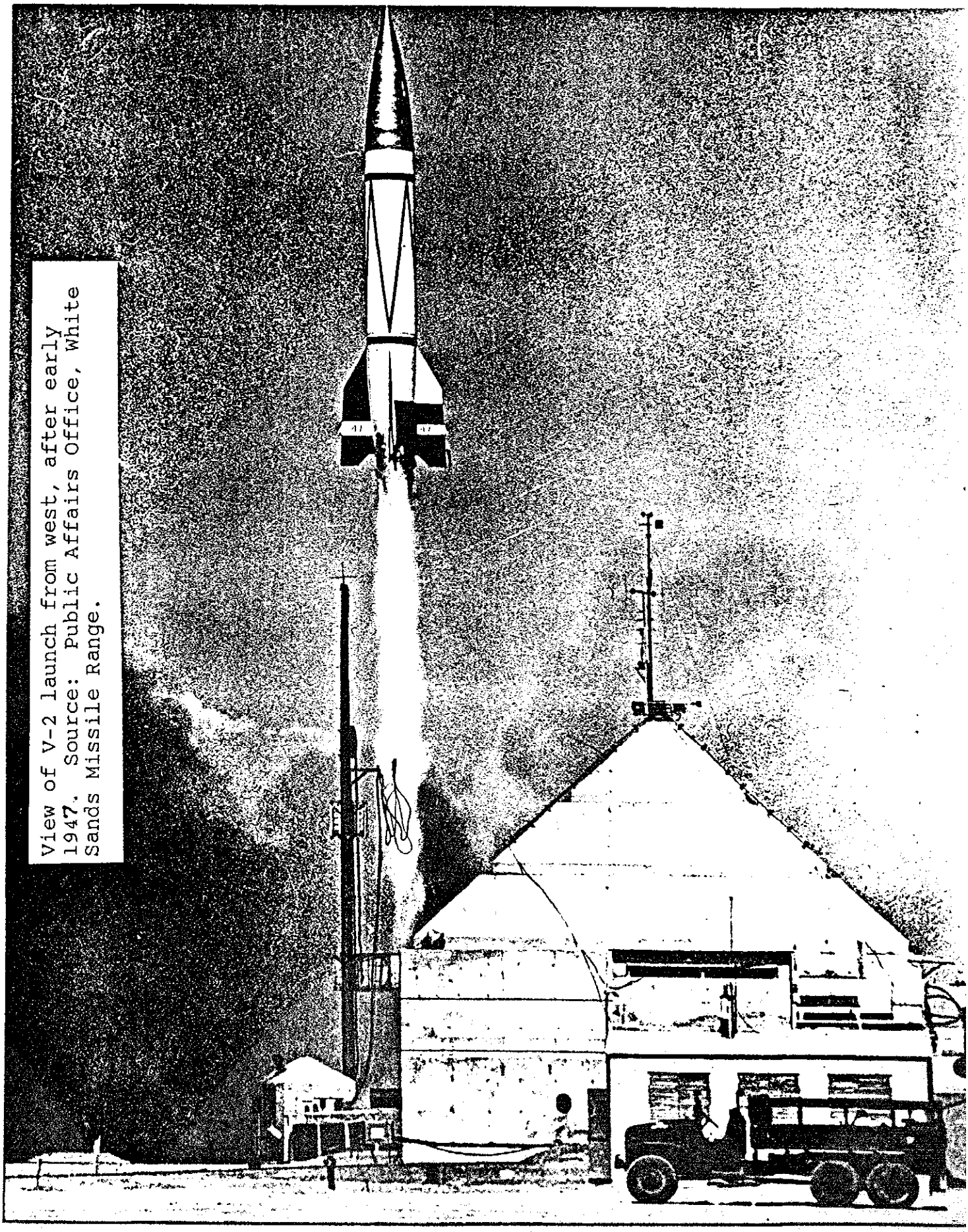


V-2 launch, no date. Source: Defense Audio-Visual Agency, photograph 21660.

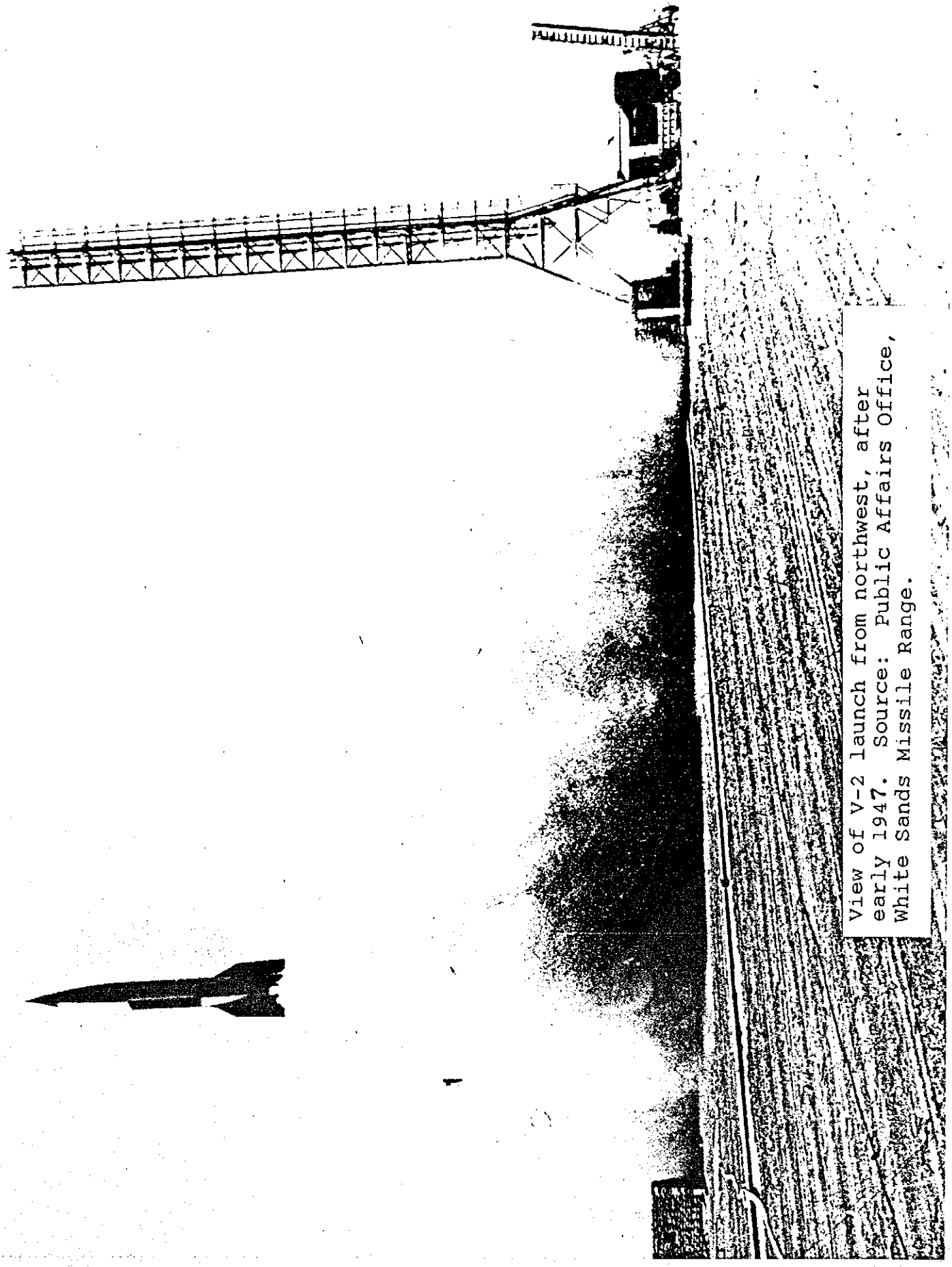


"Project Bumper" (two-stage rocket composed of V-2 and WAC Corporal) launch, between May 1948 and July 1949. Source: Public Affairs Office, White Sands Missile Range.

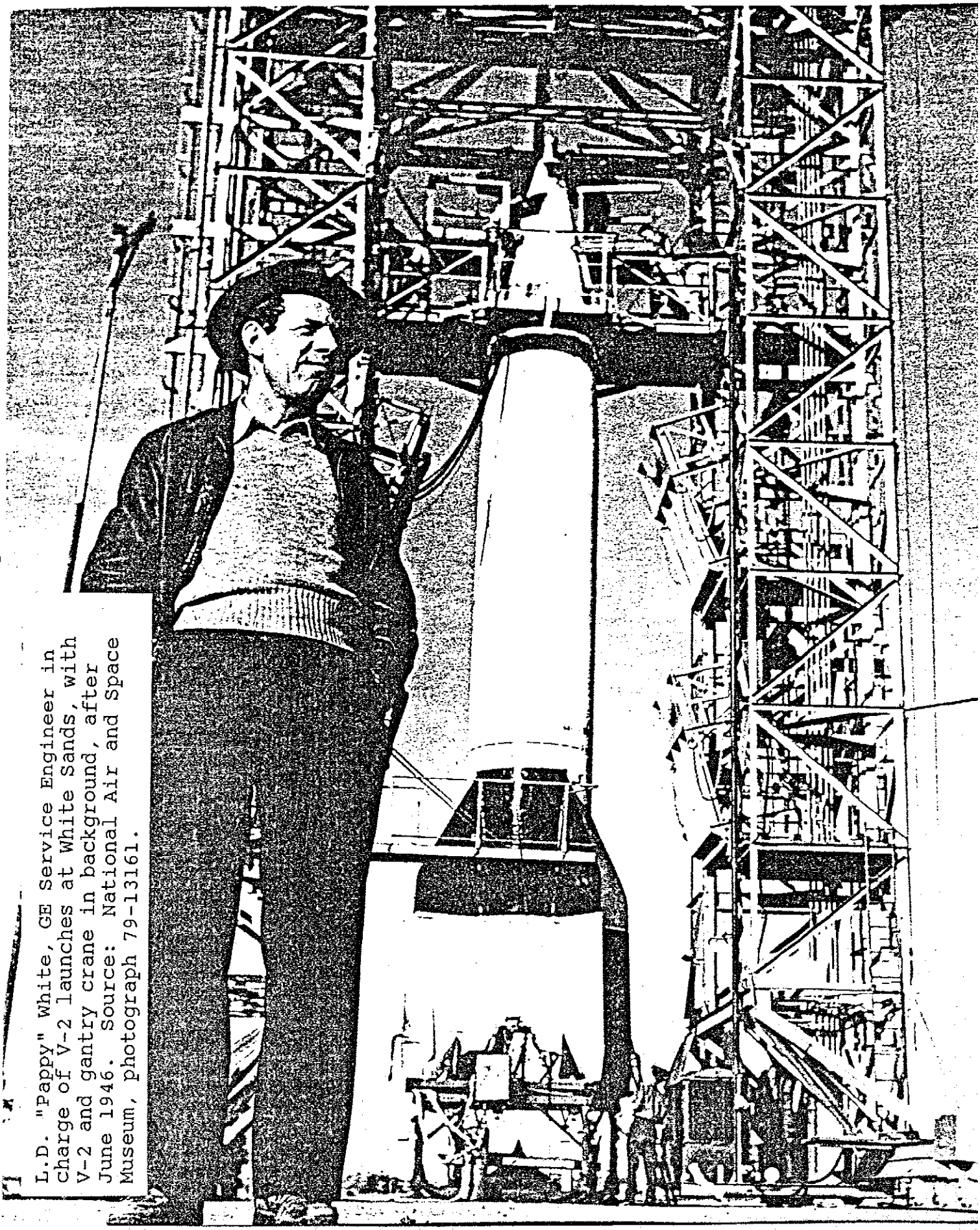
V-2 WAC CORPORAL, FDL - [redacted] number [redacted]



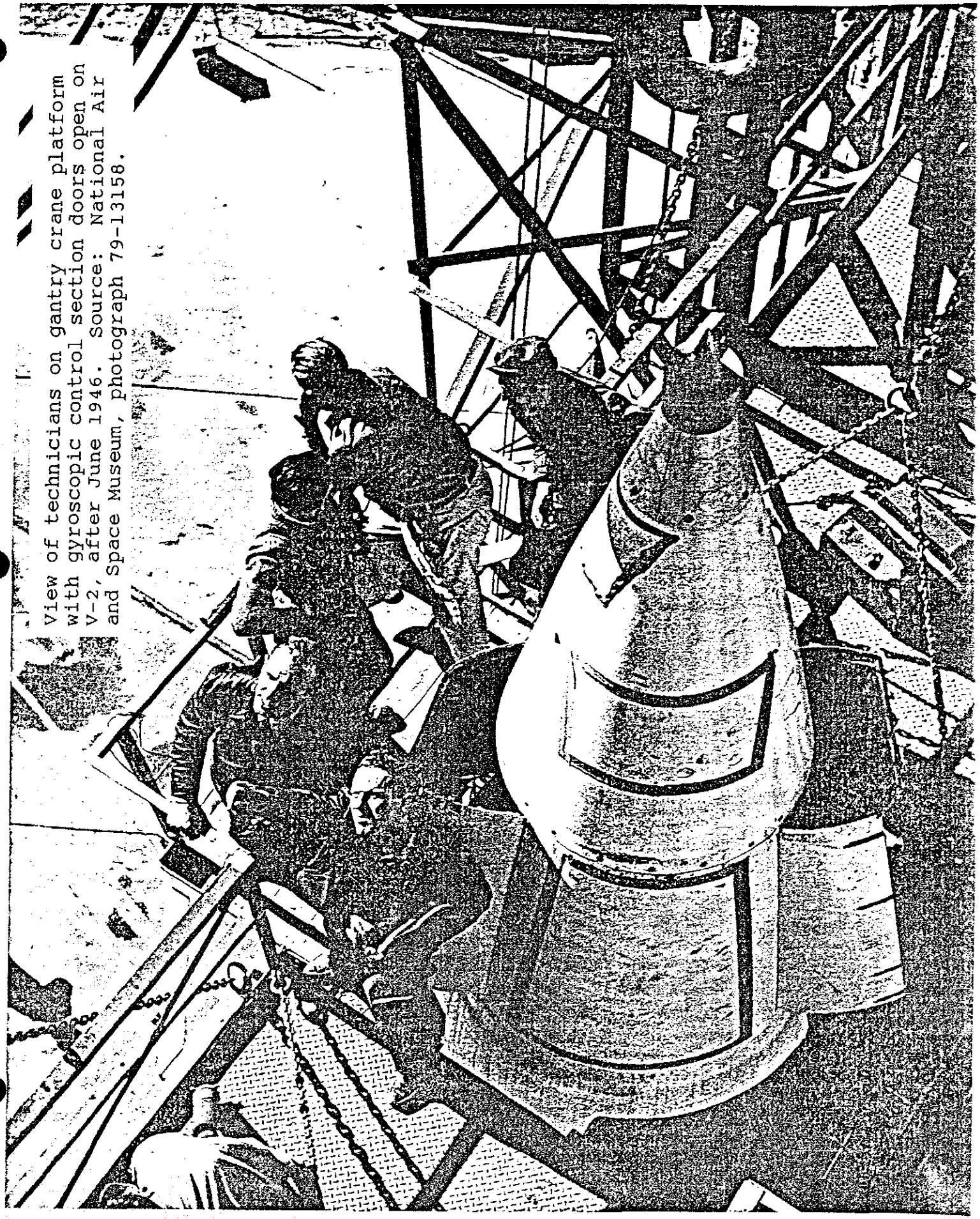
View of V-2 launch from west, after early 1947. Source: Public Affairs Office, White Sands Missile Range.



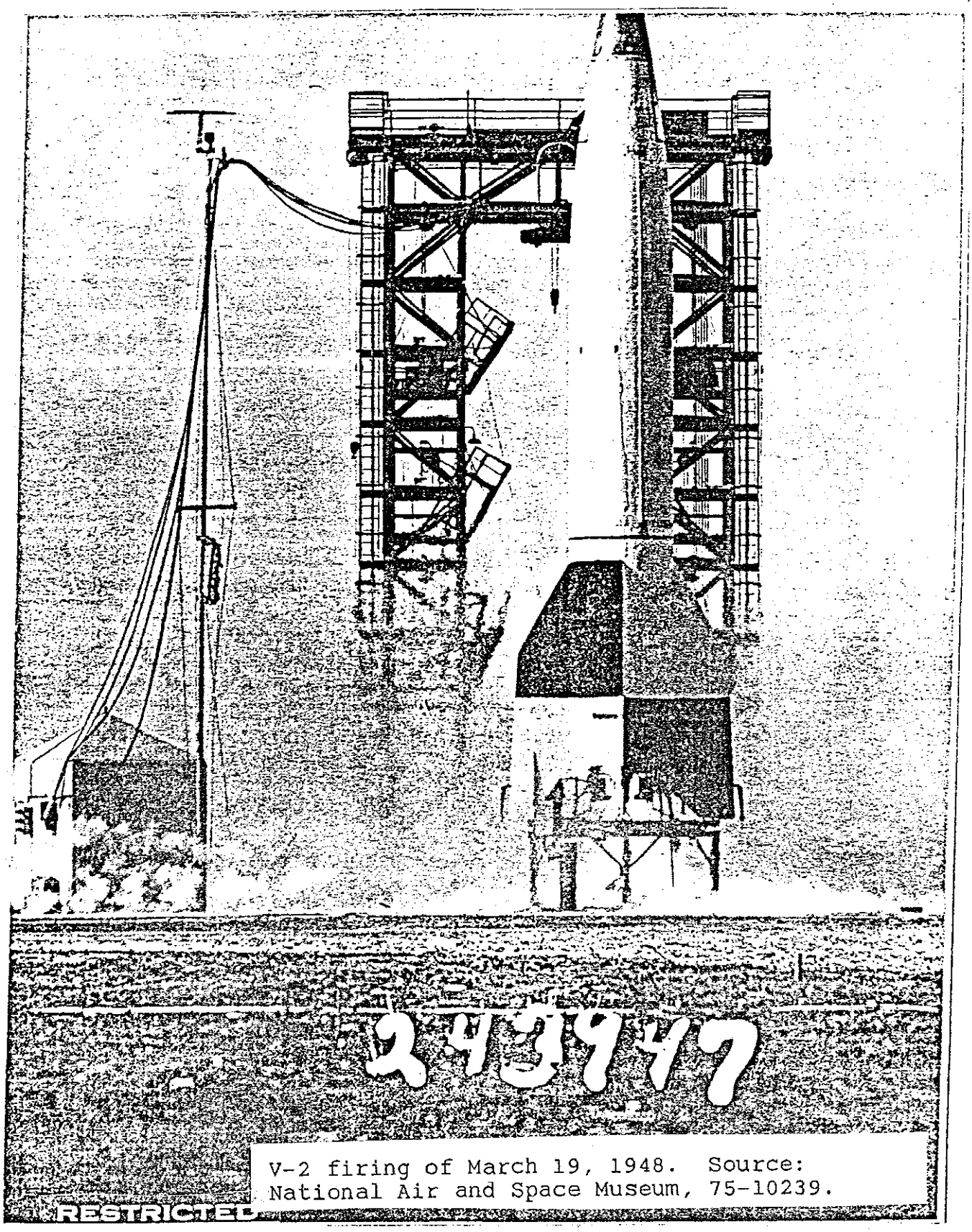
View of V-2 launch from northwest, after early 1947. Source: Public Affairs Office, White Sands Missile Range.



L.D. "Pappy" White, GE Service Engineer in charge of V-2 launches at White Sands, with V-2 and gantry crane in background, after June 1946. Source: National Air and Space Museum, photograph 79-13161.



View of technicians on gantry crane platform with gyroscopic control section doors open on V-2, after June 1946. Source: National Air and Space Museum, photograph 79-13158.

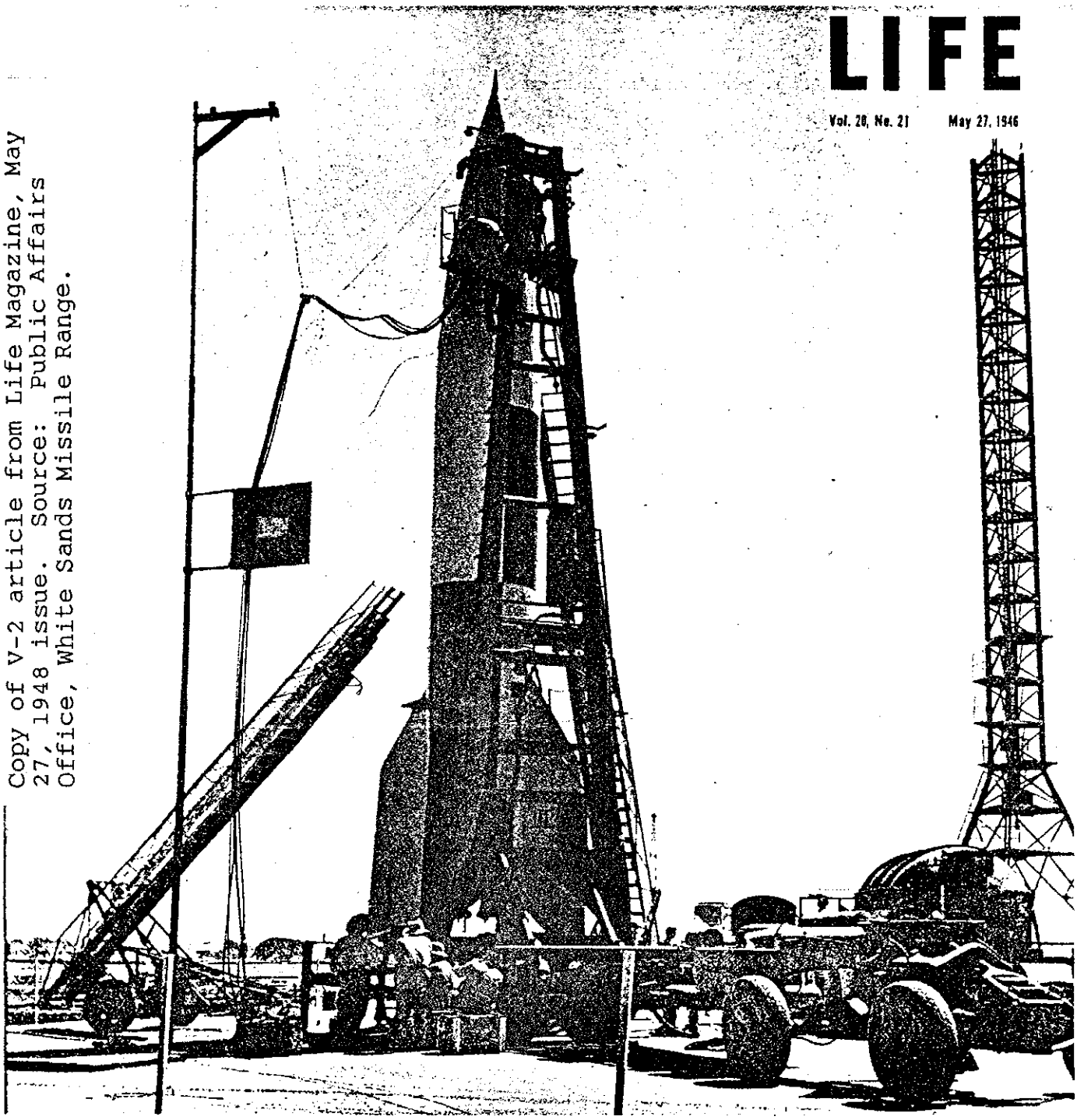


V-2 firing of March 19, 1948. Source: National Air and Space Museum, 75-10239.

Copy of V-2 article from Life Magazine, May 27, 1948 issue. Source: Public Affairs Office, White Sands Missile Range.

LIFE

Vol. 28, No. 21 May 27, 1946



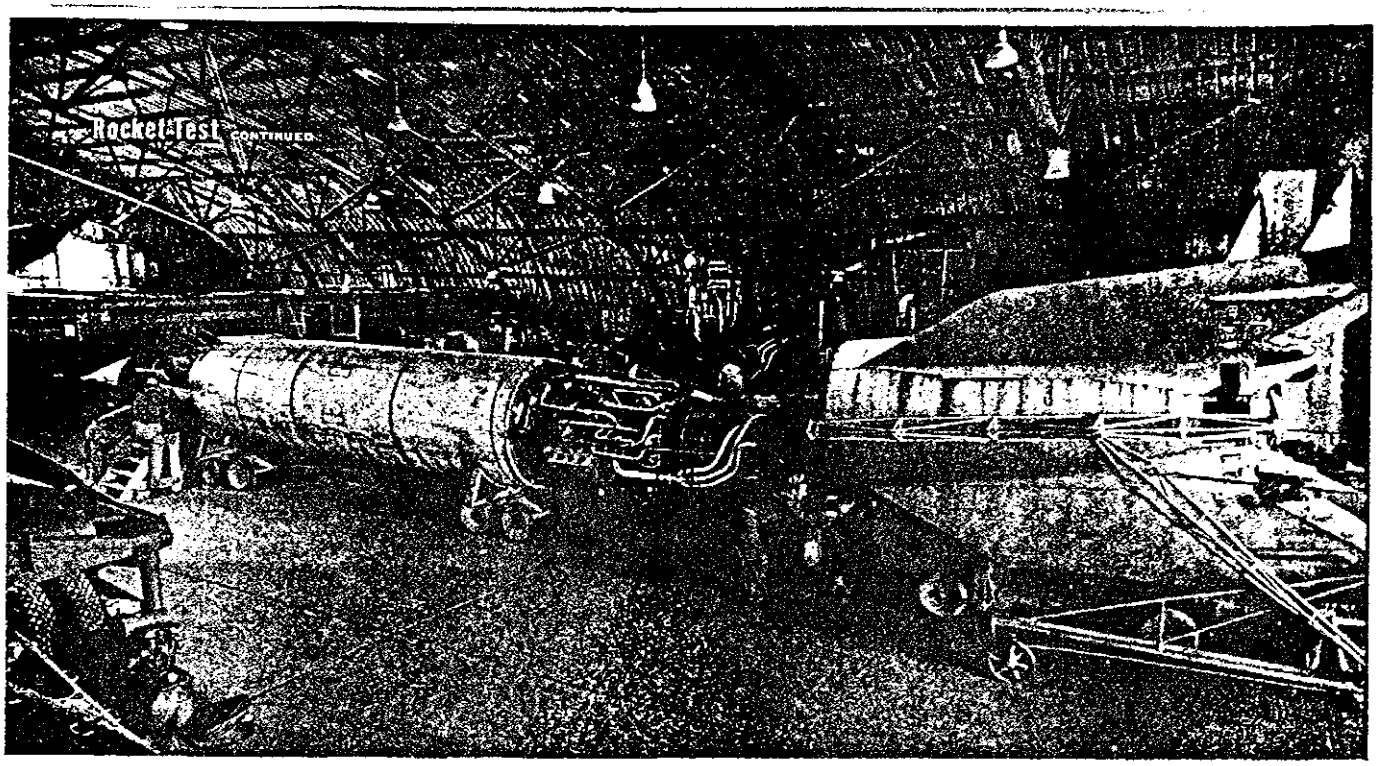
BEFORE ITS FLIGHT THE V-2 IS FUELED ON THE WHITE SANDS FIRING RANGE. TOWER AT THE RIGHT HOLDS SMALLER U. S. WAC CORPORAL ROCKET, FIRED LATER

U.S. TESTS ROCKETS IN NEW MEXICO

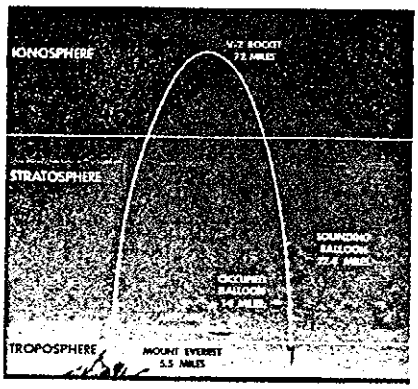
On May 10 the Army reminded the U.S. how science multiplies the hazards of future atomic wars. At glaring White Sands Proving Ground in New Mexico it shot off the first of a series of captured German V-2 rockets to be tested through the summer. During the late war V-2 had carried one ton of ordinary high explosive a maximum distance of 230 miles. In another war similar rockets might carry atomic bombs anywhere in the world.

The main purpose of the Army ordnance tests was to prepare the U.S. for the possibility of such a war. Since German rocket technology had been by far the world's most highly developed, the Army hoped that the U.S. could improve on it by an exhaustive study of the V-2. At the same time the Army prepared possible defenses against rockets by testing its radar against the V-2 in flight.

But the V-2 tests were to be more than a development of new weapons and defenses. The first New Mexico V-2 carried only a radio beacon for the radars to follow and track. Later rockets would carry aloft instruments which would send back information about temperature, gases and cosmic rays in the earth's little-known upper atmosphere.



V-2 ASSEMBLY reaches final stage in desert hangar. Tail section is being wheeled into place to fit over the motor. On steps at left soldiers are installing the steering mechanism. Behind them is pointed warhead. The mass of pipes coiling around the motor are fuel lines bringing alcohol and oxygen from the middle body of rocket.



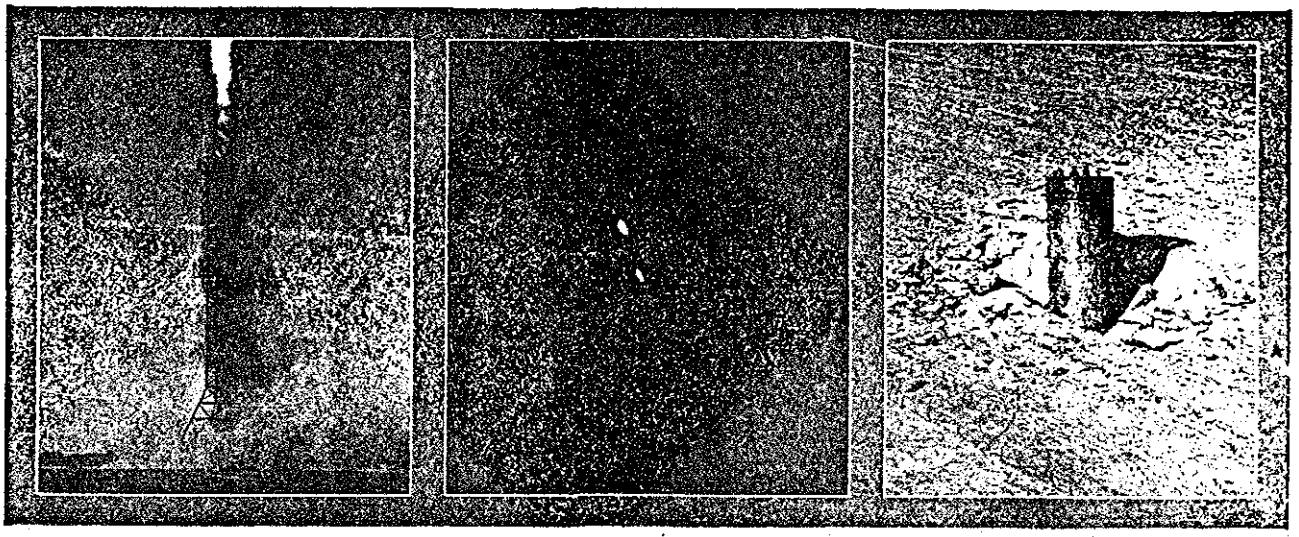
TRAJECTORY OF V-2 is compared with the greatest heights reached heretofore. Later flights will go higher.

U.S. ROCKETS ARE MADE FROM CAPTURED GERMAN PARTS

The V-2 rocket fired at White Sands was part of the spoils of war seized by the U.S. Army in Germany. At Nordhausen and Peenemünde, the Americans found enough parts to make 100 V-2s. They also found a group of German experts who took great pride in showing how to put the parts together. The parts and the experts were shipped to White Sands.

Keys to German success with V-2 were its fuel pumps and gyroscopic controls. The pumps are driven by a dwarf steam engine which develops 580 hp from the combustion of hydrogen peroxide and permanganate. This forces liquid oxygen and alcohol at high speeds into a combustion chamber. Combining there, they burn in a fierce flame which spurts out at 6,800 feet a second past the tail fins. Gyroscopes set before the take-off control these fins so that at proper time they will move, changing the course of the rocket and aiming it at the target. During the war V-2s were accurate only for area bombing, could not be aimed at any specific target. With atomic bombs, of course, area bombing will be sufficient.

The main body of V-2 (*above*) is entirely filled with alcohol and liquid oxygen. In the nose are warhead and gyroscopes. At tail is motor. V-2 fired in New Mexico had no explosive in its warhead. Though the Germans found that one in five V-2s misfired, their rockets were still far ahead of anything developed by Americans, whose best rocket was small 16-foot-long WAC Corporal (*see below*).

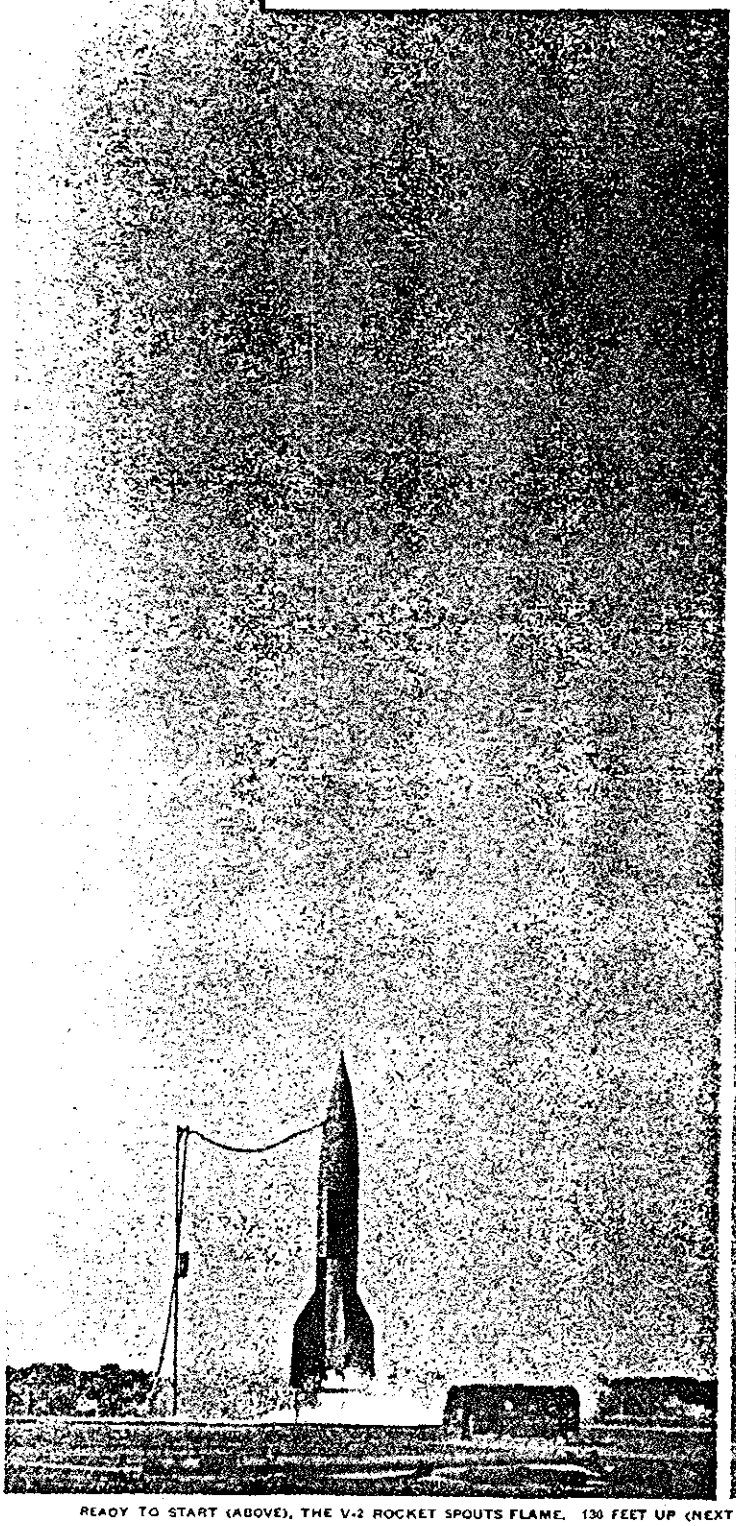


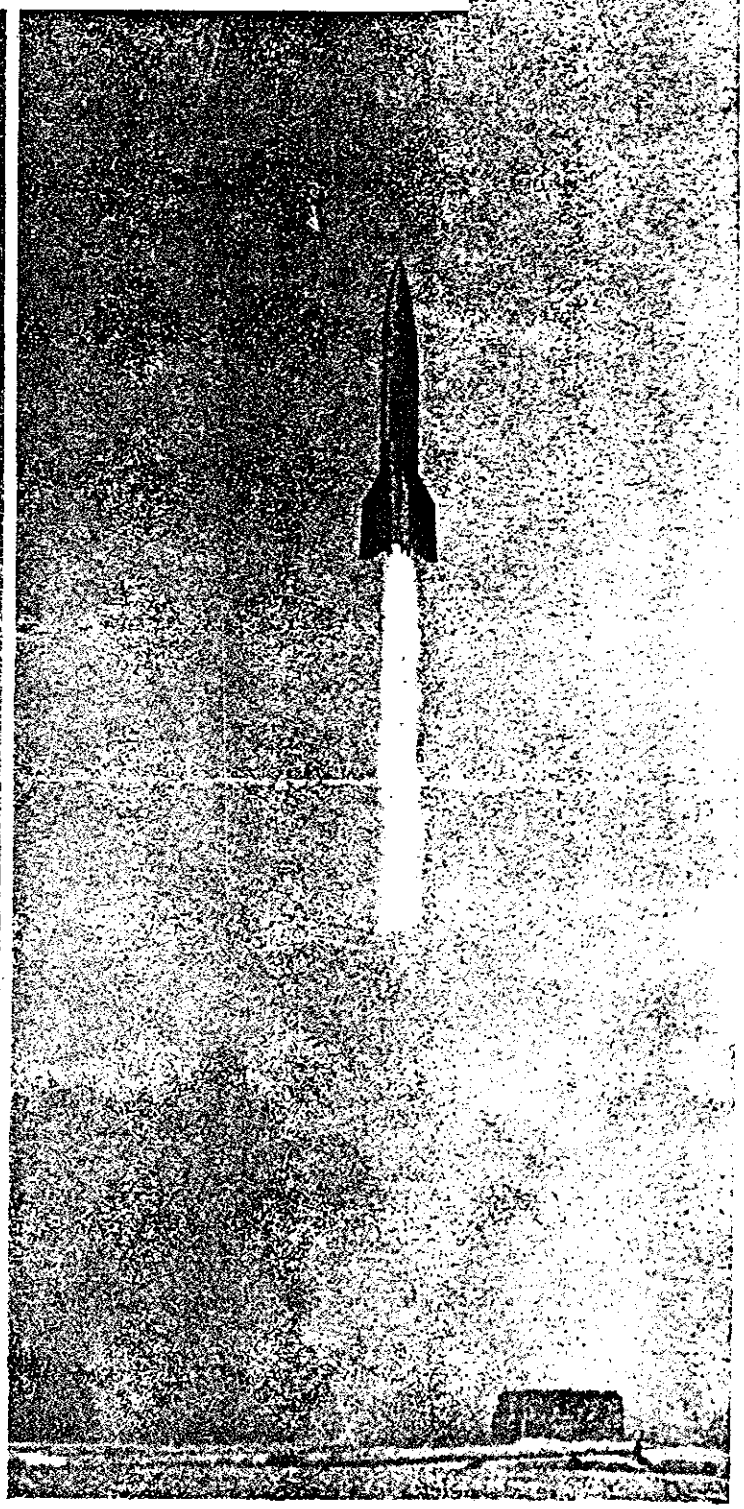
WAC CORPORAL, U.S. Army's small 700-pound rocket, goes off so fast that camera cannot catch it. With aid of rocket booster, it hits speed of 800 mph in a second.

IT COMES APART in mid-air as booster falls off and the WAC Corporal goes on. Unlike the V-2, WAC has no steering device, can be used only for weather study.

EIGHT-FOOT BOOSTER buries itself, only part of WAC to be recovered. Army experts say Germans had 12-year start, admit WAC is inferior to V-2 in every way.

Copy of V-2 article from Life Magazine, May 27, 1948 issue. Source: Public Affairs Office, White Sands Missile Range.

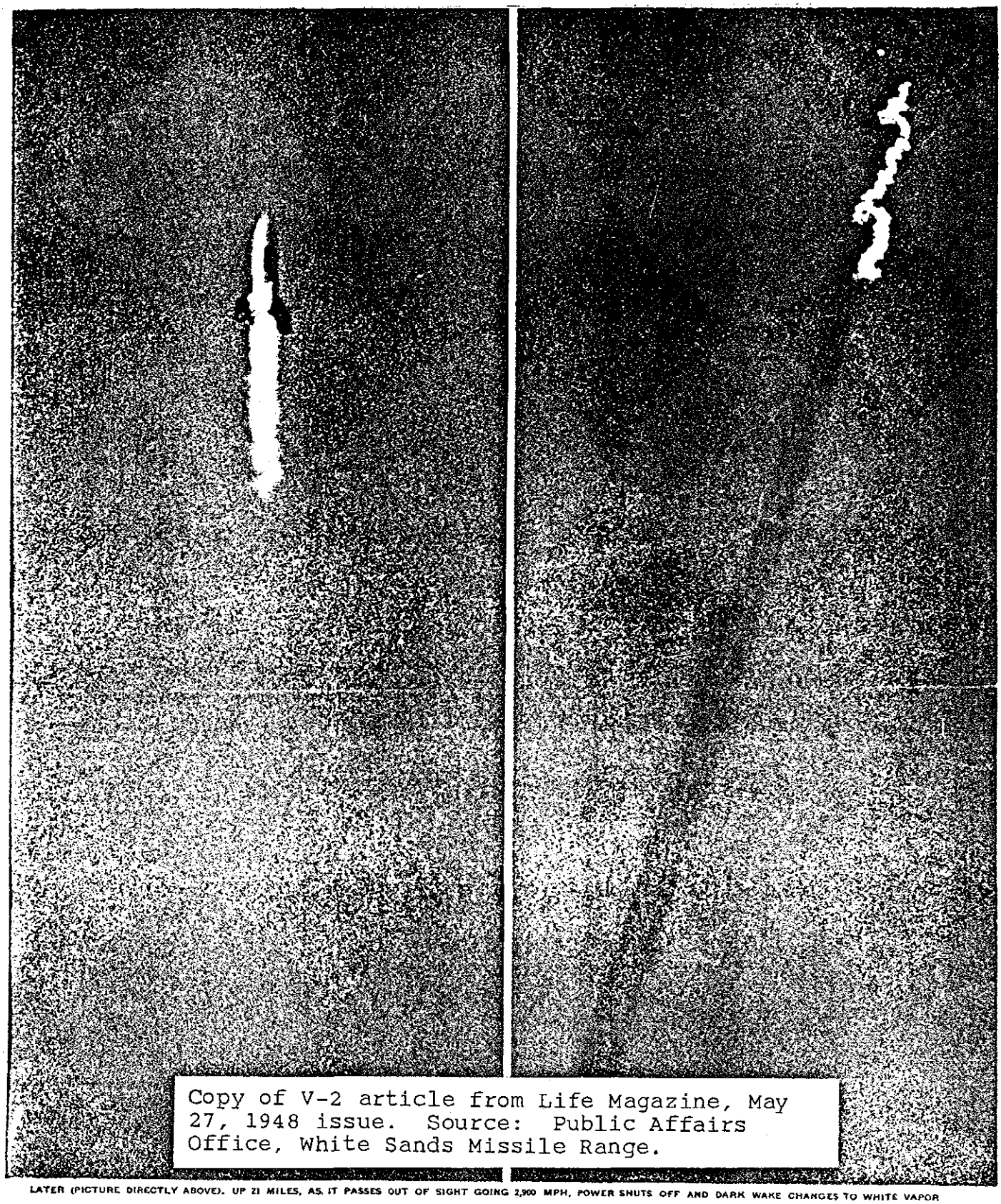




READY TO START (ABOVE), THE V-2 ROCKET SPOUTS FLAME. 130 FEET UP (NEXT PICTURE) THE ROCKET GOES ONLY 60 MPH. IT HITS SPEED OF 615 A FEW SECONDS

V-2 TAKES OFF

Balancing perfectly on its fiery tail, the V-2 rocket rose almost straight up from the New Mexico desert, vanished in a cloud of its own vapor and returned five minutes later to make a great hole in the sand 37 miles away. Its thrust had taken it 72 miles upward. Starting off slowly with a small, crackling noise, it picked up speed with a huge roar. Before the end of the first minute it was making 2,900 mph. At this point, with a tenth of its fuel still unused, the V-2's power was cut off by radio,



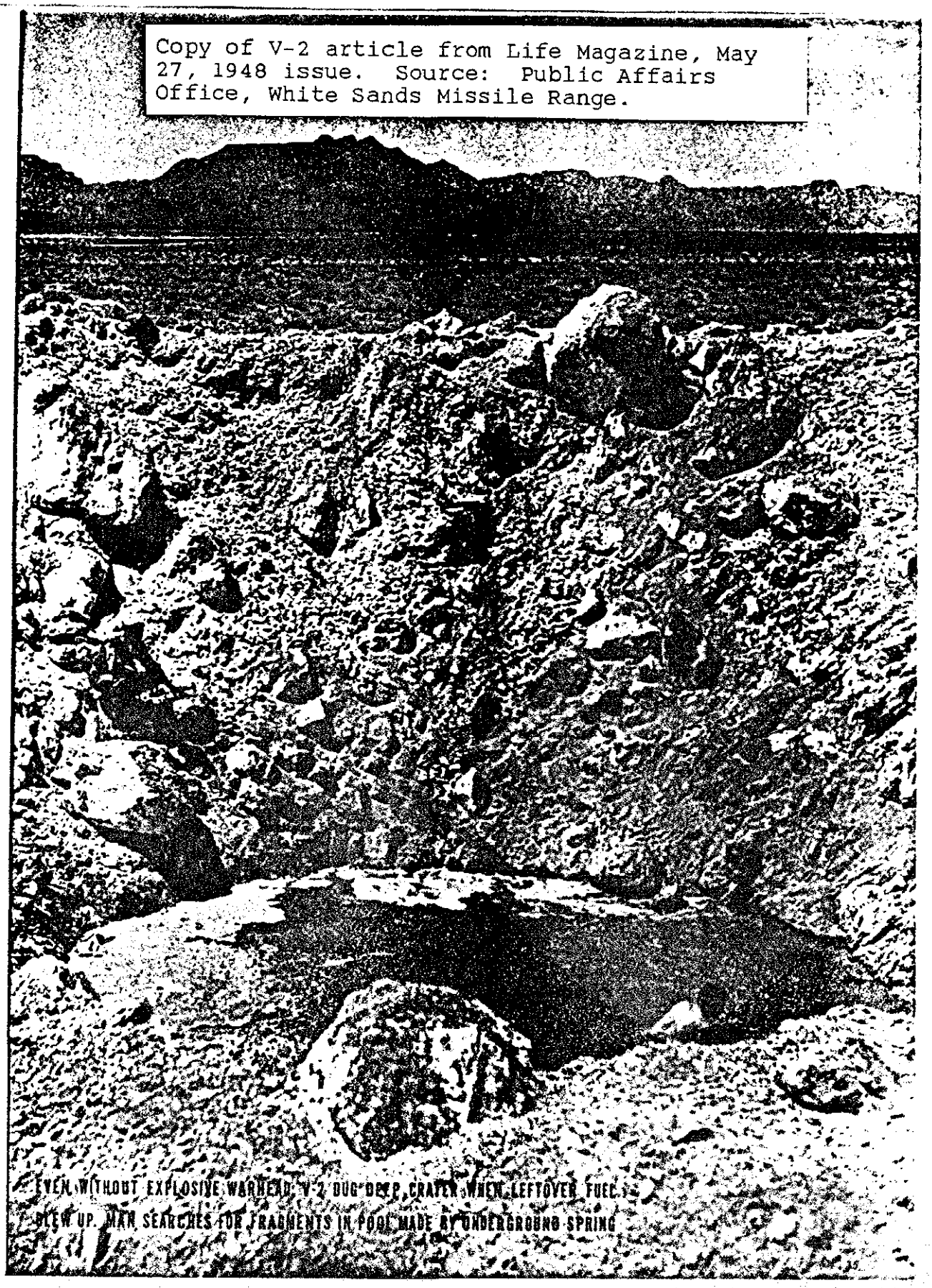
Copy of V-2 article from Life Magazine, May 27, 1948 issue. Source: Public Affairs Office, White Sands Missile Range.

LATER (PICTURE DIRECTLY ABOVE), UP 21 MILES, AS IT PASSES OUT OF SIGHT GOING 2,900 MPH, POWER SHUTS OFF AND DARK WAKE CHANGES TO WHITE VAPOR

according to a cautious plan. Although the ascent was orderly, Army Ordnance did not want to take chances on its going out of the 125-mile range of White Sands Proving Grounds. Later rockets will be sent to maximum height, a probable 120 miles.

While the power was on, the V-2 left a straight dark streak of carbon exhaust in the air (*see picture at right*), much like gasoline exhaust. When the ground controls failed to close the valves completely, a heavy cloud of vapor streamed out behind and was quickly blown by the stratospheric gales into a crude spiral visible from ground even though it was 21 miles up. From there, though the power was shut off, momentum carried the rocket into the ionosphere where there is no sound and the sky is black.

Copy of V-2 article from Life Magazine, May 27, 1948 issue. Source: Public Affairs Office, White Sands Missile Range.



EVEN WITHOUT EXPLOSIVE WARHEAD, V-2 DUG DEEP CRATER WHEN LEFTOVER FUEL BLEW UP. MAN SEARCHES FOR FRAGMENTS IN POOL MADE BY UNDERGROUND SPRING