CAPE CANAVERAL AIR FORCE STATION, LAUNCH COMPLEX 31/32
2317 - 2327 Flight Control Road
Cape Canaveral
Brevard County
Florida

HAER No. FL-8-12

PHOTOGRAPHS
WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
Southeast Regional Office
National Park Service
U.S. Department of the Interior
100 Alabama Street, S.W.
Atlanta, GA 30303

HISTORIC AMERICAN ENGINEERING RECORD

CAPE CANAVERAL AIR FORCE STATION, LAUNCH COMPLEX 31/32

HAER No. FL-8-12

Location:	Cape Canaveral Air Force Station Launch Complex 31/32 2317 - 2327 Flight Control Road Cape Canaveral Brevard County Florida USGS Cape Canaveral Quadrangle, Universal Transverse Mercator Coordinates: 17/543489.94/3147419.98
Date of construction:	1959-1960
Engineer:	U.S. Army Corps of Engineers (USACE)
Present owner:	U.S. Air Force (USAF)
Present use:	Deactivated
Significance:	Launch Complex 31/32 is significantly associated with early missile development testing for the United States Air Force (USAF), specifically the Minuteman missile. Launch Complex 31/32 served as a research and development launching site from 1962 through 1973. During this time, it hosted launches of the three Minuteman series, and mobile launches of the Pershing 1A missile. In 1987, the silos became the resting place of the Challenger Space Shuttle debris.
Report prepared by:	Dr. Susan Enscore, Ms. Julie Webster, Ms. Angela Fike, and Mr. Martin Stupich U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory 2902 Newmark Drive Champaign, IL 61822
Date	December 2008

HISTORICAL OVERVIEW OF CAPE CANAVERAL AIR FORCE STATION[1]

Cape Canaveral Air Force Station

Cape Canaveral Air Force Station (CCAFS) is located in Brevard County on the east coast of central Florida, approximately 155 miles south of Jacksonville and 210 miles north of Miami (Figure 1). It occupies 15,804 acres and is bounded by the Atlantic Ocean to the east, and the Banana River to the west. A barge and ship channel called Port Canaveral is located to the south, while the John F. Kennedy Space Center is located to the west and north.[2] The CCAFS is part of the Eastern Range (including administrative headquarters at nearby Patrick Air Force Base) launch sites at Cape Canaveral and Kennedy Space Center, and downrange tracking facilities that extend 10,000 miles down the Atlantic to the Indian Ocean.

Cape Canaveral and the Cold War

As the launching site for a majority of the U.S. missile and space programs, both military and civilian, CCAFS played a critical role during the Cold War. This era in history, spanning roughly 1946 to 1989, pitted the ideologies, economies, technologies, and military power of the United States (U.S.) against those of the Union of the Soviet Socialist Republics (USSR or Soviet Union).[3] This struggle originated in Europe, but eventually spread around the globe. The defining feature of the Cold War was the massive arms race that developed between the Soviet Union and the United States. This arms race relied heavily on constantly advancing technology. The Soviet Union and the United States both developed massive missile and space programs after World War II. Although military and political goals fueled the early missile and space efforts of the United States, one important offshoot of these efforts was the emergence of a separate civilian space program. The civilian space program, which included both manned and unmanned missions, grew alongside and benefited from the military missile and space programs. The

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[1] This historical overview is utilized in all ERDC-CERL HABS/HAER reports for Cape Canaveral Air Force Station for reasons of continuity. It first appeared in McCarthy, et al, *Determination of Eligibility,* 1993. It has since been edited and expanded by Susan Enscore.

[2] David Barton and Richard S. Levy, *An Architectural and Engineering Survey and Evaluation of Facilities at Cape Canaveral Air Force Station, Brevard County, Florida*, (Resource Analyst, Inc., 16 March 1984), 1.

[3] These dates correspond to Winston Churchill's "Iron Curtain" speech delivered at Westminster College in Missouri and the destruction of the Berlin Wall, an event generally accepted as signifying the end of the Cold War.

military programs, in turn, also benefited from the successes of the civilian space program.

Origins of the United States Missile Program

America's early efforts in rocketry revolved around the work of Robert H. Goddard. Goddard conducted experiments with rockets in the 1920s and 1930s, and carried out the first-recorded launching of a liquid-propelled rocket on March 16, 1926.[4] Some of Goddard's more impressive achievements included adapting the gyroscope to guide rockets, installing movable deflector vanes in a rocket's exhaust nozzle scope to guide rockets, patenting a design for a multistage rocket, developing fuel pumps for liquid fuel motors, experimenting with self-cooling and variable thrust motors, and developing automatic parachute deployment for recovering instrumented rockets.[5]

Around the time Goddard was conducting his experiments, the Germans were also engaging in rocket research. In 1937 and 1938, they established huge research and test facilities at Peenemünde, Germany, on the Baltic Coast, where they developed the V-1 "buzz bomb" and the more advanced V-2 ballistic rocket. Although the U.S. military experimented with some crudely developed guided missiles during World War II, there was not much interest in rocketry among U.S. military leaders until the Germans began firing their V-1 and V-2 rockets at Allied cities in the summer of 1944. Allied anti-aircraft batteries quickly learned to shoot down the slow-flying V-1. There was no defense, however, against a 3,500 mile-per-hour (mph) V-2. The German V weapons made it clear that missiles would revolutionize the future of warfare. Recognizing this, the different branches of the U.S. Armed Services scrambled to create their own missile programs, each hoping to gain future operational and deployment responsibility.

Immediately after World War II, the Army brought several hundred German engineers and scientists, including Dr. Wernher von Braun, to the United States during "Operation Paperclip." The Army organized a team of rocket specialists from Peenemünde, including Dr. von Braun, at Fort Bliss, Texas to conduct studies concerning the development of long-range surface-to-surface guided missiles. In an effort to refine the German V-2, these scientists began helping the Army test launch captured V-2 rockets at the adjacent White Sands Proving Grounds in May 1946. In 1950, the Army moved

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[4] Warren R Young, ed., *To The Moon*, (New York: Time-Life Records, 1969), 21.

[5] Ibid., 18.

the team to the Redstone Arsenal in Huntsville, Alabama, where they began to develop the Redstone missile.

The Navy and Air Force also began their own missile programs in the 1940s. For a brief time, however, it appeared that a single, national, guided missile program might be established to eliminate duplication of effort among the services. The Army and Navy both favored such a development. But the Air Force (at that time still known as the Army Air Forces or AAF)[6] strongly opposed such a plan. AAF officials feared that a single program would jeopardize their chance of gaining sole responsibility for development and deployment of long-range guided missiles.[7] Consequently, fierce inter-service rivalries developed as each service sought to define its role and mission in the development and control of guided missiles.

In 1949, Secretary of Defense Louis A. Johnson initiated a review of the nation's missile programs, as an attempt to clarify the roles of each service branch and to reduce the waste resulting from the duplication of effort. The Air Force emerged from this review with "formal and exclusive" responsibility for developing long-range strategic missiles and short-range tactical missiles. Even after the review, however, both the Army and Navy continued to conduct missile "studies" that eventually progressed to the development stage.[8]

Aside from the inter-service bickering, a major obstacle to long-range missile development for the United States in the 1940s was lack of a range large enough to test new missiles. The nation's largest missile range in 1946 was the White Sands Proving Grounds in New Mexico and it was only 150 miles long.[9] In order for the United States to develop long-range missiles, a new missile proving ground would have to be established.

Committee on Long Range Proving Grounds

In October 1946, the Joint Research and Development Board of the War Department (later the Department of Defense) created the Committee on Long Range Proving Grounds. Charged by the War Department with selecting a site that would be suitable for a

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[6] The National Security Act of 1947 divided the military services into the three separate departments of the Army, the Navy, and the Air Force.

[7] Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945-1960*, (Washington, DC: Office of Air Force History, United States Air Force, 1990), 50-52.

[8] Ibid., 55-56.

[9] "Cape History: Establishment of the Eastern Test Range," NASA, *Spaceport News*, 14 October 1977.

long-range proving ground, the committee considered sites in California, Georgia, Texas, and Florida.[10]

The committee's first choice was the El Centro Marine Corps base in the Gulf of California area. The U.S. government immediately initiated negotiations with the Mexican government to secure sovereignty rights for tracking stations. When these negotiations failed, the committee then recommended the Cape Canaveral area in Florida. Cape Canaveral had several factors working in its favor, not the least of which was an over-water range that would allow long-range missile flights over an area relatively free from major shipping lanes and inhabited land masses. In addition, the numerous islands extending out into the Atlantic Ocean offered suitable locations for permanent stations to track missile flights and to record performance information. The relative isolation of the Cape area was ideal for safety and security reasons, and the weather conditions of the area would allow for year round operation.[11] Also, the Banana River Naval Air Station, located only about twenty miles from the Cape, would make an ideal support base. Aside from these advantages, locating the missile proving ground at Cape Canaveral also had economic advantages. The U.S. government already owned portions of the Cape and the undeveloped land on the Cape was considerably less expensive than land at other locations.[12]

Initial Developments

The Department of Defense (DoD) accepted the committee's recommendations and officially chose the Cape Canaveral area as the site for the envisioned missile test center. In May of 1949, President Harry S. Truman signed Public Law 60 authorizing the establishment of the joint long-range proving ground to be used by the Army, Navy and Air Force for the development and testing of missiles and other weapons.[13] The DoD assigned responsibility for developing the range to the newly created Department of the Air Force. Brig. Gen. William L. Richardson was named to direct the project.[14] During the next few years, the acquired land in the Cape area and began negotiations with the British government to acquire islands in the Bahamas and West Indies for use as tracking sites. The negotiations concluded with the signing of the Bahamas Agreement on July 21, 1950, permitting construction

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[10] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 3.
[11] *From Sand to Moondust: A Narrative of Cape Kennedy, Then and Now*, (U.S. Air Force and Pan American World Airways, Inc., 1974), 9.
[12] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 3.
[13] "Cape History: Establishment of the Eastern Test Range."
[14] *Master Plan of the Cape Canaveral Missile Test Annex*, (Pan American World Airways, Inc., 1971), 1.

of downrange stations on such islands as Grand Bahama, Grand Turk, Antigua and Ascension.[15] Future downrange stations were added as far away as Pretoria, South Africa.

On June 10, 1949, the Banana River Naval Air Station was reactivated and an advance headquarters was set up on October 1, 1949.[16] Brigadier General Richardson assumed command the following April. The name of the Banana River Naval Air Station was changed on August 1, 1950 to Patrick Air Force Base (PAFB) in honor of Major General Mason M. Patrick, the Army Air Corps' first Chief. During that same year, construction began on the first missile launching pad (known as Pad 3) and the first support facilities at Cape Canaveral. In June, Cape Canaveral was officially declared operational and became Operating Sub-Division No. 1, or Station 1, of the Joint Long Range Proving Ground.[17]

Name Changes

Over the years, the installation at the Cape, together with the entire range, underwent numerous name changes. Initially known as the Joint Long Range Proving Ground, the range became known merely as the Long Range Proving Ground in 1950. By 1952, it was known unofficially as the Florida Missile Test Range and on May 1, 1958, it was officially designated the Atlantic Missile Range. The name was changed once again in May 1964 to the Air Force Eastern Test Range (AFETR). The latest redesignation occurred in the fall 1990, when the range became simply the Eastern Range. Operating Station 1 (or Sub-division No. 1) was commonly known as Cape Canaveral from 1950 to 1963.[18] In November 1963, the Cape area was officially named Cape Kennedy in honor of President Kennedy, but then, in early 1974 the name was changed back to Cape Canaveral.[19] In April 1994, the name was changed yet again to Cape Canaveral Air Station and then in 2000, to the current name of Cape Canaveral Air Force Station.

Land Acquisition in the Cape Area

The U.S. government contracted the civil engineering firm of Sverdrup and Parcel of St. Louis to conduct a land survey of the

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[15] "Cape History: Establishment of the Eastern Test Range."
[16] The Navy had transferred the installation to the Air Force several years earlier.
[17] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 4.
[18] Ibid., 9. Between October 5, 1951 and December 15, 1964, the Cape was designated as Cape Canaveral Auxiliary Air Force Base. Between December 15, 1955 and January 22, 1964, the Cape carried the designation Cape Canaveral Missile Test Annex.
[19] Ibid.

Cape Canaveral area in January 1948. The government began acquiring land on the Cape in 1950. Of the original 12,000 acres acquired, 2,328 acres were purchased by the end of 1950. The U.S. government acquired the south half of the launching area from April- June 1950 as a result of condemnation petitions, and acquired the north half of the launching area in June 1950. In 1951, the value of government-acquired land and facilities at the Cape totaled about $7.5 million.[20] In 1956-1957, the government acquired an additional 682 acres in the south Cape area and from 1956-1959, acquired 1,924 acres in the northern Cape area. By 1959, the total acreage at the Cape was approximately 14,600 acres.[21] Later acquisitions brought the total to 15,804 acres.[22]

CONSTRUCTION HISTORY OF CAPE CANAVERAL

Early Construction at Cape Canaveral

Extensive construction was necessary to prepare Cape Canaveral for its role as a missile research and development test center. The first facilities built at Cape Canaveral were technologically primitive by today's standards. Many of the early structural designs became obsolete as missile technology advanced. Although facilities within launch complexes were often adapted and re-used for other functions, launch complexes designed for one type of missile or missile series were rarely used for subsequent missile programs because complexes that were useful for one missile or missile series were not configured to handle the later, often larger, and more sophisticated missiles. It was generally more cost effective to build a new launch complex than to adapt an existing launch complex. Some obsolete complexes were salvaged for reusable metal, sold to scrap metal dealers, demolished, or in a few cases used in the testing of anti-tank weapons.[23]

The Department of Defense designated USACE as the prime construction agency at Cape Canaveral and nearby PAFB. The Jacksonville District Corps of Engineers established a small area office at PAFB in May 1950, and awarded a contract for the construction of the first launch pad at the Cape. The launch pad (Pad 3) was completed by June 1950.[24] During the following month, the Army used the pad to launch the first missile from Cape Canaveral.

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[20] ''Master Plan of the Cape Canaveral Missile Test Annex," 2.
[21] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 4.
[22] Ibid., 1.
[23] ibid., 55.
[24] "Cape History: Establishment of the Eastern Test Range."

The Canaveral area office of the Corps, under the Jacksonville District, supervised and inspected $1.7 million in construction work and $700,000 in road contracts in the six months after the Bumper launch.[25] During the next three years, contractors constructed facilities for testing of cruise type missile weapons such as the Matador, the Snark and the Bomarc. The Air Force test-launched these missiles from Complexes 1-4. These complexes were located in an area northeast of the lighthouse at the point of the Cape. Other structures built in the area around this time included a communications building, a water plant, a fire station, and several camera tower roads. Tracking stations, an administrative area, and a bivouac area were built just northwest of this point. A skid strip was constructed in the center of the Cape, and south of the launching pads more camera tower roads, a guidance station, sky screen stations, a fuel storage area, a tracking station, a transmitter building, headquarters, and a guard house were built.[26]

The construction of Port Canaveral, a deep-water port located at the south end of the Cape, began in July 1950 and continued through 1952. The Corps of Engineers carried out the dredging of the port. Ships delivered missile components at Port Canaveral, and the Navy docked and serviced its tracking ships and missile launching submarines there as well.[27]

On December 31, 1953, the Air Force contracted with Pan American World Services for the operation and maintenance of facilities and equipment at PAFB and Cape Canaveral.[28] Two months later, Pan American chose the RCA Service Company as its primary sub-contractor for communications, photography, and electronic and optical tracking services. The management and direction of range operations remained the responsibility of the Air Force Missile Test Center. Air Force, Army, and Navy military personnel, along with civilian missile contractor personnel, conducted missile checkouts and launchings.[29]

Originally, contractors delivered missile components to PAFB. The contractors assembled the missiles at the base and then, transported them by truck to launching pads at the Cape. Because the bumpy ride to the Cape caused problems for the delicate missile parts, the Air Force decided in the early 1950s to build

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[25] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 6.
[26] Ibid., 43.
[27] Ibid., 6.
[28] Johnson Controls was awarded the launch base support contract in the late 1980s.
[29] "Cape History: Establishment of the Eastern Test Range"; John Hilliard, written correspondence with Susan Enscore, 17 May 2008.

hangars on the Cape itself, in order to assemble the missiles there. This decreased the distance the missiles needed to be carried, thereby reducing the wear and tear they were exposed to during transport. Construction of the first hangars at Cape Canaveral started in 1953, with the building of Hangar C and Hangar O.[30]

As the missile program progressed at Cape Canaveral, the missiles became more sophisticated and also more powerful. It became apparent that the hangars used to assemble the missiles were dangerously close to the launch pads. In the mid-1950s, with safety considerations in mind, the DoD decided to construct new missile development facilities at the Cape.[31] In early 1952, a "Development Plan for Cape Canaveral" had been prepared by Mr. James H. Deese, Chief of the Equipment Design Branch of Air Force Missile Test Center (AFMTC) Facilities Engineering Division, and Lt. Hal Snyder, USAF Reserve.[32] Major goals laid out in this plan included separation of launch pads for different project developments, with the northeast coastline reserved for future intercontinental ballistic missile pads and the southeast coastline reserved for light short-range ballistic missiles (Figure 2). Another aspect of the plan proposed a new industrial area in the western part of Cape Canaveral, safely away from the launch pads.

The Industrial Area

The Industrial Area, located next to the Banana River and midway between the southern and northern boundaries of the Cape, began to take shape in 1954-55. The Industrial Area was comprised of missile assembly buildings, shops, chemical storage areas, standards laboratories, heating plants, a cafeteria, a fire station, operational buildings, emergency power plants, and other miscellaneous utilities and structures (Figure 3). Contractors constructed the first assembly hangar in the Industrial Area (Hangar I) in 1955.[33] Other hangars were eventually built, and since the mid-1950s the majority of vehicles launched from the Cape have been assembled at the hangars located in the Industrial Area Figure 4). The newly created Industrial Area also contained

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[30] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 6.
[31] Ibid., 43.
[32] Memorandum from James H. Deese to Susan Enscore, 24 January 2001, 4-5; *Origins and Early Years of the John F. Kennedy Space Center, NASA (Through December 1965)*, Kennedy Space Center Historical Monograph Number 4, (Kennedy Space Center, Florida: NASA, 1971), II-19-20.
[33] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 6.

the Range Control Center, the main operations control facility for the Eastern Range and for Range and public safety.[34]

Later Construction

Development and construction continued at Cape Canaveral during the remainder of the 1950s and 1960s. After 1953, launch facilities were constructed primarily to support the intermediate range ballistic missile and intercontinental ballistic missile programs. A new period of construction began at Cape Canaveral in 1962, when the Air Force began its Titan III program at the installation. Due to safety considerations and area size requirements, Air Force contractors constructed facilities for this program on dredge spoil in the Banana River, about a mile from the west side of the Cape. New missile handling technology, engineering, and launching techniques characterized the Titan III program.

Utilizing a concept known as Integrate-Transfer-Launch (ITL), the new Titan III facilities allowed for off-pad assembly of the missile, integration of the boosters, payload checkout, and rail transport to one of two launching pads, all while the missile was in a vertical position. The ITL approach enabled the Air Force to obtain a high launch frequency, without requiring additional launch pads.[35]

The Titan III facilities, completed in 1964, included two launch complexes (40 and 41), special assembly buildings (including the Vertical Integration Building and the Solid Motor Assembly Building), and the first rail line at Cape Canaveral. Since that time, construction at Cape Canaveral has been limited to modifying various complexes and facilities, providing additional storage, assembly and checkout buildings, and a central heating plant in the Industrial Area.[36]

By 1966, activities at Cape Canaveral had reached their peak and, in the years following, there was a gradual operational decline. Most of the construction activity had shifted to the Kennedy Space Center, in conjunction with efforts by the National Aeronautical and Space Administration (NASA) to land a man on the moon. A few of the launch complexes and support buildings at Cape Canaveral that had served their purposes, and were either not

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[34] It was replaced by a new facility, the Range Operations Control Center (now the Morrell Operations Center) on Phillips Parkway in 1995. Hilliard, written correspondence, 17 May 2008.
[35] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 2.
[36] Ibid.

adaptable to other uses or not maintainable for economic reasons, were deactivated or put on standby. Facilities with ownership transferred to NASA during the early 1960s were gradually transferred back to the Air Force for use in their continuing space program activities at the Cape.[37]

By the late 1960s, there were three primary launching zones at Cape Canaveral (Figure 5). At the point of the Cape were Complexes 1, 2, 3, 4, 21/22, and 43. Except for Complex 43, which supported weather rocket launches, these complexes had generally been used for various winged missile programs (such as Snark, Bomarc, Matador, Bull Goose, and Mace). Above the point of the Cape were eleven complexes situated in a line along ICBM Road (11, 12, 13, 14, 15, 16, 19, 20, 34, 36, and 37). These complexes supported Atlas, Titan, and Saturn launches. Complexes 5/6, 9, 10, 17, 18, 25, 26, 29, 30, 31, and 32 were located under the point of the Cape. These sites had been built to support Redstone, Jupiter, Navaho, Thor, Blue Scout, Vanguard, Polaris/Poseidon, Pershing, and Minuteman launches. A new area was emerging near the northern boundary of Cape Canaveral with Complexes 40 and 41 for the Titan III.

MISSILE TESTING AT CAPE CANAVERAL

Designs for long-range missiles generally fall into two basic categories: aerodynamic cruise or “winged” missiles, and the more advanced ballistic missiles. Cruise missiles, resembling unmanned airplanes, require oxygen to support engine combustion and are therefore restricted to the earth’s atmosphere. Ballistic missiles, on the other hand, carry their own oxygen source allowing them to travel beyond the earth’s atmosphere. Faster and more effective than cruise-type missiles, ballistic missiles travel in long, arcing trajectories before striking their targets. Ballistic missiles themselves are further divided into two basic types: intermediate range ballistic missiles (IRBMs) and intercontinental ballistic missiles (ICBMs). The range of an IRBM can be as great as 1,500 miles while the range of an ICBM can be well over 5,000 miles.

Early Missile Research and Development

While the Army was beginning to test-launch captured German V-2 rockets at the White Sands Proving Ground in 1946, the AAF (Army Air Force was the immediate predecessor of the USAF, which was established in 1947) began funding its first long range missile

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[37] Ibid.

development studies. In January of that year, engineers from the Consolidated Vultee Aircraft Corporation (Convair) at Ft. Worth, Texas, presented the AAF with two design proposals for a missile capable of carrying a 5,000 pound warhead over a range between 1,500 and 5,000 miles. One design was for a cruise-type missile, and the other for a ballistic missile. AAF officials awarded Convair a study contract on April 2, 1946.[38] Headed by the Belgian-born engineer Karl Bossart, the Convair effort became known as Project MX-774. In order to collect the necessary data, Bossart gained permission to build thirteen test vehicles. Funding cutbacks soon forced Bossart to abandon the cruise missile design and concentrate solely on the ballistic missile design. Bossart and his team concentrated their efforts on improving the structural design and performance of the German V-2 rocket, but continued funding cutbacks forced the cancellation of the program in July 1947. Even though funding for the project was terminated, the AAF allowed Bossart and his team to use their remaining unexpended funds to complete and to flight test three vehicles. These flight tests, conducted at the White Sands Proving Grounds between July and December 1948, validated Bossart's design changes.[39] Later ballistic missile programs benefited from information gained during this project.

In the late 1940s, the United States drastically reduced its defense spending as the nation adjusted back to a peacetime economy. The reductions forced the Air Force to decide between developing either cruise-type long range missiles or ballistic long range missiles. Air Force officials decided to pursue development of the cruise-type missiles on the grounds that this type would become operational sooner than the expected ten-year time frame necessary for the development of an operational ballistic missile.[40] In the late 1940s and early 1950s, the Air Force began to invest heavily in the development of several cruise missiles. These included the Matador, Snark, and Navaho missiles. The Army, meanwhile, continued its work with the V-2.

Early Missile Testing at CCAFS

The Army was the first service to conduct a missile launch at Cape Canaveral. The missile was the Bumper, captured German V-2 rockets with WAC-Corporal second stages. Bumpers No. 1-6 had been previously launched at White Sands Missile Range, but a larger range was needed for the final two Bumpers. The first Cape launch, Bumper No. 8, took place on July 24, 1950, at Complex 3.

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[38] Neufeld, *Development of Ballistic Missiles*, 45.
[39] Ibid., 48-49; Hilliard, written correspondence, 17 May 2008.
[40] Neufeld, *Development of Ballistic Missiles*, 48.

A combined U.S. Army and General Electric Corporation team launched the rocket under primitive conditions, fueling the rocket directly from tank trucks and using a temporary blockhouse to control the launch.[41] The rocket, whose primary mission was to prove the feasibility of separating stages while in flight, traveled about 190 miles down range. The Army launched Bumper No. 7 from Complex 3 on July 29, 1950, completing the Bumper program.[42]

Aside from the Army Bumper launches, the majority of launches at Cape Canaveral in the early 1950s were Air Force winged missile launches. The first Air Force launch at the Cape occurred on October 25, 1950, when a team launched a Lark interceptor missile. The Lark had first been used by the Navy against Japanese aircraft during World War II. The Air Force's Lark flight lasted less than two minutes and covered only one mile. The Air Force continued to launch Larks at the Cape until July 1953.[43]

The tactical Matador winged missile was the first Air Force missile program to become operational, after being tested at Cape Canaveral. It was also the first missile to be successfully tracked by the downrange station on Grand Bahama Island. The Air Force conducted the first Matador launch from the Cape on June 20, 1951. Over the next ten years, the Air Force conducted a total of 286 Matador launches from Complexes 1, 2 and 4 and from the mobile launch area near the ocean.[44]

The Air Force's Snark missile was a surface-to-surface, pilotless bomber with a range of more than 5,000 miles. It was the first and only long-range, intercontinental, winged missile. Launched from Complexes 1 and 2 between August 29, 1951 and December 5, 1960, ninety-seven downrange flights occurred. Although the Snark was the first missile to be tracked by the downrange stations at both Antigua and Ascension islands, many of the Snark flights were unsuccessful, ending up in the Atlantic Ocean. Despite the many mishaps during testing, the Snark achieved a number of "firsts." These included being the first missile to return and land at Cape Canaveral's skid strip, the first missile to be equipped with a ballistic nose that separated from the missile

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[41] *From Sand To Moondust*, 9.

[42] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 12; Hilliard, written correspondence, 17 May 2008. Bumper No. 7 had misfired on the pad several days earlier; No. 8 was used first.

[43] "Lark," *The Range Quarterly*, September 1965, 3. The Air Force's Lark launches at Cape Canaveral served primarily as training vehicles for its Bomarc missile program.

[44] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 12.

and fell on its target, and the first missile to use a stellar guidance system.[45]

In August 1955, the Air Force began the test phase of its Navaho program at Cape Canaveral. The Navaho launched from Complexes 9 and 10 from November 1956 through November 1958, and was a surface-to-surface missile intended as an intercontinental strategic weapon. It was carried aloft, piggyback fashion, by a liquid-fueled booster. Although the Air Force eventually canceled the program, the Navaho pioneered the development of inertial guidance systems and large rocket engines.

Other winged missiles tested by the Air Force at Cape Canaveral included the Mace, the Bomarc and the Bull Goose/Goose.[46] The Air Force first launched the Bomarc from Complex 4 on September 10, 1952. The defensive winged missile was designed to intercept and destroy enemy aircraft. Bull Goose/Goose testing occurred at Complex 21/22 between March 13, 1957 and December 5, 1958.[47] Also a defensive winged missile, the Bull Goose/Goose was a diversionary missile designed to confuse an enemy's air and ground forces. The Mace, an improved version of the Matador, was launched from Complex 21/22 between October 29, 1959 and July 17, 1963.

U.S. Ballistic Missiles

In the early 1950s, the U.S. Congress began to reassess the military cutbacks of the late 1940s. As U.S. troops fought in Korea, Congress increased funding for military projects. The Air Force took advantage of the increased funding to initiate a long-range missile study, contracting Convair to carry out the effort. Designated Project MX-1593, this effort later became known as Project Atlas, a ballistic missile development project. The Air Force began funding further studies of the Atlas ballistic missile design in 1952. This funding, however, remained very low compared to the funding for the Air Force's cruise missile programs.[48]

While the Air Force Atlas ballistic missile program proceeded slowly, the Army was making significant progress in ballistic missile development. The Army had moved its team of German scientists working at White Sands to the Redstone Arsenal in

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[45] Ibid., 12, 15.
[46] The missile's designation changed from Bull Goose to simply Goose in May 1958.
[47] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 15.
[48] Neufeld, *Development of Ballistic Missiles*, 241.

Huntsville, Alabama in 1950. This team developed the Redstone missile. The Army began testing the Redstone at Cape Canaveral in 1953, the first launch occurring on August 20 at Complex 4. This was the first ballistic missile launch at Cape Canaveral. The Army continued launching Redstones at Cape Canaveral throughout the mid-1950s. In 1956, the Redstone became the first ballistic missile to be deployed in the field by U.S. troops. In 1958, the United States placed the Redstone in the North Atlantic Treaty Organization (NATO) arsenal.[49]

Although the Redstone was a ballistic missile, it had a maximum range of only 200 miles, and served merely as an extension of the Army's artillery. The DoD desperately desired a long-range missile that, when launched from U.S. soil, could reach Soviet targets. Early ICBM designs, however, called for giant, impractical missiles. These designs were based on the thrust requirements necessary to loft the heavy atomic warheads being produced at the time. Even if such a missile could be produced, considerable gains in guidance system technology would be necessary to make the missile accurate enough to be effective. Several important developments in the early 1950s, however, significantly impacted ballistic missile design requirements. The first was the detonation of the world's first thermonuclear device by the United States in 1952. This event paved the way for development of the powerful hydrogen bomb. Soon after the detonation, the Atomic Energy Commission (AEC) predicted that the production of smaller nuclear warheads with tremendous destructive potential would soon be feasible. Smaller, yet more powerful warheads would solve many of the problems associated with missile weight, and would also eliminate the need for pinpoint accuracy. This news, combined with intelligence reports indicating that the Soviet Union was making significant progress in developing both long-range missiles and thermonuclear warheads, prompted a reexamination of the U.S. strategic missile programs.

The Air Force convened a panel of leading U.S. scientists in 1953 to examine the Snark, Navaho, and Atlas missile programs. Known as the Teapot Committee, the panel's report, submitted on February 10, 1954, contained recommendations for relaxing performance requirements for long-range missiles (based on the new, lightweight, high-yield thermonuclear weapons), and

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[49] "Redstone," *The Range Quarterly*, September 1965, 7. In the mid-1960's, the Army replaced the Redstone missile with the Pershing missile. The Army tested the 100-400 mile-range Pershing missile at Cape Canaveral February - April 1963.

accelerating the development of the Atlas ICBM.[50] During the following months, these recommendations received the approval and support of high-ranking civilian and military leaders. Then, Air Force officials, and in particular Trevor Gardner, Special Assistant for Research and Development, began campaigning vigorously to convince Congress and the President of the urgency of ICBM development. These efforts paid off on September 8, 1955, when President Dwight D. Eisenhower assigned the highest national priority to the ICBM development program.

Air Force officials originally hoped to achieve operational capability with the Atlas by 1960. As a hedge against failure in the Atlas program, however, the Air Force initiated a second ICBM development program in 1955. This alternate ICBM became known as the Titan. By 1958, the Air Force began funding development of yet another ICBM, the Minuteman. The three-staged Minuteman was a solid-fueled ICBM designed for instantaneous launch from a heavily protected underground silo.

As the pace of the Air Force ICBM program quickened, intelligence reports indicated that by 1960 the Soviet Union would likely have a number of operational ICBMs armed with nuclear warheads. Fearing the United States would not be ready to match that threat, DoD officials decided that an IRBM should be developed, and based in Europe, to act as a stopgap measure until a sufficient number of American ICBMs became operational. After it was concluded that an IRBM with a 1,500 mile range could be developed in a relatively short time, the Joint Chiefs of Staff granted approval in 1955 for two IRBM programs the Air Force Thor IRBM program and the Army/Navy Jupiter IRBM program. Both programs advanced simultaneously, in direct competition with each other.[51]

IRBM Programs

The Army was the first branch of the armed services to test-launch an IRBM at Cape Canaveral. This occurred on March 14, 1956, when a modified Redstone with Jupiter components (known as Jupiter A) lifted off the pad at Complex 6. The first Jupiter IRBM launch occurred at Cape Canaveral one year later on March1, 1957. The Army conducted a total of 65 Jupiter launchings through January 22, 1963 at Launch Complexes 5/6 and 26.[52] The Jupiter

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[50] Neufeld, *Development of Ballistic Missiles*, 99-103.
[51] Ibid., 143-148. The IRBM programs were assigned equal priority with the ICBM program in January 1956.
[52] Ibid; Hilliard, written correspondence, 17 May 2008.

became operational in 1960. Although developed by the Army, it was the Air Force that actually gained operational responsibility for the weapon system. This situation came about in November 1956, when Secretary of Defense Charles Wilson issued a memorandum that divided responsibilities for research and development of ballistic missiles among the armed services. Wilson restricted the Army to developing weapons with ranges of 200 miles or less. At the same time, Wilson assigned sole responsibility for the development and deployment of IRBMs and ICBMs to the Air Force. The Navy received responsibility for developing ship-based IRBM systems.[53] The Army completed the development of the Jupiter IRBM and then turned it over to the Air Force for deployment.[54] The Air Force had operational Jupiter IRBM squadrons in Italy and Turkey by mid-1962.

The Navy initially took part in the development of the Jupiter IRBM with hopes of converting the missile for use on submarines. However, the Navy eventually determined that the liquid fuels of the Jupiter were too volatile and unpredictable to be carried aboard a submarine. In 1956, the Navy withdrew from the Jupiter project and began developing the solid-fueled Polaris IRBM.[55] The Polaris was designed to be launched from submarines, whether the submarine was surfaced or submerged. The Polaris program began at Cape Canaveral in 1957, with the construction of Launch Complex 25. While construction of Complex 25 was underway, the Navy conducted its first Polaris launch at the Cape at Complex 3 on April 13, 1957. The first launch at Complex 25 occurred on April 18, 1958.[56] The Polaris became operational in 1960, although the Navy continued test launching versions of the missile at Cape Canaveral through the 1970s. In 1968, the Navy began testing its second generation Poseidon Ship-Launched Ballistic Missile (SLBM) at Cape Canaveral, and in 1977, the Navy began its Trident SLBM program at Cape Canaveral.[57]

The Air Force Thor IRBM program began at Cape Canaveral in 1956, when the Air Force initiated construction of Complex 17 (Pads A and B, a dual complex). The first Thor launch occurred at Cape

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[53] Barton and Levy, *Architectural and Engineering Survey and Evaluation*, 17.
[54] The Army did continue to develop the Jupiter as a space booster.
[55] Neufeld, *Development of Ballistic Missiles*, 143-148.
[56] *Chronology of the Joint Long Range Proving Ground, Florida Missile Test Range and Atlantic Missile Range, 1938-1959*, History Office, 6550th Air Base Group, Air Force Eastern Test Range (Air Force Systems Command, 1975), 105, 111.
[57] In order to service its missile launches, the Navy built a complex at the south end of the Cape which included launch complexes, missile assembly and checkout facilities, administrative buildings, and a Navy pier facility at Port Canaveral.

Canaveral on January 25, 1957, at Complex 17. Unfortunately, the missile exploded and burned on the pad. Three more mishaps followed until finally, on September 20, 1957, the Thor completed a fully successful test launch. The Air Force conducted the research and development testing phase of the Thor program at Cape Canaveral, and the operational testing phases of the program at Vandenberg Air Force Base (AFB), California. Such was the case with the Air Force Atlas, Titan, and Minuteman ICBM programs as well. The Thor became operational in May 1960. By the end of that year, the Air Force had deployed four squadrons of sixty missiles with the Royal Air Force in England. The U.S. Air Force began to phase out these Thor squadrons in 1962 and 1963 as its Atlas and Titan ICBM sites became operational. Because of its reliability and versatility, the Thor continued in service as the booster for a wide variety of space missions.[58]

ICBM Programs

At the same time the Air Force was developing its Thor IRBM, it was also making significant headway in its ICBM programs. The Atlas research and development testing program began on June 11, 1957, at Cape Canaveral. The Air Force conducted Atlas test launches at Complexes 11, 12, 13, and 14 through 1962. During the course of the Atlas program, the Air Force tested several models of the missile. These models were designated series A through F. The Air Force eventually stationed the D, E, and F models, equipped with warheads and inertial guidance systems, at bases around the country, as part of the U.S. national defense arsenal. At one point, a total of 129 Atlas ICBMs were on strategic alert. The Air Force phased out its Atlas arsenal in 1964 and 1965, following the development of the Titan II and Minuteman ICBMs. Similar to the Thor, the Atlas also remained in service as a booster for America's manned and unmanned space missions.

The Air Force first tested its Titan ICBM at Cape Canaveral on February 6, 1959. Twenty of the first twenty-five Titan launches were completely successful. The Air Force declared the Titan ICBM operational in December of 1961. By the end of 1962, six Titan squadrons were operational at five western Air Force bases. The first launch of the Air Force's second generation Titan, the Titan II, occurred on March 16, 1962, at Cape Canaveral. The Titan II, America's largest ICBM, was capable of carrying a heavier load than Titan I. The Titan II used an inertial guidance system rather than a radio guidance system, and had the capacity to be launched from a silo. The Air Force declared the Titan II operational in December of 1963. Titan II was deployed at three

[58] *From Sand to Moondust*, 15; Hilliard, written correspondence, 17 May 2008.

Air Force bases and also was used as the booster for Project Gemini. The Air Force tested the Titan I and Titan II missiles at Complexes 15, 16, 19 and 20. The Air Force also developed a Titan III, but this missile was not a weapon system. It was developed as a standardized launch vehicle for space programs. The Air Force first launched a Titan IIIA vehicle on September 1, 1964. The Air Force used Complexes 40 and 41 for the Titan III program.[59]

Liquid propellants fueled most of the early weapons systems developed at Cape Canaveral. The Minuteman, the first multi-stage solid-fueled ICBM, was designed around the concept of instantaneous response to enemy attack. It was lighter, smaller, simpler and less expensive than the Atlas and Titan ICBMs. The Air Force eventually developed and test-launched three versions of its Minuteman ICBM. Complex 31 hosted the first Minuteman launch on February 1, 1961. The Air Force continued to test-launch its Minuteman I, II and III ICBMs at Complexes 31 and 32 at Cape Canaveral through December 14, 1970.[60] The Air Force first deployed Minuteman ICBMs at its bases in 1962. These missiles eventually became the backbone of the nation’s strategic, land-based, nuclear missile force.

BEGINNINGS OF THE U.S. SPACE PROGRAM

The official beginnings of the U.S. space program can be traced to 1955, when President Eisenhower announced that the United States would launch a small, unmanned, Earth-circling, scientific satellite as part of the nation’s participation in the International Geophysical Year (IGY).[61] While planning late in 1954 for the IGY, the International Scientific Committee discussed satellite vehicles as a way of obtaining information about the upper atmosphere. The IGY provided a perfect opportunity for the United States to start a satellite program that would not appear to be motivated by military considerations. In reality however, U.S. military leaders were extremely interested in developing a military space program. Although the Air Force, Army, and Navy all had been conducting upper air research programs of varying magnitude, none had initiated any major efforts to start a satellite program by the early 1950s.

President Eisenhower’s announcement concerning the IGY prompted three U.S. Armed Services to begin devising plans for a satellite program. By April, three separate plans had emerged. The first

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[59] Hilliard, written correspondence, 17 and 19 May 2008.
[60] *From Sand to Moondust*, 20.
[61] The IGY extended from July 1957 to December 1958.

was a joint effort by the Army and Navy, and was designated Project Orbiter. This plan called for placing a simple, non-instrumented satellite into orbit utilizing an Army Redstone booster. A second plan, by the Navy alone, was eventually designated Project Vanguard, and involved using a Navy Viking rocket as the first-stage of a three-stage rocket. The Air Force's plan was the third plan, and recommended using an Atlas coupled with an Aerobee-HI second stage.

Faced with these three plans, the DoD set up a special advisory group to review the proposed satellite programs and to make recommendations. Although favoring the use of the Atlas, the committee eventually decided that the Navy program had the best chance of placing the most useful satellite into orbit within the IGY, without interfering with the priority of ballistic missile development. As a result, the Navy was given permission to proceed with Project Vanguard.

Even after the DoD advisory group announced their official support for the Vanguard program, the Army continued to push its own proposed satellite program. Although the proposal was continuously rejected, the Army Ballistic Missile Agency continued to claim it could launch a satellite with only a four-month notice. The Army's persistence would eventually pay off.

In August 1957, the Soviet Union announced that they had successfully launched a multi-stage, long-range ballistic missile that had reached a "very high, unprecedented altitude." [62] The Soviets followed this launch with an even more impressive feat. On October 4, 1957, the Soviets shocked the world by placing Sputnik, the first man-made satellite, into orbit with one of their rockets. They quickly followed this launch with another during the following month. On November 3, 1957, a Soviet rocket placed the 1,120-pound Sputnik 2 satellite, carrying a live dog, into orbit. The Sputnik launches also served to focus public attention on the United States' own fledgling missile and space programs. Reacting to the public furor created by the Sputnik launches, Congress increased funding for ICBM development, while the DoD pushed hard to match the Soviet feat by placing its own satellite into orbit.

While the Soviets were successfully placing satellites into orbit, the Navy satellite program was experiencing many problems. The Vanguard launch vehicle blew up on its pad several times

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[62] Carl Berger and Warren S. Howard, *History of the 1st Strategic Aerospace Division and Vandenberg Air Force Base, 1957-1961*, (Vandenberg Air Force Base, California: Headquarters, 1st Strategic Aerospace Division, April 1962), 8.

during a string of failed launch attempts. This was all the more embarrassing for the United States, given the spectacular success of the Sputnik launches. While the Navy worked frantically to conduct a successful launch, the Army beat them to it. After the Sputnik launches, the Secretary of Defense gave approval to the Army to proceed with its satellite program. Eighty-four days later, on January 31, 1958, an Army team succeeded in placing the first U.S. artificial satellite, Explorer I, into orbit by using a modified Redstone missile known as Juno I. This historic launch occurred at Complex 26. The Vanguard team finally succeeded in placing a satellite into orbit on March 17, 1958. The three-pound Vanguard I satellite, launched from Complex 18, studied temperatures and upper atmosphere conditions, and also revealed the earth to be slightly pear-shaped.[63]

U.S. Military Space Program

The Vanguard and Explorer launches were early efforts to place fairly primitive scientific satellites into orbit. The DoD, however, gained valuable experience in satellite launch techniques as a result of these early efforts. Eager to build upon that experience, DoD officials soon began planning the development of satellites that could be used specifically for military purposes. Although there had been interest among the armed services in developing reconnaissance satellites as far back as 1945, several obstacles delayed their development. Chief among these were the considerable technological challenges posed by achieving and maintaining orbit, and the problems of data transmission.

Initially, the development of military satellites did not receive a high priority because the DoD focused its attention on the development of operational long-range missiles. By the mid 1950s, however, when it became clear that the Soviet Union would soon have numerous operational ICBM sites, posing a threat to the security of the United States, American leaders quickly realized the importance of identifying the characteristics and location of those weapon systems. On March 1, 1954, the independent, not-for-profit Research and Development (RAND) Corporation produced Report R-262 (Project FEEDBACK) that recommended the Air Force develop a surveillance satellite program.[64]

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[63] C.W. Scarboro, *20 Years in Space: The remarkable story of the activities spanning two decades at the world's most popular dateline,* (Cape Canaveral, FL: Scarboro Publications, 1969), 155.

[64] William E. Burrows, *Deep Black: Space Espionage and National Security,* (New York: Random House, 1986), 83; Hilliard, written correspondence, 17 May 2008.

In response to this study, within a year the Air Force began calling for proposals from industry for the development of a photographic reconnaissance satellite. Two basic types of satellite systems were subsequently proposed. One was a "non-recoverable" radio-relay reconnaissance system in which television cameras aboard a satellite would photograph ground targets, store the images on tape, and then relay the images to ground receiving stations when the satellite passed close enough overhead. The second type of satellite featured a "recoverable" system in which a capsule loaded with exposed film would be ejected from its satellite and return to earth where it would then be recovered. The development plan was approved in July 1956, and the Air Force awarded the Lockheed Corporation a contract to develop both types of satellites in October 1956. The project would become known as WS-117L (Weapon System-117L).[65]

By 1958, the National Security Council (NSC) assigned highest priority status to the development of an operational reconnaissance satellite. In November 1958, the DoD announced plans for its WS-117L program, revealing that it would consist of three separate systems: DISCOVERER, SENTRY, which would later be called Satellite and Missile Observation System (SAMOS), and Missile Defense Alarm System (MIDAS). The first two were reconnaissance systems, and the latter was the nation's first ballistic missile, early warning, satellite system. The Air Force conducted launches under these programs, using Thor and Atlas boosters coupled with various upper stages (primarily the Agena), throughout the 1960s and beyond. All of the DISCOVERER and SAMOS launches occurred at Vandenberg AFB. Cape Canaveral supported the first two MIDAS launchings on February 26 and May 24, 1960.[66]

The U.S. military satellite launchings did not go unnoticed in the Soviet Union. On several occasions, the Soviets complained bitterly about the satellites. In light of statements by the Soviets on the illegality of such activities and the increasingly credible threat to shoot U.S. reconnaissance satellites down, officials in President John F. Kennedy's administration decided to drastically curtail any official publicity concerning U.S. military satellite programs. By 1962, all military launches were classified as secret. The national reconnaissance effort continued, but henceforth was conducted under the highest degree of official secrecy.[67] Government officials hoped that the

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[65] Burrows, *Deep Black*, 84. The WS-117L project was code-named Pied Piper.
[66] Hilliard, written correspondence, 17 May 2008.
[67] After the launch of SAMOS 5 in December 1961, officials would no longer even admit the existence of the SAMOS project. Jeffrey T. Richelson, *The United States' Secret Eyes in Space: The U.S. Keyhole Spy Satellite Program,* (New York: Harper & Row, 1990), 53.

blackout of these activities would make it much harder for the Soviets to pick out the military satellites from the various other non-military application satellites the United States was launching.[68] In addition, the Kennedy administration hoped that if the Soviet Union was not unnecessarily embarrassed in front of the other nations of the world, Soviet officials would not complain as loudly about U.S. satellite reconnaissance activity.[69]

By the mid 1960s, reconnaissance satellites were yielding a regular supply of photographs to officials in the military services and the Central Intelligence Agency (CIA), allowing them to stay up to date with the latest Soviet military developments. By revealing that the Soviets did not have as many ICBMs deployed as U.S. officials had previously thought, reconnaissance satellite photographs were greatly responsible for dispelling fears of the much-publicized "missile gap."[70] Reconnaissance satellites also proved invaluable in monitoring compliance with international arms treaties, such as the 1963 Nuclear Test Ban Treaty and the Strategic Arms Limitation Treaty (SALT).[71]

The United States also has launched other types of satellites that have military applications. These include defense communication, weather, and navigational satellite systems. Some of the important non-reconnaissance military satellite launches of the late 1960s and 1970s include the Initial Defense Satellite Communication System (IDSCS) and the Defense Satellite Communications System (DSCS II and DSCS III), the Tactical Communications Satellite system (TACSAT I), the Fleet Satellite Communications system (FLATSATCOM), the Defense Meteorological Satellite Program (DMSP), and the Navigational Satellite Time and Ranging (NAVSTAR) Global Positioning System (GPS) program. Most of the above satellites have been launched from Cape Canaveral or the Kennedy Space Center. The DMSP, as well as numerous early navigational satellites, have been launched from complexes at Vandenberg AFB.

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[68] Ibid., 65.
[69] Burrows, *Deep Black*, 142.
[70] President Kennedy used the "missile gap" argument as a campaign issue in the presidential election of 1960. He charged that the Soviet Union was gaining a strategic advantage over the United States in ICBMs. In 1961, photographs recovered from the DISCOVERER satellites reduced the estimate of Soviet ICBMs from the hundreds previously thought to ten to twenty-five, thereby dispelling the missile gap notion. Richelson, *The United States' Secret Eyes in Space*, 349.
[71] The Nuclear Test Ban Treaty, signed by the United States, Great Britain, and the Soviet Union, prohibited nuclear testing in the atmosphere, in space, and under water.

The military space program played a crucial role in the nation's strategic efforts during the Cold War. Satellites have kept the United States abreast of the qualitative and quantitative characteristics of the weapons systems deployed by potential adversaries. This has helped the leaders within the U.S. government more accurately assess potential threats to national security, and has guided them in policy deliberations. In addition, and perhaps more importantly, the military space program made a significant contribution to the maintenance of international stability, particularly between the two nuclear superpowers of the Cold War era. Arms control resolutions and treaties would have carried little weight had there not been satellites capable of accurately monitoring the degree of compliance among the signatory nations. In addition, by virtually eliminating the possibility of a surprise attack on the United States, reconnaissance satellites have dramatically reduced the possibility that any nation might be tempted to launch such an attack.

U.S. Unmanned Civilian Space Program

Besides spawning the nation's military space program, the early Explorer and Vanguard launches signaled the beginning of the U.S. civilian space science program as well. From these pioneering scientific launches evolved programs to study the earth, the solar system, interplanetary space, the Moon, other planets and their moons, the galaxy, and ultimately, the universe. Besides enormously expanding our pool of scientific knowledge, these efforts greatly contributed to the nation's effort to send men safely to the moon and back. Information gained from the various U.S. space science programs also has been applied toward practical ends, resulting in numerous application satellite programs. These programs have had a profound effect on the lives of a large proportion of the world's population.

NASA is the primary Federal agency responsible for civilian space programs. Other agencies, such as the National Science Foundation, the Department of Defense, and the Smithsonian Astrophysical Observatory, have specialized or complementary roles. After the Soviet Sputnik launches, President Eisenhower assigned temporary responsibility for the U.S. space program to the DoD. The DoD subsequently established the Advanced Research Projects Agency (ARPA) in February of 1958. ARPA became, in essence, the first U.S. space agency. The Eisenhower administration, however, envisioned this as only a temporary measure. The president was hoping to reach an agreement with the Soviet Union that would limit the use of outer space to peaceful purposes only. Realizing that a U.S. space agency headed by the military would jeopardize this goal, Eisenhower pushed for the creation of a civilian space agency.[72]

The National Aeronautics and Space Act that became law on October 1, 1958, established NASA as the primary U.S. space agency responsible for developing and carrying out a national space program. NASA was created with the expressed intent that its space program be directed toward peaceful pursuits. The new civilian agency was to carry out aeronautical and space activities except those associated with defense, which were the responsibility of the Department of Defense. In anticipation of conflicts between NASA and the Department of Defense, provisions were made for mediation between the two via the President and a newly formed National Aeronautics and Space Council.[73]

In August of 1961, NASA and the DoD chose a section of Merritt Island (across the Banana River, three miles west from Cape Canaveral) as the launch center for the Manned Lunar Landing Program. This would become the site of the John F. Kennedy Space Center, owned and operated by NASA. During the period of the land acquisition and development, NASA built and modified a number of existing Air Force launch and support facilities at Cape Canaveral, to carry out manned and unmanned space programs.[74]

Almost immediately, NASA initiated a National Launch Vehicle Program aimed at eliminating the proliferation and duplication of orbital launch vehicles. Consequently, five launch vehicle families evolved. These included the Scout, the Thor (which eventually evolved into the Delta), the Atlas, the Titan, and the Saturn vehicles. Separate complexes at Cape Canaveral supported launchings of these space boosters. The successful launch vehicle program enabled NASA and the DoD to turn to each other for launch services whenever a certain payload better fit the other agency's launch vehicle, regardless of who sponsored the launch vehicle.[75]

NASA's civilian unmanned space program consisted of both science and application satellite and space vehicle programs. Throughout most of the 1960s, these programs were under the direction of the NASA Office of Space Science and Applications. A reorganization within NASA in 1972 resulted in the separation of the science and

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[72] U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Space Science and Applications, "United States Civilian Space Programs, 1958-1978," report prepared by Science Policy Research Division (Marcia S. Smith and others), Congressional Research Service, Library of Congress, 97th Congress, 1st sess., January 1981, Committee Print, 46-48.
[73] Ibid., 52.
[74] "Master Plan of the Cape Canaveral Missile Test Annex," 1.
[75] U.S. House, "United States Civilian Space Programs, 1958-1978," 184.

application satellite programs, with each given its own office headed by an associate administrator.[76]

Many of the missions in NASA's space science program have been directly related to physics and astronomy. Although some of these missions have been sub-orbital, involving sounding rockets and balloons, and others have traveled as far as the Moon, the majority of NASA's physics and astronomy missions have been Earth orbital. The orbital missions have been especially rewarding to scientists because they allow measurements to be taken of phenomena well above the reach of sounding rockets or balloons. Orbital missions also have helped revolutionize astronomy by placing telescopes above the distortion caused by either atmospheric turbulence or electromagnetic, infrared, and short-wave radiation.[77] Explorer spacecraft and several more complex orbiting observatories, such as the Orbiting Solar Observatory (OSO), the Orbiting Astronomical Observatory (OAO), the Orbiting Geophysical Observatory (OGO) and the High Energy Astronomy Observatory (HEAO), provide NASA with its principal means of conducting long-term automated investigations of the Earth, interplanetary space in close proximity to the Earth, sun-Earth relationships, and astronomical studies of the sun, stars, and galaxies.[78] Explorer missions, many of them undertaken with a significant degree of international cooperation, have been launched from both Cape Canaveral and Vandenberg AFB, using a variety of launch vehicles. Launches in the Explorer series began in 1958 and have continued into the 1990s. NASA launched most of its orbiting observatories from Cape Canaveral complexes in the 1960s and 1970s. However, a few OGOs were launched from Vandenberg AFB from 1965-1969.[79]

Major NASA programs involving investigations of the sun, the moon, the planets, and distant interplanetary space include: Helios, Pioneer, Pioneer-Venus, Ranger, Surveyor, Lunar Orbiter, Mars, Mariner, Viking, and Voyager.[80] In supplying scientists and technicians with invaluable information and images, these programs have dramatically increased the U.S. knowledge and understanding of its solar system, and beyond.

Besides purely scientific programs, the U.S. unmanned space program has also encompassed a multitude of application satellite programs. Too numerous to list here in detail, these programs

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[76] Ibid., 718.
[77] Ibid., 721.
[78] Ibid., 723.
[79] Hilliard, written correspondence, 17 May 2008.
[80] For detailed descriptions of these programs, see U.S. House, "United States Civilian Space Programs, 1958-1978."

included communication satellites, meteorological satellites, monitoring satellites of earth resources and environment, ocean sensing satellites, geodynamic satellites, and navigation satellites. Application satellites have had a tremendous impact on modern life. They have linked together remote areas of the earth, exerted a lasting impact on the growth and application of the science of meteorology, and provided numerous new ways to examine and map the Earth and its oceans.[81] Also, there has always been a close correlation between civilian and military application satellites, especially for communications, weather and geodetics. Application satellites characterized as "military" often provide useful information to the civilian sector, while "civilian" satellites, in turn, often furnish important information to the military.[82] The U.S. application satellite programs, combined with the nation's space science programs, have revolutionized the ways the world is viewed and lived in.

U.S. Manned Space Program

In April of 1961, Russian cosmonaut Yuri Gagarin rode the Vostok I into an orbit around the earth, becoming the first man in space. This achievement further shook American officials into action. On May 25, 1961, in a special message to Congress, President Kennedy stated that the United States, "... should commit itself to achieving the goal before this decade is out, of landing a man on the Moon and returning him safely to the earth."[83] Public support was widespread and Congress heartily endorsed the measure. NASA was responsible for carrying out the nation's ambitious goal. The American manned space program was divided into three phases: the Mercury, Gemini and Apollo programs. Cape Canaveral supported all of these phases.

Project Mercury

The goals of Project Mercury were to demonstrate that it was possible for a man to tolerate the conditions necessary to send him into space and to bring him back. These included withstanding

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[81] For information on specific civilian application satellite programs see U.S. House of Representatives, Subcommittee on Space Science, Application of the Committee on Science and Technology, "United States Civilian Space Programs: Volume II,Application Satellites" 98th Congress, 1st session, May 1983.

[82] For example, the Department of Defense's DMSP satellites regularly provide weather data to the National Oceanic and Atmospheric Administration (NOAA). Conversely, in March 1984, the NOAA's Landsat 4 earth resources satellite helped Department of Defense officials detect a Soviet ballistic missile-firing submarine testing equipment designed to smash through Arctic ice prior to underwater missile launch (see Burrows, supplemental photos).

[83] *From Sand to Moondust*, 29.

the acceleration of rocket launches, adapting to long periods of weightlessness, and then withstanding the high deceleration period during re-entry. Project Mercury had two parts, a sub-orbital stage and a manned orbital stage. During the first stage, NASA launched the chimpanzee, Ham, on a sub-orbital flight aboard a Mercury/Redstone vehicle on January 31, 1961. Alan B. Shepard, Jr., a former Navy test pilot, became the first American in space on May 5, 1961, when he rode aboard a modified Redstone rocket. An Air Force officer, Lt. Col. Virgil I. "Gus" Grissom's flight followed on July 21, 1961.[84]

Lt. Col. John H. Glenn, Jr., a Marine aviator and test pilot, became the first American to successfully accomplish a manned orbital flight mission. He circled the earth three times aboard Mercury/Atlas (MA-6) on February 20, 1962. The 22-orbit flight of Col. L. Gordon Cooper, Jr., USAF, which ended on May 15, 1963, concluded Project Mercury. It was the fourth manned mission. NASA launched the first two manned Mercury flights from Complex 5/6, and the remaining four from Complex 14.[85] These flights were controlled from the Mercury Mission Control Center. It was located on what became Mission Control Road at Cape Canaveral, and construction for the center began in 1957. The control center took over flight control when the rocket left the pad, and maintained control through splashdown. In 1965, this control function was transferred to the Johnson Space Center in Houston, supporting the Gemini, Apollo, and Space Shuttle programs.[86] The Mercury program lasted 55 months and led directly to Project Gemini.[87]

Project Gemini

NASA publicly announced Project Gemini on January 3, 1962. The goal of Project Gemini was to perfect space rendezvous and docking techniques and to attempt extravehicular walks in space. The successful completion and mastering of these operations was necessary in order to move on to the next step of landing men on the moon and then recovering them. Sophisticated manned space flight was mastered during this project.

NASA used a modified Titan II as the booster for Project Gemini capsules and a Mercury capsule - twice the size of earlier

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[84] Barton and Levy, *Architectural and Engineering Survey and Evaluation,* 28.
[85] Ibid., Appendix 7.
[86] *Man In Space: Study of Alternatives,* (United States Department of the Interior, National Park Service, 1987), 35; Hilliard, written correspondence, 17 May 2008.
[87] *Man In Space*, 28.

capsules was used to accommodate two astronauts. The first Gemini launch took place on April 8, 1964, from Complex 19. The first Gemini manned flight took place on March 23, 1965. There were a total of ten manned Gemini flights, placing twenty astronauts into orbit. These flights allowed the astronauts to conduct sophisticated maneuvering exercises and return back to earth safely.[88]

Project Apollo and Beyond

The goal of Project Apollo was to send a three-man crew aboard a spacecraft that would orbit around the Moon, land two of the astronauts on the Moon while the third continued to orbit, return the two men back to the orbiting spacecraft, and then return all the men safely to earth. NASA announced on January 9, 1962, that the Saturn V rocket would be the launch vehicle. The Saturn V was a huge rocket standing 363 feet tall (with the Apollo spacecraft) and capable of generating 7.5 million pounds of thrust.[89] NASA divided Apollo into two phases: earth orbital (unmanned and manned) and lunar. Missions were designed to test spacecraft launch vehicles, equipment and crew procedures. Tragedy struck on January 27, 1967, when an oxygen fire in the Apollo spacecraft at Complex 34 took the lives of astronauts Virgil Grissom, Edward White, and Roger Chaffee, who became the first casualties of the U.S. space program.
Despite the tragedy, the Apollo program continued. The first Saturn V test flight took place on November 9, 1967, with the launch of the unmanned Apollo 4 from Complex 39. The first manned Apollo launch took place on September 26, 1968, when Apollo 7 put three astronauts into earth orbit from Complex 34 using a Saturn IB rocket. The first lunar orbiting occurred during Apollo 8 on December 21, 1968 using a Saturn V from Complex 39. This was also the first manned Saturn V flight. Finally, on July 20, 1969, Commander Neil Armstrong became the first man ever to set foot on the moon during the Apollo 11 mission. Six additional moon missions followed. Apollo 17, launched on December 7, 1972, was the last mission in the series. The Apollo launches took place at Complex 34 at Cape Canaveral and Complex 39 at the adjacent Kennedy Space Center.[90]

Three other manned Apollo space missions occurred from Kennedy Space Center to the Skylab Station. The Skylab mission began on May 14, 1973, and involved placing a large inhabitable structure into orbit around the earth for use in collecting scientific

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[88] Ibid., 30.
[89] *From Sand to Moondust*, 29.
[90] Ibid., 29; Hilliard, written correspondence, 17 May 2008.

data. Apollo-Soyuz was a cooperative project between the Americans and the Russians involving the docking of two manned spacecraft in space. NASA launched this project from Complex 39 at the Kennedy Space Center. NASA first launched the Space Shuttle, the world's first reusable spacecraft, from Pad A at Complex 39 on March 12, 1981. Complex 39 continues to support Space Shuttle launches from Pad A and Pad B.[91]

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[91] *From Sand to Moondust*, 32.

HISTORY OF COMPLEX 31/32

Launch Complex 31/32 is located at the end of Flight Control Road on the southeastern side of Cape Canaveral Air Force Station (see Figure 5 for the general area). The Minuteman complex was not the first use of this site. When construction began on Complex 31/32, the site was then partially occupied by Launch Complex 9/10 (Figure 6).

Construction of this earlier complex began in 1953, to support testing of the Navaho surface-to-surface missile.[92] Produced and tested by North American Aviation, Inc., the Navaho was to be a long-range, winged ramjet-powered intercontinental cruise missile. Although the initial test version (X-10) was launched like an airplane on a landing strip, the more advanced version (G-26) tested at Complex 9/10 took off vertically, with its two ramjet engines supplemented by a liquid-fueled booster. The missile retained the earlier test version's incorporation of retractable landing gear that would have been utilized upon returning to the Cape Canaveral skid strip. The primary structures at Complex 9 were a blockhouse and launch pad. The complex was completed by the U.S. Army Corps of Engineers (USACE) in 1955, and the first Navaho launch occurred November 6, 1956.[93] A total of eleven launches were conducted from Complex 9, ending on November 18, 1958.[94]

Launch Pad 10 was constructed in 1955-56 to support testing of the Navaho from its mobile launcher. The pad had a mobile service tower on rails, which moved between its center and northwest edge. The launch pad was first used for a static test in February 1957.

Just five months later, the Navaho program was cancelled, a victim of the growing emphasis on the IRBM and ICBM programs. Nevertheless, five remaining Navaho missiles were launched to gather data on high temperature environments and supersonic aerodynamics. The Navaho testing program, while not leading to a deployed weapon system, did provide useful data on liquid-fueled rocket engines, propellant, and guidance systems that contributed to the success of the Atlas, Redstone, Jupiter, and Thor missiles.[95]

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[92] Kimberly Hinder, "Cape Canaveral Air Force Station, Launch Complex 9 & 10," HAER No. FL-8-10, (Sarasota, FL: Archeological Consultants, Inc., 2003), 1.

[93] Ibid.

[94] John Hilliard, written correspondence with Susan Enscore, 30 January 2009.

[95] Hinder, "Cape Canaveral Air Force Station, Launch Complex 9 & 10," 23.

Launch Pad 10 continued in use for another year or so, even though Launch Pad 9 was deactivated after November 1958. Launch Pad 10 hosted launches of the Jason and Alpha Draco missiles. An Air Force research rocket, the Jason had six launches from the site between August 14 and September 2, 1958.[96]

The Jason was a five-stage rocket, put together from existing hardware: an Honest John first stage, topped with two Nike stages, then a Recruit fourth stage, and finally, a T-55 fifth stage.[97] The Jason in 1958 was used to monitor radiation from the high-altitude nuclear explosions that were part of the Argus experiment.

There were three launch sites for the Jason: Cape Canaveral, Wallops Island, Virginia (NASA Pilotless Aircraft Test Station), and Ramey AFB, Puerto Rico.[98] The Jason took off from a mobile launcher set in the middle of the pad (

Figure 7).[99]

The final missile tested at Launch Pad 10, the Alpha Draco, was a surface launched, hypersonic, wingless missile with two stages. The first stage was a Thiokol Sergeant TX-20 solid-fueled rocket, and the second was a Thiokol TX-30, also solid fueled.[100] Developed by McDonnell Aircraft Corporation of St. Louis, the missile was designed to glide without power after reaching a peak altitude of 98,000 feet, and then continue to its target. The Alpha Draco program (renamed Draco in February 1959) was used for gathering information on aerodynamic heating and structural effects under continuous roll conditions, as well as the feasibility of aeroballistic missiles. The three test firings at

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[96] Ibid.

[97] The Recruit was a smaller version of the Sergeant, and the T-55 was a Thiokol Company solid fuel artillery rocket. Norman J. Bowman, *The Handbook of Rockets and Guided Missiles*, (Newtown Square, PA: Perastadion Press, 1963), 439-440, 506.

[98] William R. Corliss, *NASA Sounding Rockets, 1958-1968 - A Historical Summary*, (NASA SP-4401) 1971; "Jason," http://www.astronautix.com/lvs/jason.htm; Lew Allen, Jr., James L. Beavers, William A. Whitaker, Jasper A. Welch and Roddy B. Walton, "Project Jason Measurement of Trapped Electrons from a Nuclear Device by Sounding Rockets," *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 45, No. 8, Aug. 15, 1959, 1171.

[99] There is some disagreement that the Jason was actually launched from Complex 10. Various sources list Jason as utilizing only LC-4, or either LC-4 or LC-10, or both (one also says LC-3). Upon examination of the source material and the LC-10 site itself, the authors are as certain as is possible without definitive proof that the Jason was launched from LC-10.

[100] Hilliard, written correspondence, 30 January 2009.

Cape Canaveral all occurred at Launch Pad 10 between February 16 and April 27, 1959. The missile was fired from a mobile launcher tied down on the concrete pad, with a concrete flame bucket descending off one side of the surface area (Figure 8).[101]

Launch Complex 9/10 was shut down in 1959. In its final configuration, the complex consisted of Launch Pad 9, containing a concrete pedestal two stories tall and a specially designed folding erector gantry that raised the missile from horizontal to vertical for mounting on the launch pedestal (Figure 9). The complex's Launch Pad 10 was a hexagonal reinforced concrete surface with tie down points and a concrete flame bucket at its west edge. The blockhouse for both pads was a one-story reinforced concrete building (

Figure 10). A wheeled, fabric enclosed, pre-launch shelter plus an air conditioning building, sentry box, pump house and reservoir building, and nitrogen shed completed the facilities.

Complex Construction and Development

Construction began in July 1959 on Launch Complex 31/32 at a site partially occupied by the blockhouse, Launch Pad 10, and other facilities of Complex 9/10. The blockhouse was left intact and became the Administration and Engineering Office building. The air conditioning building became storage for tools and lockers, and the pump house became a support shop. The nitrogen shed became the pad service building. Launch Pad 10 was reconfigured as Launch Pad 31A.[102]

The original plan for the site of Launch Complex 31/32 contained nearly all the structures it would eventually hold. This dual complex contained two basically identical sets of facilities, each including a blockhouse, launch pad, launch silo, optical alignment building, underground equipment rooms, and utilities (Figure **11**). There was also a shared launch support building with its own utilities, and an array of camera pads and television pads.

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[101] "AFMTC History Jan-June 1959," (Patrick Air Force Base, Florida: 45th Space Wing Office of History, courtesy of Mark Cleary, Historian, 1959), 189-191.
[102] Hinder, "Launch Complex 9 & 10, HAER No. FL-8-10," 11.

The complex's construction, like all missile program construction at Cape Canaveral, was conducted by the U.S. Army Corps of Engineers. Under contract DA-08-123-ENG-2962, the dual facilities were constructed simultaneously, and the main facilities (minus the silo launch tubes), were completed in November 1960.

The most interesting architectural aspects of the construction were presented by the blockhouses (Figure 12, Figure 13, and Figure 14) and the silos (Figure 15, Figure 16, and Figure 17). The dual configuration was due to the high priority of the Minuteman program as part of the nation's response to the Cuban Missile Crisis. Two sets of facilities were required to insure no testing time would be lost due to potential launch facility damage. In light of the government's need to get the missile up and running as fast as possible, the program used a concurrency concept. This meant the facilities "were being designed and being built before many of the missile system characteristics were finalized."[103] One result of this was that the concrete casements for the launch tubes were built before the tubes' diameter had been determined. They were simply built large enough to handle all options. Another example of the concurrency process is found in the optical alignment buildings. Minuteman guidance used an optical reference for azimuth (usually the horizontal angle from true north). Although the optical reference system for later launches was established in the silos, the optical alignment buildings were constructed to provide optical reference for the launch pads. The earlier Minuteman missiles had little memory capacity available for trajectory correction, so accurate azimuth alignment was a critical factor. In the later versions, increased memory vastly improved the accuracy of the system. When the first Minuteman launch occurred at the site, the launch azimuth was unknown, as "nothing had impacted that far down range before."[104] So, the optical alignment buildings were constructed to accommodate different launch azimuths until the necessary ones were established. The concurrency process worked well, with the construction and subsequent missile testing quickly accomplished.[105]

The complex (Figure 18, Figure 19) was turned over to the Air Force under Voucher 61-1239, dated April 18, 1961. The silo launch tubes were constructed under contract DA-08-123-ENG-3149, and the formal transfer of property occurred under Voucher 62-1138 on September 15, 1961. Some auxiliary construction continued

[103] Col. Jack Hilden, ret., written correspondence with Susan Enscore, 5 February 2009.
[104] Ibid.
[105] Ibid.

at the site, with contract DA-08-123-ENG-3190 providing construction of a mobile unit support structure, a supporting substation, fencing, rails, and road, in an area northwest of the Complex 32 blockhouse (with the rails extending from there to Launch Pad 32A). This work was completed in December 1961.[106]

In addition to the main buildings and structures, there were many other lower order facilities including revetments, sewage lines, water lines, cable ducts, storm drains, fences, sidewalks, roads, parking areas, a public address system, electrical distribution lines, security lights, flood lights, a fire alarm system, and a compressed air distribution system. By the end of 1961, the complex had assumed its complete configuration (Table 1; Figure 20).[107]

Table 1. Launch Complex 31/32 facilities as of December 1961.

Facility #	**Original Facility #**	**Original Description**	**Original Cost**	**In Place?**
17700	17780B	Launch Pad 31A	$174,991	Yes
17700	17708E	Launch Equipment Room Pad 31A	$13,324	Yes
17701	17780H	Launch Pad 32A	$210,547	Yes
17701	17780K	Launch Equipment Room Pad 32A	$13,324	Yes
17702	17780A	Blockhouse CX 31	$279,181	Yes
17703	17780G	Blockhouse CX 32	$279,181	Yes
17704	17780F	Optical alignment bldg 31A	$19,886	Yes
17705	17780M	Optical alignment building 32A	$19,886	Yes
17706	17780V	Storage building (9/10 A/C bldg)	$3,836	Yes
17707	17780GS	Septic tank—Blockhouse CX 31	$1,500	Yes
17708	17780AS	Septic tank—Blockhouse CX 32	$1,500	Yes

[106] "Real Property Accountable Record for Complex 31/32," Cape Canaveral Air Force Station, Florida; "Real Property Record Cards for Silos 31B and 32B," Kennedy Space Center, Florida.

[107] Ibid. This figure was compiled from the cost given for individual facilities on the original Real Property Cards for Launch Complex 31/32 as a whole. Due to some figures being crossed out and replaced, and other figures from individual property cards for LC 31/32 facilities differing, this total is best used only as a rough approximation.

Facility #	Original Facility #	Original Description	Original Cost	In Place?
17750	17780C	Silo 31B	$735,079	Yes
17750	17780D	R&D Equip Room 31B	$14,000	Yes
17751	17780J	Silo 32B	$733,082	Yes
17751	17780L	R&D Equip Room 32B	$14,000	Yes
17756	17780W	Storage bldg (9/10 launch pedestal)	$65,469	Yes
17765	17780RS	Septic tank - Admin & Eng. office	$700	No
17766	17780R	Admin & Eng. Office bldg (9/10 blockhouse)	$92,525	Yes
17767	17780U	Pad Service Bldg (9/10 nitrogen shed)	$37,638	No
17768	17780N	Support shop (9/10 pump house)	$65,765	Yes
17769	17780T-1	Electric switch station	$2,000	Yes
17770	17780X	Mobile unit support building	$35,006	Yes
17771	17780Y	Substation	$3,328	Yes
17772	17780XS	Septic tank (mobile unit support bldg	$650	Yes
17781	17780P	Launch support bldg	$42,419	Yes
17782	17780T	Substation	$11,434	Yes
17783	17780PS	Septic tank (launch support bldg)	$1,500	Yes
no number assigned	17780Q	Sentry house	$1,671	No

A few small changes were also made to the complex in 1961, consisting of additional sidewalks, installation of floodlights, and adding air conditioning to the missile support shop. The following year, four roof fans were removed from that building, exhaust fans were installed in the silos, a parking area was added to the old Navaho launch pedestal (then a storage building), and an addition was placed on the Complex 9/10 blockhouse (then an administration and engineering office) for a latrine. Work for 1963 consisted of air conditioning the mobile unit support building, installing three showers in the launch support building, and providing each silo with a water cooler. In 1964, there was the installation of an exhaust fan in the storage building, and drinking fountains in the silos. The following year, the silos also received heaters for the research and development (R&D) equipment rooms. A UHF Doppler (UDOP) multi-static radar and multi-radar system, used for missile tracking and trajectory measurement, was added to the complex in 1964. In 1965, blast gauges were installed in the R&D equipment rooms, and in 1966, a concrete pad was constructed outside the launch support building and an air compressor was installed.[108]

The relocation of facilities and components between various CCAFS launch complexes picked up at Complex 31/32 in 1966, when rails for the Minuteman spur were relocated to the "T III Area." The main alterations noted on the record cards during the 1967-68 transition to Minuteman III seem connected to safety concerns. Those changes involved the installation of eyewash stations and showers (from Complex 11) in Silo 31B and the pedestal storage building, and plumbing fixtures in the support shop and in the pedestal storage building (from Facility 1309X). The support shop received a concrete pad, with metal shed and an air compressor, in 1969. An electronics shop (Facility 44409) was relocated to Complex 31 in 1969 as Facility 17780 AB, and moved to Complex 32 the next year (subsequently moved to Complex 30 later in 1970 as 56920L). That same year, work shop Facility 07820 became part of Complex 31/32 as Facility 17780AC and received a relocated transformer, and Launch Pad 31A received an air compressor (moved to another complex in 1971). Fire alarm bells were installed in the blockhouses in 1970.[109]

After the Minuteman program ended in late 1970, facilities began to be removed for use elsewhere, or turned over to other CCAFS entities for control and/or use. For example, Launch Pad 31A was transferred in 1971, the 9/10 launch pedestal was abandoned in place, and the sentry house was transferred in 1972. There were some changes made to Complex 31 during 1973 for the Pershing 1-A launches, including construction of revetments, installation of power drops, removal of a fire hydrant, and installation of a safety barricade at silo 31B. Slow deconstruction of the complex continued after the Pershing program ended, when the complex was deactivated. Air compressors, water coolers, floodlights and poles, wind indicators, and the blockhouse cooling towers were all removed by 1981.[110]

During the 1980s, the 45th Space Wing Mobile Combat Communications Group conducted training activities at the Complex 31/32 site.

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[108] "Real Property Accountable Record for Complex 31/32."
[109] Ibid.
[110] Ibid.

Those activities included a driving course, bivouac area (concrete tent pads were constructed for this), and a temporary communications field station. As part of their training, they utilized Facility 17781 (launch support building) and Facility 17768 (support shop) as classrooms, and turned the old 9/10 blockhouse (17766) into quarters for the group's instructor. The communications group was reassigned in 1990.[111]

A more permanent use for Complex 31/32 arose in late 1986. In the wake of the Space Shuttle Challenger (STS-51-L) disaster, over 235,000 pounds of debris were recovered. After the investigation into the causes of the loss the shuttle and its entire crew, a site was needed for long-term storage of the debris from the explosion. The site needed to be large enough, secure, and accessible if necessary.

Air Force Col. Edward O'Connor headed the salvage operation and came up with the idea to use the silos.[112] It was decided that the two silos at Complex 31/32 would provide the needed security and 31,000 cubic feet of storage space for the debris. The silos were prepared by removing their covers and excavating new hatchways into the equipment rooms, which were later sealed. Work platforms and rocket stands within the silos were removed in December 1986 and early January 1987, along with air conditioning equipment, electrical equipment, and other material.[113] The material was delivered to the site, and deposited in the silos and adjoining equipment rooms, beginning on January 8, 1987 (Figure 21). The openings were sealed with massive concrete caps on February 24, 1987.[114] The construction work was carried out by Pan Am Services, Inc. Later that year, the two silos were transferred from Air Force property rolls to NASA accountability.

In 2005, a plan was developed to construct buildings at Complex 31/32 to provide a site for a Force Protection Training Area. Four buildings, located along the southwestern edge of the

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[111] "Documentation of Adverse Effect for the Demolition of Facility Number17767 at Former Launch Complex 31/32, on Cape Canaveral Air Force Station, Florida," (Patrick Air Force Base, Florida: 45th Space Wing, Environmental Flight, U.S. Air Force, 2005), 1-2.

[112] "NASA studies storing Shuttle debris in silo," *Florida Today*, 29 August 1986, 1.

[113] "Environmental Assessment Proposed Long-Term Storage Facility Cape Canaveral Air Force Station, Florida," (Cape Canaveral, Florida: Pan Am World Services, Inc., 1986), 1-3; "Determination of No Adverse Effect for Proposed Long-Term Storage of STS 51-L Debris, Complex 31/32, CCAFS," (Cape Canaveral, Florida: Pan Am World Services, Inc., 1986, 2; "Challenger's remains find their resting place," *The Missileer,* 9 January 1987, 1.

[114] "1987 KSC Chronology," http://www-lib.ksc.nasa.gov/lib/ksconly/library.html.

complex, were constructed in early 2006 to provide an urban training facility. The plan also called for the refurbishment of Facilities 17768 (support shop), 17770 (mobile unit support bldg), and 17780 (9/10 launch pedestal). The new construction was completed to the extent of the four concrete block shells (Facilities 17752 - 17755), but it is not clear if the other planned refurbishments actually took place. For example, 17780 does not appear to have been touched.[115]

In 2004, Facility 17767 (latrine/former pad service building 17780U/former 9/10 nitrogen shed) was extensively damaged by a series of hurricanes. It had been converted to a latrine to support training activities for the 45th Space Wing Mobile Combat Communications Group/2nd Combat Training Communications Group. Prior to the conversion, the building had not been used since 1990. It was demolished by March 2006. The septic tank for the group instructor’s quarters (Facility 17765) was demolished in July 2007.[116]

Current facilities at Complex 31/32

Documented in this report:

17700 (1960) – Launch Pad 31A
17701 (1960) – Launch Pad 32A
17702 (1960) – Blockhouse CX 31
17703 (1960) – Blockhouse CX 32
17704 (1960) – Optical alignment building 31A
17705 (1960) – Optical alignment building 32A
17707 (1960) – Septic tank—Blockhouse CX 31
17708 (1960) – Septic tank—Blockhouse CX 32
17750 (1960) – Silo 31 (storage facility)/NASA owned
17751 (1960) – Silo 32 (storage facility)/NASA owned
17770 (1961) – Paint crew support building (mobile unit support bldg)
17771 (1960) – Substation
17772 (1960) – Septic tank
17781 (1960) – Commo group training facility (launch support bldg)
17782 (1960) – Substation
17783 (1960) – Septic tank

[115] “Proposal to Construct a Force Protection Training Area at Former Launch Complex 31/32 on Cape Canaveral Air Force Station, Florida,” (Patrick Air Force Base, Florida: 45th Space Wing, Environmental Flight, 2005), 1-3; “Real Property Accountable Record for Complex 31/32.”
[116] “Real Property Accountable Record for Complex 31/32.”

Not documented in this report:[117]

17706 (1960) – Storage building (outside fence line; former 9/10 air conditioning bldg)
17766 (1960) – Communications group instructor's quarters (former 9/10 blockhouse)
17768 (1960) – Communications group training facility (former 9/10 pump house)
17769 (1960) – Electric switch station
17773 (1993) – Paint storage shed (new)

Missile Launches from Complex 31/32

Two different missile systems were test fired from Complex 31/32: the Minuteman (Minuteman I, II, and III), and the Pershing 1-A. The complex was specifically constructed for the Minuteman test program, which lasted from 1961 through 1970. The site then was utilized in 1973 for a series of Pershing 1-A mobile launches from Pad 31A. Minuteman launches took place from Pad 31A, Silo 31B, and Silo 32B. Launch Pad 31B was a standby facility and was never used.

Minuteman I

In 1954, the Air Force proposed a plan to develop an ICBM with advanced capabilities. The first generation ICBMs were the Atlas and the Titan. Both missile systems were expensive to produce, and labor intensive to maintain and operate. The Atlas and the Titan depended on liquid propellants that were volatile and corrosive. In addition, fueling took about two hours for a space launch and had to be done as close to takeoff as possible.[118] These challenges prompted a second-generation ICBM.

Col. Edward Hall, USAF, was Chief of Propulsion Development for the Air Research Development Command's (ARDC) Western Development Division (WDD). He headed the small working group tasked with developing solid propellant rocket motors. Within weeks, Hall

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[117] These facilities were not documented in this report due to: 1) being outside the fence line delineating the historical boundaries; or 2) being recent intrusions to the site not associated with the period of significance for Launch Complex 31/32.

[118] Fueling of both the Atlas and Titan was much faster if not for a space launch, anywhere from 5 to 15 minutes depending on the vehicle (Hilliard, written correspondence, 30 January 2009).

proposed "a remarkable new missile whose range could be varied by simply assembling its three interchangeable propulsion stages in different combinations."[119] The new missile was called the Weapon System Q and later Sentry, and finally changed in September 1957, to Minuteman SM-80 (or LGM-30), after the American Revolutionary heroes who were ready to fight on a moments notice.[120] Project and program details were kept top-secret, including the location where the WDD team developed the Minuteman. The Minuteman missile was a product of intense research efforts being placed on developing a long-range ballistic missile designed for carrying nuclear warheads. As visualized by Hall's group, the Minuteman would be a reliable, easy to maintain system with the ability to be stored a long time, and ready to launch very quickly.[121] His idea for deploying the missile was to place them in unmanned, hardened and dispersed silos that had electronic linkages to launch control facilities. He wanted a missile with enough propulsion to "accelerate so quickly that it could fly through its exhaust flames and not be significantly damaged (Figure 22)."[122] The Minuteman accomplished all of Hall's goals and was "one of the fastest research and development programs of any arrival at the Cape" becoming operational within an eighteen-month period.[123]

In 1958, the US government contracted with Boeing Airplane Company to assemble and test the Minuteman missile. The following American companies won contracts to work on the missile's propulsion stages: The Thiokol Chemical Corporation for the first stage, the Aerojet-General Corporation for the second, and the Hercules Powder Company for the third stage. The re-entry vehicle was contracted to the AVCO Corporation of Boston and the Minuteman's guidance and control systems went to the Autonetics Division of North American Aviation.[124]

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[119] "History of Minuteman Missile Sites Minuteman Missile National Historic Site," U.S. Dept. of the Interior, National Park Service, www.nps.gov/archive/mimi/history/srs/history.htm

[120] Robert Frank Futrell, *Ideas, Concepts, Doctrine Basic Thinking in the United States Air Force 1907-1960*, Vol .I, (Alabama: Air University Press, 1989; L.B. Taylor, Jr. *Lift Off! The Story of America's Spaceport* (New York: E.P. Dutton & Co., 1968), 121.

[121] Roy McCullough and Julie Webster, *Missiles at the Cape: Missile Systems on Display at the Air Force Space and Missile Museum, Cape Canaveral Air Force Station, Florida*, SR-01-22, (Champaign, IL: U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, 2001), 66.

[122] "History of Minuteman Missile Sites," www.nps.gov/archive/mimi/history/srs/history.htm

[123] Ibid.; McCullough and Webster, *Missiles at the Cape*, 66.

[124] "History of Minuteman Missile Sites," www.nps.gov/archive/mimi/history/srs/history.htm

The Minuteman became the world's first missile to be powered with solid fuel propellant.[125] This allowed for rapid deployment, and for a more effective and less expensive weapon system. Technological advancements enabled the Minuteman missile's warhead to weigh less than 25 percent of the Atlas and the Titan warheads.[126] Advanced technology also allowed the missile to be designed to be maintained within, and remotely launched from, hardened underground silos where it would be immune from an enemy nuclear attack. Such was the speed of its firing preparation that the missile was nicknamed the "Instant ICBM" in comparison to its predecessors.

The Minuteman missile diminished in size upwards, as each of the three cylindrical, steel-cased propulsion stages was a little smaller than the one before. Filled with a mixture of fuel and oxidizer, the three stages led to the guidance system in a small compartment above the third stage, with a reentry vehicle/nose cone for the warhead that completed the missile. The missile was designed with a range of 6,300 miles.[127]

In 1960, the first Minuteman missile was sent to Cape Canaveral for testing. Some preliminary single-stage and tethered testing had been done from a silo at Edwards AFB in September 1959, but the program was moved to the Cape for its multistage free flight (Figure 23).[128] The first launch occurred on February 1, 1961 from Launch Pad 31A (Figure 24). Unlike other missile development programs, where test flights launched missiles with only one live stage and dummies for any other stages, the Minuteman tests were all conducted on "full-up" missiles, meaning all three stages were live.[129]

That first launch went flawlessly, with the missile igniting with a loud bang, and then shooting off into the sky (Figure 24). The three stages burned out, then fell away, and the unarmed warhead landed squarely on target at a distance of 4,600 miles. According to Air Force Chief of Staff General Thomas D. White, the launch was "one of the most significant steps this Nation has ever taken

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[125] Bowman, *The Handbook of Rockets and Guided Missiles*, 346.
[126] Ibid.
[127] "History of Minuteman Missile Sites," http://www.nps.gov/archive/mimi/history/srs/history.htm
[128] Results of these tests determined the diameter of the launch tubes (Hilden, written correspondence, 5 February 2009).
[129] "Minuteman Missile History," www.strategic-air-command.com/ missiles/ Minuteman/ Minuteman_Missile_History.htm; Mark Cleary, *The 6555th Missile and Space Launches Through 1970,* (Patrick Air force Base, Florida: 45th Space Wing History Office, 1991).

toward gaining intercontinental missile supremacy."[130] It was a huge leap ahead in the Air Force's ability to have a quick reaction nuclear missile. The full-up test was a coup for the Air Force and Cape Canaveral, and after the first launch when the "sleek swift missile charged all the way down the range it was a major step ahead in its development program."[131] There were eventually two types of Minuteman I developed, the "A" and "B." The first "A" type had a less-successful first stage, and its range was slightly limited. The "B" missile improved this performance and achieved the desired 6,300 mile range.[132]

The Minuteman I testing program continued into 1964, with a strong record of successful flights.[133] There were only three initial flights from a launch pad. Thereafter, silos were used exclusively for the remainder of the Minuteman testing through 1970 (Table 2; Figure 25). The first silo launch resulted in a fiery explosion, but failures were uncommon, although they could be spectacular when they occurred (Figure 26). By September 1962, test flights were taking place from a silo at Vandenberg AFB.[134]

Table 2. Minuteman I flights at Complex 31/32.

Date	Vehicle	Series Number	Pad/Silo	Result
1 Feb 1961	Minuteman 1A	401	31A	Success
19 May 1961	Minuteman 1A	402	31A	Failed
27 July 1961	Minuteman 1A	403	31A	Success
30 August 1961	Minuteman 1A	404	32B	Failed
17 November 1961	Minuteman 1A	405	32B	Success
18 December 1961	Minuteman 1A	406	31B	Success
5 January 1962	Minuteman 1A	407	31B	Success
25 January 1962	Minuteman 1A	408	31B	Success
15 February 1962	Minuteman 1A	410	31B	Success
8 March 1962	Minuteman 1A	409	31B	Success
22 March 1962	Minuteman 1A	411	32B	Success
24 April 1962	Minuteman 1A	412	32B	Failed
11 May 1962	Minuteman 1A	413	32B	Success
18 May 1962	Minuteman 1A	414	32B	Success

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130 "History of Minuteman Missile Sites," www.nps.gov/archive/mimi/history/srs/history.htm

131 Taylor, *Lift Off! The Story of America's Spaceport*, 121.

132 McCullough and Webster, *Missiles at the Cape*, 67.

133 Mark Cleary, "Eastern Range Launch History," (Patrick Air Force Base, Florida: 45th Space Wing History Office), n.d.

134 Hilliard, written correspondence, 30 January 2009.

Date	Vehicle	Series Number	Pad/Silo	Result
8 June 1962	Minuteman 1A	415	32B	Success
29 June 1962	Minuteman 1A	416	32B	Success
12 July 1962	Minuteman 1A	417	31B	Failed
9 August 1962	Minuteman 1A	418	32B	Failed
18 September 1962	Minuteman 1A	421	31B	Success
19 September 1962	Minuteman 1A	420	31B	Success
17 October 1962	Minuteman 1A	422	31B	Failed
19 November 1962	Minuteman 1A	421A	31B	Success
7 December 1962	Minuteman 1B	424	32B	Success
14 December 1962	Minuteman 1B	423	31B	Success
20 December 1962	Minuteman 1A	426	32B	Failed
7 January 1963	Minuteman 1B	423A	31B	Failed
23 January 1963	Minuteman 1B	419	32B	Success
20 February 1963	Minuteman 1A	421B	32B	Success
18 March 1963	Minuteman 1B	425	31B	Success
27 March 1963	Minuteman 1B	419A	32B	Success
10 April 1963	Minuteman 1B	425A	31B	Success
18 May 1963	Minuteman 1B	425B	32B	Failed
28 May 1963	Minuteman 1B	428	31B	Success
5 June 1963	Minuteman 1B	427	32B	Success
27 June 1963	Minuteman 1B	429	31B	Success
1 July 1963	Minuteman 1B	431	32B	Success
17July 1963	Minuteman 1B	430	32B	Failed
25 July 1963	Minuteman 1B	432	31B	Success
5 August 1963	Minuteman 1B	433	32B	Failed
27 August 1963	Minuteman 1B	435	31B	Success
7 November 1963	Minuteman 1B	434	32B	Failed
13 November 1963	Minuteman 1B	446	31B	Success
18 December 1963	Minuteman 1B	447	32B	Success
16 January 1964	Minuteman 1B	438	32B	Success
28 January 1964	Minuteman 1B	448	31B	Success
12 February 1964	Minuteman 1B	436	32B	Success
25 February 1964	Minuteman 1B	437	31B	Success
27 February 1964	Minuteman 1B	439	32B	Success
13 March 1964	Minuteman 1B	440	32B	Success
20 March 1964	Minuteman 1B	442	31B	Success
30 March 1964	Minuteman 1B	441	32B	Success
7 April 1964	Minuteman 1B	443	31B	Success

Date	Vehicle	Series Number	Pad/Silo	Result
24 April 1964	Minuteman 1B	444	31B	Success
29 September 1964	Minuteman 1B	445	31B	Failed

As development of the missile moved ahead, the Strategic Air Command (SAC) was making plans to provide for a mobile capability for the Minuteman. Fearing the silos were too tempting a target, a system was developed for moving somewhere between 50 and 150 missiles around on rails while encased in a portable launcher/rail car (Figure 27).

A series of tests called "Operation Big Star" was conducted from Hill AFB in Utah. Beginning on June 20, 1960, a train set out across the central and western United States, with technicians aboard to measure the stress on the missiles and the capacity of the railroads. In all, four train runs occurred, which completed the test objectives satisfactorily.

In the fiscal 1962 budget, funds were requested for three mobile Minuteman squadrons. As development of the mobile program was still underway, President Kennedy recommended, in April 1961, that they be deferred in favor of three fixed-base squadrons.[135] Before anything could get up and running, the Air Force cancelled the project on 7 December 1961, in favor of underground launchers.[136]

The mobile system testing program, however, had physical results at Launch Complex 31/32, including a mobile unit support building (17780X/17770), co-located utilities, and a railroad spur reaching toward launch Complex 32A. The facilities were needed for missile launching from a rail car and for support of the missile car. The mobile unit support building would provide checkout and repair of the missile car, and the missile would be transferred to the car at Pad 32A. The amount of track laid for this purpose was 1,700 feet. This facility was finished just as the program was being cancelled, and it is unlikely it was ever used for mobile testing with rail cars.[137]

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[135] "Defense Sec McNamara Backs Stronger Forces," *The Fort Riley Post*, 21 April 1961, 3.
[136] Bowman, *Handbook of Rockets and Guided Missiles*, 346.
[137] "Real Property Accountable Record for Complex 31/32;" "Site Plan for Transfer-Mobile Unit, Checkout and Launch Facility for the Minuteman Program, Complex 32, CCMTA, Florida," 23 August 1960 in Record Group 341, Entry 139, Box 1, File: Patrick 1961-62, National Archives and Records Administration, College Park, MD.

In addition to the facilities at Complex 31/32, the Minuteman program utilized other resources at Cape Canaveral (Figure 28). Missile component checkout occurred in Hangars G, I, and N (Facilities 1606, 1711 and 1728, respectively). Buildings AB, AC & AD were used for missile assembly (Facilities 55820, 55810, and55815, see Figure 29). There were two engine receiving and inspection buildings (Facilities 55805 and 55840), one propellant inspection building, two engine storage buildings, one assembly and support building, and one missile storage building. Prior to assembly, Minuteman stages were inspected for cracks in the solid propellant at the propellant inspection building/non-destruct test laboratory (Facility 77380). After assembly, the missile was delivered to the pad on a flatbed trailer with a special erector/cradle for the missile, called a "strongback." After raising the missile to a vertical position with the strongback (Figure 30), it was attached to an 80-ton crane and either placed on the pad launcher, or lowered into the silo (Figure 31).[138]

Once in place, the missile's controlling umbilicals were installed and checked out; instrumentation, guidance and control equipment were installed; and the re-entry vehicle containing a data-collecting instrumentation system was attached (in lieu of the warhead on deployed missiles) (Figure 32, Figure 33). Due to the use of solid propellant, no on-site fueling was required. During the second half of 1961, the operational transporter/ erector (enclosing the missile) replaced flatbed, crane, and cable system for loading the missile into the silo (Figure 34). This new system continued in use for the Minuteman II and III launches (Figure 35).[139]

A testing program of this magnitude required a large group of personnel to carry it off. The Minuteman team was composed of both Air Force and contractor personnel. The Air Force activated the Minuteman Project Division in 1959, under the Air Force Ballistic Missile Division's (AFBMD) Assistant Commander for Missile Tests. Essentially a liaison agency, the AFBMD interacted closely with the Boeing, TRW, and other contractors who were preparing the complex for use during late 1960.[140] The 6555th Test Wing (Development) activated its Minuteman Operations Division in July 1960, and was combined with the Minuteman Project Division on April 17, 1961, to become the Minuteman Weapons Branch. Over time, the 6555th increased its involvement in the actual launches,

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[138] John Hilliard, electronic correspondence with Susan Enscore, 11 November 2007.

[139] Ibid.

[140] An associate contract structure was used that provided the Air Force separate contracts with TRW, Boeing, Avco, Autonetics, and the three motor contractors (Hilden, written correspondence, 5 February 2009).

with the first all-military launch on June 29, 1962. Previous to that, all launches had been conducted by Boeing and the other contractors. The Minuteman Weapons Division took responsibility for the complex in 1963, and conducted most of the launches after that time.[141] For the entire length of the Minuteman program at Cape Canaveral, Boeing and the other contractors were responsible for all missile testing and assembly. Boeing's Blockhouse Section personnel preformed preflight tests of all systems, and served as test conductors (Figure 36, Figure 37).[142]

Minuteman II

Advancements resulted in a missile that was "longer and heavier than the Minuteman I," and "could carry 34 percent more propellant, resulting in increased range."[143] The Minuteman II (aka Minuteman F) had the following important new features:[144]

- An improved first-stage motor to increase reliability
- a new-technology, single, fixed-nozzle with liquid injection thrust vector control (TVC) on a larger, second-stage motor to increase the missile range
- additional motor improvements to increase reliability
- improved guidance system, incorporating semiconductor integrated circuits and miniaturized electronic parts;
- penetration aids system to camouflage the warhead during its reentry into an enemy environment
- larger warhead in the reentry vehicle (RV) to increase kill probability[145]

The overall advancements of Minuteman II included greater range, multiple-target selection and flexibility, improved guidance, accuracy, and reliability, lighter weight and size, and an increase in the survivability of the guidance system in a nuclear environment.[146] The improved inertial navigation guidance system, designed by Autonetics (a division of Boeing), introduced a microelectronic system that could store data on multiple targets.

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[141] Cleary, *The 6555th: Missile and Space Launches Through 1970*, chapter III, section 8, 1-4.
[142] Ibid.
[143] Lethbridge, "Cape Canaveral Rocket and Missile Programs," *Spaceline, Inc*. http://www.spaceline.org.
[144] ICBM Prime Team, TRW Systems. "Minuteman Weapon System History and Description," (Hill AFB: Intercontinental Ballistic Missile (ICBM) System Program Office (SPO), 2001), 31.
[145] Minuteman II warhead was larger than Minuteman IA, but the same size as Minuteman IB (Hilliard, written correspondence, 30 January 2009).
[146] ICBM Prime Team, "Minuteman Weapon System History and Description," 31.

In addition, there were two improved versions of the Avco-manufactured RV to utilize, either of which could deliver a two-megaton warhead.[147] The deployed missiles were also given hardened launch facilities to make them less vulnerable to attack.[148]

Development of Minuteman II began in 1962, and the first test launch occurred at Cape Canaveral in September 1964.[149] Testing of the Minuteman II was completed in 1968.[150] The Minuteman II test flights from Complex 31/32 went remarkably well, with no failed launches (Table 3). Of the twenty-one missiles launched in this phase, twenty left from the silos. The sole exception was the last Minuteman II flight on March 14, 1970, nearly at the end of Minuteman III testing. The missile launched from ground level at Launch Pad 31A as a "Mobile Feasibility Test" utilizing a tube launcher (Figure 38). A dummy missile with only a little first-stage propellant was fired and successfully flew for about twenty to thirty seconds, "just like a big bazooka."[151]

Table 3. Minuteman II launches at Complex 31/32.

Date	Vehicle	Series Number	Pad/Silo	Result
24 September 1964	Minuteman II	449	32B	Success
29 October 1964	Minuteman II	450	32B	Success
15 December 1964	Minuteman II	451	32B	Success
18 December 1964	Minuteman II	452	31B	Success
28 January 1965	Minuteman II	453	31B	Success
7 May 1965	Minuteman II	455	32B	Success
25 May 1965	Minuteman II	456	32B	Success
3 August 1965	Minuteman II	457	32B	Success
23 August 1965	Minuteman II	454	31B	Success
24 September 1965	Minuteman II	458	32B	Success
1 October 1965	Minuteman II	459	31B	Success
5 January 1966	Minuteman II	461	32B	Success
10 February 1966	Minuteman II	460	31B	Success
31 March 1966	Minuteman II	462	31B	Success
8 July 1966	Minuteman II	463	32B	Success

[147] Lethbridge, "Cape Canaveral Rocket and Missile Programs."
[148] "History of Minuteman Missile Sites," www.nps.gov/archive/mimi/history/srs/history.htm
[149] Ibid.
[150] Ibid.
[151] Mike Stephano, electronic communication with Julie Webster, 22 October 2008.

Date	Vehicle	Series Number	Pad/Silo	Result
17 January 1967	Minuteman II	464	32B	Success
24 February 1967	Minuteman II	465	32B	Success
17 August 1967	Minuteman II	466	32B	Success
6 November 1967	Minuteman II	467	32B	Success
6 February 1968	Minuteman II	468	32B	Success
14 March 1970	Minuteman II	n/a	31A	unknown

Minuteman III

While the Minuteman II still was being tested, Minuteman III was being developed. The Minuteman III (also known as Minuteman G) had several performance improvements realized. The missile was now capable of carrying three independently targeted nuclear devices, had an advanced reentry system, and had advances in guidance to increase computer memory and improve accuracy.[152] The Aerojet and Thiokol companies jointly designed the larger third-stage engine, which could produce a thrust of 34,400 pounds and extended the missile's range to 8,000 miles (Figure 39). The third stage also featured a new post-boost propulsion system (the Propulsion System Rocket Engine, or PSRE) from Bell Aerospace, which added to Minuteman III's increased range.[153]

Launch Complexes 31 and 32 were being prepared for the Minuteman III test program in 1968.[154] The first launch of Minuteman III occurred at Cape Canaveral on August 16, 1968.[155] A total of seventeen test flights occurred at Complex 31/32, and all were successful (Table 4). In all, ninety-two Minuteman I, II, and III missiles were launched from Complex 31/32 between February 1, 1961 and December 15, 1970 (Figure 40, Figure 41). The following chart (Table 5) summarized characteristics of the Minuteman over the course of its development, and the timeline of the first research and development test flight occurring at Cape Canaveral. Testing of the Minuteman III was completed in December 1970.[156]

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[152] ICBM Prime Team, "Minuteman Weapon System History and Description," 33; Taylor, *Lift Off!*, 122.
[153] Lethbridge, "Cape Canaveral Rocket and Missile Programs."
[154] "Cape Canaveral LC31," http://www.astronautix.com/sites/capllc31.htm
[155] Cleary, *The 6555th Missile and Space Launches Through 1970*.
[156] McCullough and Webster, *Missiles at the Cape*, 68.

Table 4. Minuteman III launches at Complex 31/32.

Date	Vehicle	Series Number	Pad/Silo	Result
16 August 1968	Minuteman III	FTM-201	32B	Success
24 October 1968	Minuteman III	FTM-202	32B	Success
26 March 1969	Minuteman III	FTM-203	31B	Success
22 April 1969	Minuteman III	FTM-204	31B	Success
27 May 1969	Minuteman III	FTM-205	32B	Success
25 June 1969	Minuteman III	FTM-206	32B	Success
31 July 1969	Minuteman III	FTM-207	31B	Success
23 September 1969	Minuteman III	FTM-208	31B	Success
6 November 1969	Minuteman III	FTM-209	32B	Success
4 December 1969	Minuteman III	FTM-210	32B	Success
13 March 1970	Minuteman III	FTM-212	32B	Success
3 April 1970	Minuteman III	FTM-213	32B	Success
29 April 1970	Minuteman III	FTM-214	32B	Success
27 May 1970	Minuteman III	FTM-215	32B	Success
16 September 1970	Minuteman III	STM 1	32B	Success
2 December 1970	Minuteman III	STM 3	32B	Success
14 December 1970	Minuteman III	STM 2	32B	Success

Table 5. Minuteman Summary.

Specifications	Minuteman I	Minuteman II	Minuteman III
Length	55.9 feet	57.6 feet	59.9 feet
Weight (lbs)	65,000	73,000	78,000
Altitude	700 miles	700 miles	700 miles
Range	6,300 miles	7,000 miles	8,100 miles
Propulsion	Solid	Solid	Solid
Warhead	Nuclear	Nuclear	Nuclear
Guidance	Inertial	Inertial	Inertial
Development Started	1958	1962	1964
Launch date	February 1961	September 1964	August 1968
Testing Completed	1964	1968	1970

In 1991, the Strategic Arms Reduction Treaty (START) was signed by President Bush and Soviet Union President Mikhail Gorbachev. Most USAF Minuteman I and II missiles have been destroyed in accordance with START (except for the ones designated a historic landmark) and their launch silos have been sealed or sold back to the public.[157] Some Minuteman I and Minuteman II motors were used as Space Launch Vehicles and Target Vehicles.[158]

Minuteman Deployment and Operational Launch Facilities

Initial plans for Minuteman I deployment focused on one very large group of missiles, but economies of scale came about in placing the missiles at separate locations, which also provided better protection for the system. It was decided to place concentrations of 150 launchers together when possible, and at a bare minimum, to place a group of fifty launchers. These were set up through the development of "wings" which had three or four squadrons with 50 missiles each, and were established at SAC bases. The squadrons were divided into five "flights" each, with a flight in charge of a single, manned launch control facility linked to ten underground, unmanned missile silos. The first deployed Minuteman location was at Malmstrom AFB, Montana. Construction began on March 16, 1961, and the silos were ready to receive missiles by the end of July. The first flight of missiles was rushed into activation on October 27, 1962, in the midst of the Cuban Missile Crisis.[159]

The USACE was responsible for developing launch facilities for the Minuteman Missile. An internal Corps of Engineers' program called the Ballistic Missile Construction Office (CEBMCO), managed the construction of 1,000 Minuteman silos and associated Launch Control Facilities (LCF).[160] Construction was fast, as prefabricated components and assembly line-construction techniques could be used.[161]

Each LCF had an associated 10 missile silos or Launch Facilities (LF) located at least three miles away. The LCF itself consisted of a fenced tract of land containing a surface level Launch Control Facility Support Building (LCFSB) and an underground Launch Control Center (LCC) directly below. The LCFSB housed the LCF crew, served as a security checkpoint, and contained the environmental support systems for the LCC.[162] The LCC was the command center for the 10 associated missile LFs, and contained a

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[157] "Cape Canaveral LC31," http://www.astronautix.com/sites/capllc31.htm.
[158] Hilliard, written correspondence, 30 January 2009.
[159] "History of Minuteman Missile Sites," http://www.nps.gov/archive/mimi/history/srs/history.htm.
[160] Lonnequest, Winkler, and Webster, *To Defend and Deter*, 80-81, 246.
[161] Ibid., 246.
[162] Ibid., 250. In later versions, the LCC environmental support systems were relocated from the LCFSB to a Launch Control Equipment Building (LCEB) adjacent to the LCC.

two-person crew compartment and the necessary equipment. The lozenge-shaped structure was built of reinforced concrete and steel plate.

The unmanned LFs served as long-term storage, service, and launch sites for the Minuteman. The component parts included a launch tube, a cylindrical two-level equipment room at the upper part of the tube, and an adjacent launch facility support building. The missile rested in the steel plate tube, and the reinforced concrete equipment room housed generators, guidance equipment, and communications equipment. The support building was an underground structure (roof at surface level) with LF heating and cooling equipment, and an auxiliary power supply.[163]

As the Minuteman program continued in the 1970s, several programs were implemented by the Air Force to improve the missile force. The Minuteman Integrated Improvement Project focused on improving survivability of the facilities, including improved suspension systems and quicker guidance data transfer. In 1985, a program was initiated to prolong the service life of Minuteman missiles, which were approaching twenty years of age. The Minuteman Integrated Life Extension program, (MILE; nicknamed "Rivet Mile"), consisted of programs to replace standby power systems, guidance systems, and command and control consoles. In addition, launch facilities were repaired, solid-propellant motors were re-manufactured, and communications equipment was updated.[164]

Pershing Missiles

The Pershing I missile was designed to replace the Army's Redstone missile.[165] The Pershing's big advantage was mobility, as it was carried on four tracked vehicles capable of cross-country travel. A feasibility study for the missile began on October 31, 1956, at the request of the U.S. Army's Chief of Research and Development. A study by the Ordnance Corps sought a ballistic missile with a range of at least 750 miles, and a contract for the missile's development was awarded by the Army Ballistic Missile Agency (ABMA) to the Glen L. Martin Company of Orlando, Florida on March 28, 1958.[166]

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[163] Ibid., 252-255. The LF support buildings were moved deep underground for the Minuteman III deployment.

[164] "Fact Sheet: LGM-30 MINUTEMAN III," http://www.af.mil/factsheets/factsheet.asp?fsID=113.

[165] The missile was named in honor of General John J. (Black Jack) Pershing, famed commander of the World War I American Expeditionary Forces. McCullough and Webster, *Missiles at the Cape*, 80.

[166] Ibid. 102.

The two-stage solid-fueled missile relied on Thiokol motors, capable of 26,290 pounds of thrust, and the reentry stage could carry a 400 kiloton nuclear warhead. Testing, with 49 launches of the Pershing 1 at Cape Canaveral Launch Complex 30, ran from February 25, 1960 to April 25, 1963. The Pershing I was first deployed in August 1963, and by the following year, had replaced the Redstone in the United States and Germany.[167]

In August 1967, the Martin Marietta Company (formed by the 1961 merger of Glen L. Martin Company and American-Marietta, and later to become Lockheed Martin) was given a contract to produce an improved Pershing, designated the Pershing 1-A. The program had been approved in 1965, and included a staging revamp, with the missile and the warhead being in the same vehicle. Additionally, the missile and its support vehicles could be airlifted on the C-130, an Air Force cargo plane. Benefits from these changes included increased reliability and flexibility, greater ease of maintenance, lower cost, and enhanced operational time. The improved missile was tested at Cape Canaveral in 1967 and 1968. The Pershing 1-A began to replace the Pershing I in 1969 and the process was completed by 1970.[168] The need for rapid-succession firing and inertial surveying of the launch site pre-firing led to a 1976 deployment of improved missiles with a sequential launch adapter (SLA) and an automatic reference system (ARS).[169]

A follow-on series of operational tests for the Pershing 1-A were conducted at CCAFS in 1973. The twelve test firings took place at Complex 31, Launch Pad A, February-March, 1973. A mobile transporter/erector/launcher was used, similar to many earlier Pershing test launches. A truck at the site provided a launch control center. The flights were grouped into four firings on each of three days, approximately two weeks apart. These were the last missiles launched from Complex 31/32.[170]

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[167] Ibid.; "Cape Canaveral LC 30," http://www.astronautix.com/sites/capllc30.htm.

[168] "Cape Canaveral LC 30," http://www.astronautix.com/sites/capllc30.htm; McCullough and Webster, *Missiles at the Cape*, 80.

[169] Andreas Parsch, "Pershing," Historical essay. http://www.astronautix.com/lvs/pershing.htm.

[170] Cleary, "The 45th Space Wing;" John Hilliard, interview with Susan Enscore, 8 December2007.

Table 6. Pershing 1-A launches from Complex 31.

Date	Vehicle	Series Number	Launch Pad
2/21/1973	Pershing 1A	101	LC31A
2/21/1973	Pershing 1A	102	LC31A
2/21/1973	Pershing 1A	103	LC31A
2/21/1973	Pershing 1A	104	LC31A
3/6/1973	Pershing 1A	105	LC31A
3/6/1973	Pershing 1A	106	LC31A
3/6/1973	Pershing 1A	107	LC31A
3/6/1973	Pershing 1A	108	LC31A
3/19/1973	Pershing 1A	109	LC31A
3/19/1973	Pershing 1A	110	LC31A
3/19/1973	Pershing 1A	111	LC31A
3/19/1973	Pershing 1A	112	LC31A

ARCHITECTURAL DESCRIPTION OF LAUNCH COMPLEX 31/32

Site description

Launch Complex 31/32 is an area approximately 65 acres in size located at the end of Flight Control Road. The complex was conceived as a double launch facility with an almost identical series of structures running parallel to each other in an east-west direction. The structures situated on the north side of the complex had the designation '32'. They were built near the base's skid strip. The structures located on the south side of the complex had the designation '31'. The bulk of 'side 31' structures were built east of the retired Navaho test area known as Launch Complex 9/10. There was some overlap, however, between Launch Complexes 31/32 and 9/10; specifically, Pad 31A was built on top of former Pad 10.

Component facilities

Original Launch Complex 31/32 construction to accommodate the Minuteman missile program included the following:

- Launch Pad 31A (Facility 17700)
- Launch Pad 32A (Facility 17701)
- Blockhouse 31 (Building 17702)
- Blockhouse 32 (Building 17703)
- Optical alignment building 31A (Building 17704)
- Optical alignment building 32A (Building 17705)
- Septic tank—Blockhouse 31 (Facility 17707)
- Septic tank—Blockhouse 32 (Facility 17708)
- Silo 31B (Facility 17750—NASA owned)
- Silo 32B (Facility 17751—NASA owned)
- Mobile unit support facility (MUSF) shop (Building 17770)
- Substation—MUSF support shop (Facility 17771)
- Septic tank—MUSF support shop (Facility 17772)
- Launch support building (Building 17781)
- Substation—Launch support building (Facility 17782)
- Septic tank—Launch support building (Facility 17783)
- camera pads (21), television pads (4), CZR camera pads (2), and M45 camera pad (1)
- Revetment

Site preparations, demolition, and new amenities

Site preparations included some clearing, contouring, and grubbing within the site boundaries. They also included demolition of some portions of Pad 10 to accommodate the construction of Pad 31. In areas of overlap, some of the Pad 10 pavement was removed or removed and replaced. According to field observations and drawings, much of the existing Pad 10 infrastructure remains in place in the pavement or beneath Pad 31. For instance, the Pad 10 autonavigator and cable trenches were left in place and simply filled with concrete. The Navaho ramjet test pad with its five steel plates remains as well (Figure 42).

In contrast, some Pad 10 features were removed from the site, including:

- Restroom structure and abutting blast wall north of Pad 10;
- Crane tracks to the Pad 10 launch pedestal (within the limits of Pad 31 construction only);
- Cable trench electrical and communications terminating equipment;
- East and west concrete stub-out pads and associated conduit; and
- Auto-navigator trench cover.[171]

New site construction included some amenities that were not associated with numbered facilities. A road, parking, and sidewalk network were put in place for vehicular and pedestrian access. This network includes bituminous roadways and parking lots, 4'0" concrete sidewalks, precast concrete surface gutters, combination curb and gutters at paving edges, and concrete flumes used to drain surface water off selected paved areas. Additional amenities include a revetment, drainage culverts and headwalls as required by the new site contours, and catch basins.

The revetment was constructed immediately to the east of Facility 17768, the former pump house for Launch Complex 9/10. An existing concrete pump foundation and associated concrete structure were removed to make room for the earthworks. The eight-inch-thick precast concrete gutters are 4'0" wide and feature a 2"-deep, centered depression. The curb and gutter combinations are 2'0" wide and feature a 6"-high curb. The concrete flumes are T-shaped curb cutouts that allow water to flow through a 2'6"clear offshoot to an adjacent drainage ditch. The drainage culverts vary by location, as dictated by area contours. Those passing under sidewalks are integrated into the sidewalk concrete and larger culverts, passing under roadways, feature headwalls with security grills to prevent

[171] Architectural/Engineering drawing set for Cape Canaveral Missile Test Annex, Minuteman Facilities WS 133 A, "Drawing No. 01-17780-014" (Air Force Missile Test Center, Patrick Air Force Base, Florida) hereinafter referred to by drawing number only; "Drawing No. 01-17780-017."

passage. Concrete catch-basins measure 2'5" x 3'3", with varying depths. Each is outfitted with a topside drainage grate.[172]

Additional site preparations included some offsite construction to facilitate site access. Namely, modifications were made to the intersection of Cape Road and Flight Control Road, to increase the turning radius at each corner. In addition, three camera pad locations were constructed outside the facility boundaries: one just outside the main gate on Flight Control Road and two on the opposite side of the skid strip.[173]

Subsequent site additions

Some site additions were made throughout the years. At some point between 1983 and 1987, several tent pads were constructed near Blockhouse 32 by the 45th Space Wing Mobile Combat Communications Group, for bivouac during training (Figure 43).[174] A larger undertaking was the construction of a semi-permanent Force Protection Training Area between Blockhouse 31 and its optical alignment building in 2006.

Launch Pads 31A and 32A (Facilities 17700 and 17701)

Pad slabs

Launch Pads 31A and 32A are located at the center of the site and the concrete *pad slabs* measure 116'0" square. The square is subdivided roughly into quadrants. These quadrants are further subdivided with longitudinal construction joints and transverse dummy (i.e., scored groove) joints. These paving joints are spaced at 14'6" intervals in both directions. The southeast quadrant is composed of 14"-thick reinforced concrete, while the remaining quadrants are 8"-thick, un-reinforced concrete. The purpose of the thicker reinforced concrete is not indicated on the as-built drawings, but this pavement may have accommodated heavy vehicles such as the flatbed and cranes. All concrete slabs are tapered at their perimeter for a thicker edge profile.[175]

Dispersed about the concrete slabs are the former anchor positions. These locations vary slightly between Pad 31 and Pad 32. There were originally three anchor types: Type A, Type B, and tie-down. Each type appeared in opposing pairs. The single Type A anchor had one 45-degree line of pull and was located outside the

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[172] "Drawing No. 01-17780-015."
[173] "Drawing No. 01-17780-003."
[174] J.P. Anderson, electronic correspondence to John Hilliard, 8 April 2008.
[175] "Drawing No. 01-17780-013."

southeast and southwest quadrants. The double Type B anchor had two 45-degree lines of pull and was located outside the northeast and northwest quadrants. The A and B anchors were screw-type with rods and wire rope. The anchor assembly, rods, and rope thimbles were galvanized; the wire rope was zinc-coated. The tie-down anchors were positioned north and south of the missile firing pit and at a 21'0" x 250'00" concrete paving projection on the center east side (labeled "two spaces" on the as-built drawings). It is likely that the tie-downs on the paving projection were utilized to anchor the flatbed transport. These anchors were U-shaped rods embedded into the concrete. The tie-down attachment points were at the apex of the U-shape at ¼" below the slab surface; hemispherical concrete slab cutouts provided access to them.[176]

Each pad was outfitted with two metal, trapezoidal blast shields at their southeast and northwest corners. The shields were located 1'0" from the concrete slab corners. Those at Pad 31 protected Cameras 12 and 13; those at Pad 32 shielded Cameras 14 and 15. The blast shields have since been removed, but the outlines of some are visible in the pavement.[177]

Firing pits

A 12'10"-deep *firing pit*, designed to withstand the intense heat and load generated by rocket motors during liftoff, is located at the center of each launch pad. The missile was centered over this pit during launches on a stationary launch stand, made up of steel plates and rings. This stand featured an integrated flame deflector designed to direct the blast away from the missile during liftoff. Although the launch stand has been removed, the pit remains. It measures 22'6" square at pad level, and 18'6" square at the bottom. Its stepped walls, drains, and steel plates form overlapping Xs, crosses, and squares in plan that once interfaced with the launch stand. Today the pit at Pad 31 is covered with metal plates and enclosed with metal pipe railing (Figure 44); at Pad 32 the pit is filled with asphalt-covered soil.[178]

Mobile service towers

The tracks for the *mobile service towers* separate the northeast and northwest slab quadrants of the launch pads (Figure 45). Although no longer present at the site, these towers were 200-ton, 65'0"-tall, six-story, steel frames used to raise and

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[176] Ibid.
[177] "Drawing No. 01-17780-004"; "Drawing No. 01-17780-025."
[178] "Drawing No. 01-17780-033."

assemble the re-entry vehicle on to the missile on the launch pads (Figure 46). They contained staircases that also enabled technicians to inspect, maintain, and adjust all parts of the missile. After a missile was emplaced, the tower was driven away from the pad and locked down, to clear space for the launch. The track leads to and from the firing pit, from the north side. It is made up of two 6"-wide steel rails set in 14"-wide concrete stem walls. The stem walls function as foundations and rest on 6'6" spread concrete footings. Rail fastening hardware is encased beneath the concrete. In areas of flexible (i.e., bituminous) paving, the rails are flanked by 6"-wide reinforced concrete strips. Each rail is positioned 15'1 5/16" off the firing pit's north-south centerline. The track ends 10'0" south of the east-west firing pit centerline.[179]

Pad equipment rooms

In the southwest quadrant of each pad is the subterranean *pad equipment room*.[180] This reinforced concrete building is irregular in shape and its length measures 61'8". Its width varies from 17'0" at the equipment room end to 22'0" at the mechanical room end. The width and height extend farther at the stair, stairwell, and sump pump locations on the center south edge. An additional projection extends 45 degrees from the northeast corner of the building. This corner is closest to the firing pit, and features the umbilical tower mounting. The 35'0" fixed steel umbilical tower (since removed) carried electrical, environmental control, hydraulic, and communication functions to the missile through umbilical lines prior to launches. When not in use, it was folded down onto the pad, using an external automotive crane. The umbilical tower mounting is made up of one umbilical mast, two large umbilical tower pads, two small umbilical tower pedestals, and concrete-encased conduit to the firing pit (Figure 47). Three equally-spaced guy wire tie-downs with large, trapezoidal anchors radiate 45'0" from the center of the umbilical mast.[181]

Floor, walls, and ceiling of the pad equipment room are made up of 18"-, 12"-, and 5"-thick reinforced concrete, respectively. The heavily-reinforced blast entry door is down a stairwell on the south side. Like the main structure, the floor, stairs, and

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[179] Ibid.; McCarthy, *Determination of Eligibility*, 109.
[180] The HAER field crew was not granted access to the pad equipment room interiors due to water hazards. Interior descriptions are based on original as-built drawings and do not reflect modifications over time since they were not verifiable.

[181] "Drawing No. 01-17780-033"; "Drawing No. 01-17780-036"; McCarthy, *Determination of Eligibility,* 109.

walls of the stairwell are of reinforced concrete. Aluminum handrails in the stairwell, and fixed and removable topside handrails, protect against falling hazards. Topside features include a removable concrete slab with lift rings over the sump pump well and asphalt-covered plywood over the stairwell opening.[182]

The pad equipment room interior was divided into two spaces: the primary equipment room and the mechanical room. Double aluminum flush doors positioned just inside the exterior blast door provided entry into the equipment room. This space housed the communication frame that interfaced with the umbilical tower of each launch pad.

Mechanical room

Double metal, louvered doors that also served as return-air registers lead from the equipment to the mechanical room. This space housed the electrical distribution panels for umbilical tower, service tower, railroad track (at Complex 32 only), lighting, cameras, warning horn, heating, cooling, and sump pump services at each launch pad. It also housed the air conditioning compressor, condenser, and air handling unit for each launch pad. Interior features included dropped acoustical tile ceilings, overhead cable trays spanning the ceiling support beams, and sloped floors pitched toward floor drains. A 4'0" square sump pump was located south of the entry stairs in a dedicated shaft. A steel access hatch covered the 2'0" x 3'0" sump access wall opening off the stairwell. A 4" pipe on the west side of the building allowed water drawn from the pad equipment room to flow onto a 3'0" x 5'0" erosion-resistant, sand-cement rip rap drainage area between the pad equipment room and the cableway. Also, two electrical duct banks are located at the southeast and southwest corners of the pad equipment rooms.[183] These connect to the cableway system.[184]

Subsequent pad modifications

In late 1958, during its Launch Complex 9/10 period, Pad 31 (then Pad 10) received minor modifications for the Alpha Draco missile program.[185] A concrete flame deflector was poured and launch stand

[182] "Drawing No. 01-17780-034."
[183] "Drawing No. 01-17780-032"; "Drawing No. 01-17780-034"; "Drawing No. 01-17780-035."
[184] "Drawing No. 01-17780-059"; "Drawing No. 01-17780-088"; "Drawing No. 01-17780-089."
[185] Joel Powell, "Uncovering old Pad 10 - The search for the Draco launch site at Cape Canaveral," *Spaceflight* 44:256.

tie-down points were installed at its west edge. Portions of these modifications remain visible (Figure 48). Similarly, following the conclusion of the Minuteman program in 1970, Pad 31 was modified again for the 1973 Pershing I-A missile launches.[186] The Pershing benchmarks remain in the pavement on the southeast quadrant of Pad 31 (Figure 48).

Blockhouses 31 and 32 (Facilities 17702 and 17703)

Blockhouse exteriors

Two identical "beehive" blockhouses, Facilities 17702 and 17703, were built just inside the main gate of Launch Complex 31/32. Facility 17702 corresponds to Launch Site 31; Facility 17703 corresponds to Launch Site 32. Each structure is a 29'2"-high reinforced concrete dome, covered with sand-cement rip rap. The concrete shell measures 15" thick at a minimum; the rip rap ranges from 3'0" thick at the top, to 6'0" thick at the foundation. This rip rap treatment of filled sand-cement bags gives each building its beehive appearance. Both the concrete shell and rip rap cover rest on a continuous, reinforced concrete footing with an enormous spread of 15'3".[187]

An open, steel stairway runs up the building exterior on the south-southeast side. A mid-stair landing is positioned just above the finished second-floor height. Steel wide-flanged columns (encased in concrete at the dome) provide support for the landing. The stairway ends at a catwalk that leads to a camera deck centered at the apex of the dome. The stair treads, landing, and catwalk are all of 1.0" steel grating. The 8'-square, reinforced concrete slab used as a camera deck is embedded atop the dome and surrounded by steel pipe hand rails. Camera power-supply boxes were mounted to these hand rails to power Cameras 17 and 18 on Blockhouse 32 and Cameras 19 and 20 on Blockhouse 31. Adjacent to the camera deck at its northernmost corner is a periscope mount that protrudes from the dome (Figure 49). Nearby, directly over the toilet room, a plumbing vent punches through the dome's rip rap cover. Similarly, a toilet exhaust pipe protrudes from the toilet room further down on the dome wall (Figure 49).[188]

Users enter both blockhouses on their west façades through an axial entry way formed by a pair of 6'6"-long chamfered concrete

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[186] Cleary, *The 45th Space Wing*.

[187] "Drawing No. 01-17780-018"; "Drawing No. 01-17780-018A"; "Drawing No. 01-17780-023"; "Drawing No. 01-17780-024."

[188] "Drawing No. 01-17780-020"; "Drawing No. 01-17780-025."

wing walls and a 5'0"-deep concrete slab entry canopy. A short concrete walk located between the wing walls ramps up to the outermost door, a single blast-resistant type that opens by means of an 18" heavy-duty handwheel. Beyond that point is an interior concrete block vestibule, with a set of double aluminum one-lite doors. These doors lead to the entrance hall that provided access to Evaluation Room 1 on the right, a stairwell on the left, and the launch control area straight ahead. The first floor had an interior radius of 25'9"and a gross area of 2,454 square feet.[189]

Blockhouse interiors

Launch control area

Taking up approximately two-thirds of the blockhouse first floor, the *launch control area* was the primary working space during launches. It housed the various instrument consoles and communications equipment used during launches. Consoles included those for missile checkout, launch control, guidance and control, payload/reentry vehicle telemetry, command destruct, and range timing. Communications equipment included ceiling-mounted speakers, television monitors, blackboards, and a periscope. To accommodate vast lengths of equipment conduit, two-layer, plywood panel flooring in the launch control area was laid over a concrete pier and steel beam support system. The sequencer isolation box, a set of relays that controlled various vehicle- and range-related launch functions, was located on the north wall. Just west of this box was a 4"0"-deep covered pit that housed the sump pump. Water collected here was pumped out to a French drain, north of the building. From the sump pit, removable flooring with flush panel pulls traced the exterior wall along the remaining perimeter of the space. Similar removable flooring formed a cross at the dome centerlines and was used for under-floor access throughout the space. The service sink and storage closet were situated against a wall shared with the stairwell. Under the periscope opening was a portable viewer's platform.[190]

Evaluation Room 1

Looking out onto the launch control area was *Evaluation Room 1*. This space was used for offline analysis of launch data, problems, or issues, thus keeping congestion and talking outside

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[189] "Drawing No. 01-17780-018"; "Drawing No. 01-17780-027." The HAER field crew was not granted access to the building interior, due to environmental hazards. Interior descriptions are based on original as-built drawings, and do not reflect modifications over time, since they were not verifiable.

[190] "Drawing No. 01-17780-018."

of the immediate launch control area. Aside from equipment needed for data analyses (e.g., tables for laying out telemetry data, optical recorders, and technical orders and manuals), the room typically did not have a lot of equipment. Evaluation Room 1 measured approximately 10'4" x 10'9". The wall nearest the blockhouse center was glazed with fixed glass for viewing launch control area activities. Since occupants of Evaluation Room 1 would have been facing the launch control area, a monitor and TV were mounted near this wall. Half of the southernmost wall was glazed similarly for the same observation purposes. The floor area nearest the exterior wall stepped up 6 1/2" to afford additional clear views of the launch control area.[191]

Stairwell to second floor

The *stairwell* provided access to the blockhouse second floor. The stairwell was configured with two 3'10"-wide stair runs, with a landing at the seventh riser. Eleven additional risers brought the occupant to the second floor. Hand railings were of aluminum. Because the exterior wall of the conical blockhouse curved inward as it rose in height, the stair runs were located toward the inside wall of the stairwell. This left a small space between the stairs and the exterior wall on the first floor. Once on the second floor, this space no longer existed, and the stairs opened to a thin landing contiguous with Evaluation Room 2.[192]

The 1,963-square-foot blockhouse second floor accommodated primarily support functions for the building. Space was provided for the following: Evaluation Room 2, mechanical equipment room, power supply room, equipment room, crew ready room, and toilet room. Structurally, the second floor was suspended from the overhead dome with a series of steel 'beam hanger' rods arranged in a circle near the dome center. A concrete beam, meant as a secondary means of support, ran beneath the floor near the outside walls of the dome. This structural system allowed for a clear span in the first-floor launch control area.[193]

Evaluation Room 2

The second-floor *Evaluation Room 2* served the same purposes as the first-floor evaluation room. It was a roughly circular space

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[191] Ibid.; John Hilliard, electronic correspondence with Susan Enscore, 19 April 2008. At some time in the late 1960s, Evaluation Room 1 became a VIP room. This displaced some personnel to Evaluation Room 2 on the second floor [unnumbered modification drawing from drawing set 86K02231].

[192] "Drawing No. 01-17780-018."

[193] Ibid.

at the center of the blockhouse dome, with additional space radiating outward toward the stairwell and toilet room. Its two primary features were a periscope sleeve that originated from the first floor, and an overhead electric hoist and monorail for lifting power supplies and mechanical equipment (e.g., batteries, electrical control panels, and air conditioning components) to the second floor. The hoistway hatch, located in the floor near the stairwell, featured a removable plywood floor panel that rested on a removable wide-flanged aluminum beam. These floor components were removed during hoisting operations.[194]

Equipment room

The *equipment room* opened directly off the east side of Evaluation Room 2. Various openings in the floor of this space served as equipment ducts to the first floor. A small, circular, blast door was located 3'0" above the floor at the south-southeast end of the room (Figure 50). This blast door provided emergency egress from the second floor. Users were to open the blast door, crawl through a 1'11 1/4"-diameter steel pipe, embedded in the concrete shell and rip rap, and end up out at a 1'8 1/2" x 2'4" blast door platform.[195]

Power supply and mechanical rooms

The *power supply room* and the *mechanical equipment room* were co-located in a space enclosed by 6"-thick insulated partitions. A large, concrete, air conditioning equipment pad was located in each of the areas. The power supply room pad was for the air handling unit, and the pad in the mechanical equipment room was for the compressor. Like the equipment room floor, this floor had various openings and pipe sleeves to accommodate mechanical ductwork, electrical conduit, and floor drains. Condenser piping exited the blockhouses to the southwest and ran below-grade to the adjacent cooling towers. Nearby, a series of electrical conduit sleeves are visible from the blockhouse exteriors (Figure 51). These fed into pull boxes for power, communications, and television service.

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[194] Ibid.; "Drawing No. 01-17780-022"; John Hilliard, electronic correspondence to Julie Webster, 4 June 2008. As mentioned previously, in the late 1960s some personnel moved from Evaluation Room 1 to Evaluation Room 2 to accommodate site VIPs. To accommodate the additional personnel, Evaluation Room 2 was expanded into the equipment room [unnumbered modification drawing from drawing set 86K02231].

[195] "Drawing No. 01-17780-018"; "Drawing No. 01-17780-020"; "Drawing No. 01-17780-032."

Additional mechanical equipment room electrical apparatus included switches, circuit breakers, and transformers for the site's critical power supply, emergency lights, fire alarm system, area warning system, camera pads, and blockhouse strip heaters.[196]

Crew ready room

The *crew ready room* was small and irregular in plan. A circular floor opening in the northeast corner channeled conditioned air to the space. A 2'0" x 4'0" access panel in the west wall provided access to the outside wall mechanical and plumbing chase.[197]

Toilet room

The *toilet room* was trapezoidal, measuring 5'0" deep at one end, and 4'0" deep at the other end. Users entered through the deep portion of the room where the sink was located. A urinal was positioned in the center of the space with a sight barrier screen between it and the sink. A single toilet stall was located in the shallow portion of the room.[198]

Finishes, fixtures

Typical room finishes throughout the blockhouse first floor included gypsum and concrete walls, linoleum flooring, wood baseboards, and acoustical plaster ceilings. An exception was the entry vestibule, which featured exposed concrete and concrete block. Typical finishes for the blockhouse second floor included gypsum and concrete walls, asphalt tile floors, wood baseboards, and acoustical plaster ceilings. Exceptions included the toilet, mechanical, and power rooms. The utilitarian mechanical and power rooms were finished with gypsum and acoustical plaster walls, concrete floors and bases, and acoustical plaster ceilings; the toilet room had glazed and gypsum wallboard walls and an exposed concrete ceiling.[199]

Typical lighting featured 3'6"-long two-bulb pendant fluorescent fixtures in large work areas, and one-bulb ceiling-mounted fixtures in small spaces and utility areas. A relay cabinet for the pad warning system was located inside each blockhouse, and

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[196] "Drawing No. 01-17780-018"; "Drawing No. 01-17780-022"; "Drawing No. 01-17780-066A."
[197] "Drawing No. 01-17780-018."
[198] Ibid.
[199] Ibid.

the system beacon warning light was mounted atop each blockhouse.[200]

Blockhouse site amenities

To the northeast of each blockhouse was a septic system (i.e., septic tank, distribution box, and septic field) for toilet room waste. Square concrete guard posts delineate and protect the septic system components. Immediately to the north of each blockhouse were two dedicated parking spaces facing true north. These spaces were for frequency interference measurement vans (FIM). Such vans were on site (not during launches) to monitor radio frequencies. They were used to determine if there were interferences between signals within Launch Complex 31/32 and with other systems on Cape Canaveral that could create problems during launch operations. Immediately adjacent to these parking spaces are racks for the necessary van communication cabinets, power boxes, and ground receptacles.[201]

Parking for standard vehicles was located across the road to the west. To the southeast of each blockhouse was a cooling tower. These towers provided cooled water by means of evaporation for the blockhouse air conditioning systems. Only the concrete pad and concrete block foundation walls of the towers remain (Figure 52).

Optical alignment buildings (Facilities 17704 and 17705)

Optical alignment building exteriors

The optical alignment buildings are located south of and 500'0" from their corresponding launch pads. Facility 17704 serviced Launch Pad 31A; Facility 17705 serviced Launch Pad 32A. Structurally, the two buildings were identical, except for varying foundation depths to accommodate their respective site conditions. Each single-story structure is rectangular in plan and measures 14'4" x 55'4. The short end walls are of reinforced concrete. The long side walls are reinforced concrete structural frames (piers and beams) enclosed with concrete block infill panels. Floors are exposed 6"-thick concrete slab. A series of steel joists was set atop the structural frame at a 3:12 pitch.

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[200] Drawing No. 01-17780-064A.
[201] John Hilliard, electronic correspondence with Julie Webster, 2 June 2008.

Exterior details include:

- Shed roof with built-up gravel roofing
- Overhanging eaves on all sides
- Wood fascia covered with aluminum coping at rooflines
- Double, aluminum, louvered entry doors
- Industrial ribbed aluminum sliding doors along front side facing launch pad (Figure 53)
- Screened 2'10"-high adjustable aluminum louvers banded along back side, away from launch pad
- 6'8"-high adjustable aluminum louvers at end wall opposite entry doors
- Reinforced concrete retaining wall on a buttressed foundation at base of front wall
- Pair of azimuth assembly trolley cart rails exiting through the double entry doors
- 8'0" x 8'4" exterior concrete pad at entry end[202]

Optical alignment building interiors

The floor plan for each of the optical alignment buildings is that of a single, open space dominated by two reinforced concrete pedestals that act as stabilizer pads (Figure 54). The larger azimuth pedestal is centered on the trolley cart rails, and runs the length of the building; it measures 5'0" wide x 2'0" high. The smaller theodolite (for triangulation) pedestal is located in the northwest corner, measures 3'0" x 6'6" in plan, and has a one-foot-square post at its west end that stands 4'6" high. Centered on this pedestal, 1'6" from its east end is a benchmark from which launch coordinates were computed.[203]

As-built construction drawings show that a middle portion of Optical Alignment Building 32 was sectioned off from its two ends in 1966, since the position of the azimuth assembly had been determined. An air conditioning unit was installed at the same time in this area for equipment cooling needs. These walls have since been removed, but their outlines remain visible in the wall paint.[204] An additional modification is the corrugated metal shed-roof enclosure attached to the north wall of Optical Alignment Building 32. A series of metal trench cover plates leads to the enclosure from the west.

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[202] "Drawing No. 01-17780-039."
[203] Ibid.
[204] "Drawing No. 01-17780-071."

Most lighting in the optical alignment buildings was provided by two-bulb fluorescent pendant fixtures hung in pairs down the length of the buildings (Figure 55). Some of these fixtures are missing from Optical Alignment Building 32 to allow space for the former mid-space partitions mentioned above. Another lighting variation for this building is a pair of movable fluorescent fixtures mounted on a trolley duct near the building's door end.

A series of utility cabinets is located in the southwest corner of each optical alignment building (Figure 56). These include a telephone cabinet, lighting panel, transformer, and a circuit breaker with lines leading to the launch support building. Air conditioning in Optical Alignment Building No. 31 was provided by two portable units mounted in two window openings on the south side. Both of these units have since been removed. Climate control in Optical Alignment Building No. 32 was provided by a single air conditioning unit, mounted in a south-side window opening that was centered in the mid-building enclosed space. While the air conditioner has been removed, its metal mounting rack is still present on the building exterior.[205]

Monuments and benchmarks

Separate from the optical alignment buildings, but associated with their function, was a series of survey markers referred to as monuments and benchmarks. These durable, permanent markers designated key points on the earth's surface for geodetic (i.e., latitude, longitude, and elevation) purposes. The benchmarks mark key vertical elevations, while the monuments mark key horizontal positions. Together, they were used for the triangulation of launch distances and directions. Two benchmarks (one per optical alignment building) are positioned on the east end of the smaller pedestal described above. Four monuments (two per benchmark) were located at a specified distance from the benchmarks. Each monument featured a 1/4"-thick bronze disk set into an 11"-square concrete post. The post was anchored to a 30"-square concrete foundation. Three 4"-square, precast concrete guard posts were set equidistance from each other, and 3'0" from the monument to protect them. While the monument locations remain visible in the landscape, some components have been removed.[206]

Launch silos 31B and 32B (Facilities 17750 and 17751)

In addition to the two launch pads (31A and 32A), two reinforced concrete launch silos (31B and 32B) were constructed for

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[205] Ibid.
[206] "Drawing No. 01-017780-015"; "Drawing No. 01-017780-004."

underground launches. Facility numbers for the silos are 17750 and 17751, respectively. The silos are located at the east end of the site, adjacent to their counterpart launch pads. Each has a dedicated access road and on each silo's south side, an irregularly shaped, underground support structure. This support structure houses the R&D equipment room and transformer vault for its silo.[207]

Caissons and launch tubes

The outer silo walls, known as caissons, are cylindrical and measure 26'0" in diameter. Silo 31B is 90'0" deep; Silo 32B is a bit shallower at 89'9" deep; both likely met the minimum required depth. The caissons were constructed by adding reinforced sections on top of a wedge section. After sand was removed, a concrete plug was placed at the bottom and finish concrete added.[208] Both silos were constructed with a heavily-reinforced concrete launch tube down the center, to accommodate the original 6'4"-diameter, 54'0"-long Minuteman I missile. Each tube measured 12'0"-diameter, leaving a 7'0" interstitial space around the launch tube perimeter. The launch tube was faced with a steel liner plate at its interior surface. Approximately two-thirds down the length of the tube was the missile mount structure. To arm the silo, a mobile transporter-erector (T-E) would lower the Minuteman missile into the launch tube where it came to rest on a 6'0"-diameter lift ring. The lift ring, suspended by two cable/pulley/spring mechanisms, attached to the launch tube via three equally-spaced inserts at the missile mount structure (Figure 57). To support the added forces of the missile's weight and thrust, the walls of the tube were thicker at this point and triple reinforced.[209]

An elevator shaft that provided staging access ran down the north side of the caisson walls. Adjacent to the elevator was a ventilation duct, for air exchange deep into the silo.[210] Below the launch tube was a flame deflector which redirected exhaust gases from the motor, to protect the missile.[211]

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[207] The HAER field crew was not granted access to the facility interior, due to its contents. Interior descriptions are based on original as-built drawings, and do not reflect modifications over time, since they were not verifiable.

[208] Hilden, written correspondence, 5 February 2009.

[209] "Drawing No. 01-17780-110"; "Drawing No. 01-17780-111"; McCarthy, *Determination of Eligibility*, 109.

[210] "Drawing No. 01-17780-075."

[211] "Drawing No. 01-17780-110."

Closures and topside features

Topping the silos were concrete covers called closures. Each closure had a hole at its center over the launch tube. During pre-launch operations, a lightweight fiberglass closure was used for silo/missile protection. To protect against potential hazardous falls, removable hand railing was installed around the hole during launch preparations. The closures had various other openings, the largest of which was the personnel and equipment access hatch. This hatch featured a removable stairway and removable hand rails. Two junction-box openings for R&D checkout van power and cable entries were located on the closure opposite the personnel hatch. The vans were likely utilized by AVCO for checkout of the instrumentation system after emplacement in the missile. A pair of pipe ducts provided for ventilation intake and exhaust, and between them was the vertical sump discharge line that emptied water into an outlet leading away from the silo. Adjacent to the closures near the intake ducts were openings and covers for the guidance alignment notches.[212] Opposite the sump discharge line was the T-E ground connection and two T-E jack points (Figure 58). Immediately surrounding the silo are a series of concrete camera pads for both still and television cameras. The north still camera pad was protected by a steel trapezoidal shield. It is likely that these were installed to provide visual information during launch as a result of the first silo launch failing due to high acoustic levels affecting the guidance system.

Launcher equipment rooms

Surrounding the launch tube at the highest level was the reinforced concrete launcher equipment room (LER). Its finished floor was located 17'8" below the top of the silo. A removable stairway from the closure opening provided access directly into the battery compartment of the LER. This area took up approximately one-third of the LER floor area, and was elevated four risers above the rest of the space. The LER housed various power receptacles, MOPS and azimuth drive junction boxes, cable trays, battery rack for immediate pre-launch power, elevator motor and controls, and the silo’s vent fan and battery exhaust fan. In addition to those features, Silo 32B LER also housed autocollimator heating and cooling equipment. A launch tube access door that hinged downward into the tube was located just

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[212] As these notches did not appear on the operational deployed Minuteman silos, it is likely they were used for experimentation purposes during the missile development program (Hilden, written communication, 5 February 2008).

west of the staging access. Openings in the LER floor allowed for the passage of various equipment ducts.[213]

Work platforms

Surrounding half the tube circumference, between the LER and tube bottom, was a series of eight work levels accessible by ladders. The work levels were made up of checkered steel plates and handrails. These plates had openings for the personnel access ladder, staging access elevator, and air duct. The distance between platforms varied from 7'8" to 12'4" as needed to access pertinent stages of the missile. At an elevation of negative 55'0", the work platform was slightly larger to accommodate access into the launch tube. Also at that level, a door in the launch tube wall led to a removable 2'0" platform that spanned the tube. Below the platforms (at the silo bottom) was a sump pit, pump, and discharge line to collect and remove any water that accumulated in the silo.[214]

R&D equipment rooms and transformer vaults

As mentioned previously, the R&D equipment room/transformer vault structure was located to the south of each silo. Each was accessible by a subterranean L-shaped staircase (Figure 59). Underground ducts between the transformer vault, R&D equipment room, and silo allowed the utility, communication, and instrumentation conduit to enter and service the silo.

The transformer vault door opened onto the mid-run stair landing. This space housed the silo transformers, providing both critical and industrial power to the silo. It also housed electrical panels for various power receptacles and light fixtures, and an exhaust fan and sump pump.[215]

The R&D equipment room door opened onto the bottom stair landing. This room was over twice the size of the transformer vault and housed (as the name suggests) cabinets for research and development equipment. The missile emergency power cutoff was located here as well. Other utility, communication, and instrumentation equipment located in, or controlled from, the R&D equipment room included: the air conditioning system (air handler, condenser, and compressor), various power receptacles

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[213] "Drawing No. 01-17780-089"; "Drawing No. 01-17780-110"; "Drawing No. 01-17780-129." MOPS stands for Missile Operations Intercom System, the rangewide amplified intercom system.
[214] "Drawing No. 01-17780-110."
[215] "Drawing No. 01-17780-089"; "Drawing No. 01-17780-104."

and light fixtures, a ground power oscillograph, exhaust fans, a sump pump, the dehydrator and humidity recorder, launch/perimeter and TV cameras, an Ampex-brand recorder, and the base transceiver system.[216]

Transfer of silos to NASA

In 1986, following the Space Shuttle Challenger accident, more than 200,000 pounds of spacecraft debris was recovered from the ocean and placed in silos 31B and 32B.[217] Ownership of the silos was given to NASA.[218]
To accommodate and secure the debris, the following modifications were made to the silos:

- Closures were removed and replaced with removable concrete covers.
- Personnel and equipment access hatch handrails and covers were removed, and removable covers were installed.
- Launch tube work platforms and missile stand assemblies were removed.
- R&D equipment room/transformer vault stairwell handrails and covers were removed, and removable concrete covers were installed.
- Concrete ceiling sections measuring 8'0" x 8'0" were removed from the R&D equipment rooms and replaced with removable slabs of the same size.
- All R&D equipment room lighting, panels, cables, air conditioning ducts and equipment, and conduit were removed from walls, ceilings, and floors.
- All transformers, electrical panels, lights, conduit, and ducts were removed from walls, ceilings, and floors in the transformer room.[219]

Mobile unit support facility (including Facility 17770)

To test rail-based Minuteman missile launches, an experimental mobile unit was added to the site in 1961. This involved construction of a rail spur and a mobile unit support facility (MUSF) shop, Facility 17770. The building is located northwest of Blockhouse 32; the rail spur runs between this building and Launch Pad 32 (Figure 60).

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[216] "Drawing No. 01-17780-089"; "Drawing No. 01-17780-104."
[217] McCarthy, *Determination of Eligibility*, 109.
[218] "Real Property Accountable Record for Complex 31/32."
[219] Cape Canaveral Air Force Station, Long Time Storage Facilities for STS-5 IL, "Drawing No. CAN 9247, Sheet 1 of 3" (Eastern Space & Missile Center, Patrick Air Force Base, Florida).

MUSF support shop exterior

The MUSF support shop is rectangular in plan and measures 30'0" x 40'0" (excluding its air compressor lean-to). The exterior features a single-story, reinforced concrete frame structure enclosed with concrete block infill panels. This structure rests on a spread concrete foundation with continuous footings. Floors are a 5"-thick concrete slab with a troweled-cement finish. Steel joists rest on exterior bearing walls, to form a shed roof with built-up roofing.

Other exterior details include: [220]

- metal gutters and downspouts on the south side, metal coping at all rooflines, and lightning rods at roof perimeter
- 4'0"-deep, reinforced concrete canopies on pipe columns over 4'0" x 5'0" concrete stoops at east entry doors
- replacement metal, one-lite doors on east side; original aluminum eight-panel overhead door on north side; original pair of aluminum louvered doors at air compressor lean-to
- original aluminum four-lite awning windows with concrete sills (painted on south side)
- replacement circular exhaust vents
- rear air compressor lean-to with corrugated aluminum walls and roof

MUSF support shop interior

The floor plan of the MUSF support shop originally featured a shop space on the west side near the overhead door, a bathroom in the southeast corner of the building, and three additional unnamed rooms. Walls of the two unnamed rooms closest to the shop have since been removed to combine these spaces with the shop. This essentially doubles the original shop area. Approximately one-sixth of the double-sized shop area is sectioned off with a wood and screen partition to form a supply crib. A 1'0"-clearance utility trench with 3/16" cover plates was once visible in the floor at the west wall of the shop, near the overhead door. This trench serviced the exterior railroad track bed. The trench has been overlaid with vinyl sheet flooring. Cuts in the vinyl allow utility conduit to pass from wall-mounted cabinets into the trench below. The northeast unnamed room may have served originally as the MUSF office and this space remains. The bathroom, accessible from the building exterior, was expanded westward approximately 5'0" to allow for the addition of a

[220] "Drawing No. 01-017780-144."

prefabricated shower enclosure. During this modification, the drinking fountain was removed from the area. The original toilet stall and urinal configuration remains, but the stall components, as well as toilet and urinal fixtures, have been replaced. The original single lavatory has been replaced with two, newer, wall-mounted lavatories along the same plumbing wall.[221]

Typical room finishes throughout the MUSF support shop include painted exterior concrete/concrete block or painted interior gypsum walls, vinyl sheet flooring, vinyl baseboards, and exposed ceilings. An exception is the office space that features a dropped acoustical tile ceiling. Typical lighting consisted of joist-mounted pendant fluorescents fixtures in the shop and bathroom, and recessed fluorescents in the office.

MUSF support shop site amenities

The toilet sanitary line exits the MUSF support shop to the south, and connects to a dedicated septic system (Facility 17772) located south of the building. The system includes the typical components (i.e., septic tank, distribution box, and drain field). Square, concrete guard posts delineate and protect the drain field. Nearby on the south side of the building is a small air conditioning condenser, which is a recent addition. Just a few feet to the west is a transformer substation (Facility 17771) that serviced the mobile Minuteman facilities. It is protected by a series of concrete guard posts.

MUSF-associated infrastructure

In addition to construction of Facility 17770, the mobile launch facility included development of (1) a new access road near blockhouse 32, (2) a rail platform adjacent to Facility 17770, (3) a rail spur to pad 32, and (4) revised security fencing in the area immediately adjacent to Facility 17770, to encircle the site's newer elements. The paved rail platform measures 120'0" long. Along that length runs a 10'0"-wide concrete railroad track bed flanked by 1'0"-clear utility trenches. Track bed utility trenches are covered with medium-duty, galvanized, riveted bars (Figure 61). A north-south utility trench runs conduit between Facility 17770 and the rail-flanking trenches (Figure 61), and is covered with solid, double, extra-heavy-duty covers. Three track bed drains are located at mid-platform between the utility trenches, to keep the area clear of fluids.[222] Cast-aluminum light poles are located at the four corners of the platform. The light

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[221] Ibid.
[222] "Drawing No. 01-017780-143."

fixtures featured a rear aluminum reflector; a front hinge-type, tempered plate glass lens; and 500 watts of illumination.[223]

The rail spur starts at the MUSF rail car bumping post, extends straight in the southeast direction, curves eastward at the north side of pad 32, curves northeast to its turnout area until it reaches the turnout bumping post, doubles back on its outbound rails straight in the southwest direction, and ends at the pad 32 bumping post (Figure 62). Two 6"-wide steel rails are set 5’0” apart in a 10’0”-wide concrete track bed. Four feet of thickened-edge concrete paving flanks the track bed on each side.[224]

The mobile Minuteman development program was cancelled in December 1961, shortly after completion of the facility. Therefore, it is unlikely that any launch train cars were ever tested at Launch Complex 31/32.

Subsequent site additions

A paint storage shed (Facility 17773) was constructed in 1993 at the end of the rail platform. The chain-link enclosure is sheltered by a flat corrugated metal roof, on steel pipe columns.

Launch support building (Facility 17781)

Launch support building exterior

The launch support building, Facility 17781, is located at the center of the east end of Launch Complex 31/32, between the two launch silos. The building serviced both Complex 31 and Complex 32, and thus its central location. It is rectangular in plan and measures 40'0" x 50'0" (excluding the compressor housing). The exterior features a single-story, high-bay, reinforced concrete frame structure enclosed with concrete block infill panels. Floors are of 5"-or 6"-thick concrete slab with a floor-hardener finish. Steel joists rest on interior and exterior bearing walls, to form a slightly pitched gable roof with built-up roofing.

Other exterior details include:

- large roof ventilators
- overhanging eaves on all sides (Figure 63)
- wood fascia covered with metal coping at rooflines

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[223] “Drawing No. 01-017780-145.”

[224] “Drawing No. 01-017780-044”; “Drawing No. 01-017780-140”; “Drawing No. 01-017780-141.”

- 3’0” chamfered concrete canopies with drip edges over entry doors (Figure 63)
- original aluminum flush and rolling overhead doors
- five vent openings topped by precast concrete lintels (including a combination of original louvered, circular replacement, and blocked vents)
- two-inch projecting chamfered foundation walls
- rear shed compressor housing of wood frame/corrugated metal

Launch support building interior

The floor plan of the launch support building is divided into three spaces: engineer support area, storage, and toilet room. The engineer support area was used for tool check-out, and approximately two-thirds of the area was sectioned off with a wire partition or "crib," for the secure storage of supplies, parts and tools. The storage area is the largest space in the building (Figure 64). It provided a common area for tables, benches, and lockers. Oversized items were accommodated by the 8'-wide overhead rolling door. The storage area likely also provided indoor space to work on equipment during bad weather.

Several electrical panels are located along the south wall of the space. Primary panels are for incoming industrial and critical electrical service, and some service the camera pads, optical alignment buildings, and launch pad equipment rooms. The conduit from these panels runs in a floor-recessed cable trench along the south wall. The trench is covered with checkered steel plates 4'0" long and feature a 4" handhold at each end for lifting.

The toilet room is located in the northeast corner of the building, and is accessible from the building exterior and the storage area. There are three toilet stalls, two urinals, and three lavatories on the interior plumbing wall. The lower portion of this wall is furred out with glazed hard board to receive the plumbed fixtures. Three self-contained prefabricated shower stalls are lined up against the exterior wall. Adjacent to the showers is a dressing bench, with coat hooks above. For cleaning purposes, the floor is pitched toward a center floor drain.

Aside from a 4" wood base at the glazed hard board surface, there are no interior finishes in the building.[225] Ceiling-mounted pendant lights are typical throughout the building.

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[225] “Drawing No. 01-17780-037”; “Drawing No. 01-17780-038”; “Drawing No. 01-17780-070”; John Hilliard, electronic correspondence to Julie Webster, 6 June 2008.

Launch support building site amenities

The toilet sanitary line exits the launch support building to the east, and connects to a dedicated septic system that angles away from the building. System components include a septic tank with pump housing, distribution box, and drain field. Square concrete guard posts delineate and protect the drain field.[226] To the north of the launch support building was a cooling tower similar to, but larger, than those found at the blockhouses. This tower provided evaporative cooling for the air conditioning systems of the launch pad equipment room. Only the concrete pad and concrete block foundation walls of the tower remain (Figure 65).[227] A transformer substation is just a few feet to the south of the launch support building (Facility 17782) that replaces the original transformer yard setup. Six concrete pads, grounding wires, and various ducts with truncated lines remain from the earlier configuration (Figure 66).

Camera pads

Launch/perimeter camera pads

Located about the site are twenty-one launch/perimeter camera pads (with numerical designations) used to document onsite launch conditions. The typical pad consists of three 1'0"-deep x 6'0"-wide concrete component pads of varying lengths: 6', 12', and 8'. The two shorter pads featured three camera mounting bolt circles; the longer pad had four camera mounting bolt circles. The area immediately around the concrete pads was lime rock, covered with a double bituminous surface treatment. Flanking the line of component pads is the nearby terminal box pad and the transformer pad across the street. Both of these support pads are centered on the overall camera pad layout.[228]

TV camera pads

In addition to the twenty-one launch/perimeter camera pads, there are also four on-site television (TV) camera pads and three off-site telemetry camera pads. A single TV camera pad was located at each launch pad and silo. The TV camera pad for Launch Pad 32 had a 5'0"square concrete base that extended 1' below grade. A single TV camera mounting bolt circle was located in the center of the pad. For Launch Pad 31, TV camera bolts were grouted into the

[226] "Drawing No. 01-17780-045."
[227] "Drawing No. 01-17780-052."
[228] "Drawing No. 01-17780-007"; "Drawing No. 01-17780-008."

existing concrete apron at the southeast quadrant of the pad. Here, the presence of concrete from the previous site configuration negated the need for new pad construction.[229]

CZR camera pads

Special cameras were used during launches, to provide photographs of missiles along their predetermined flight paths, from lift-off to 3,000 feet. These are referred to as fixed metric, ribbon frame, or CZR cameras. These cameras sampled a launch vehicle's position at 30 to 180 frames per second on five-inch aerial film.[230] Two pads for this camera type were located outside the Launch Complex 31/32 site boundaries. A tear-drop-shaped CZR site was located just outside the main gate on Flight Control Road; its designation was U44R79. A trapezoidal CZR site was located on the opposite side of the base skid strip; its designation was U30R47.

The pads each featured:

- 8'0" x 30'0" dimensions
- tapered guide rail projections at one end
- two circular camera locating inserts, centered on a standard bronze survey marker
- three pins on each camera locating insert, positioned between the guide rails[231]

The guide rails allowed for alignment of the camera vehicle's tires. Once in place, the three pins engaged the camera vehicle to fix it into position, using the survey marker for reference. Then feet were deployed to lift the vehicle off its tires. This system prevented movement of the CZR camera vehicle during launches, leaving all missile-tracking movement to the camera mount.[232]

Perpendicular to the length of each CZR pad were two pairs of target poles, used for alignment during pre- and post-flight calibrations. Each pair was positioned 150'0" in front of the pad, aligned at one and two degrees outside the line of sight to Launch Pad 32A.[233]

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[229] "Drawing No. 01-17780-008."
[230] Hilliard, electronic correspondence, 19 April 2008.
[231] "Drawing No. 01-17780-010"; "Drawing No. 01-17780-012."
[232] Hilliard, electronic correspondence, 2 June 2008.
[233] Ibid. Although the CZR camera mounts were aligned with pad 32A, there was ample room to turn the cameras on a vehicle at pad 31A and use the target poles for pad 31A calibrations.

M-45 camera pad

One additional camera type used during launches was the M-45 Intermediate Focal Length Tracking Telescope or IFLTT. This camera tracked missiles at an intermediate distance, with focal lengths ranging from 40" to 240". A single M-45 camera was installed on a modified M-45 machine gun mount (thus the name) atop an excavated mound. The mound was located on the opposite side of the base skid strip, north and west of the CZR camera pad. The M-45 camera was centered on the line of sight to Pad 32A. Electrical power to the camera was provided by a dedicated power supply centered on the pad.[234] This camera pad is now being used as an equipment pad in support of Delta launch operations from Launch Complex 17.[235]

Aboveground cableways and underground duct banks

Aboveground cableways run between the blockhouses and their corresponding launch pads. These cableways once carried communication lines for monitoring launch status from the blockhouses. Each cableway has three nodes referred to as "transitions," in reference to their change in direction. The type I transition is located behind the blockhouses (Figure 67). The type II transition aligns with the east side of the pad equipment rooms (Figure 68). The type III transition terminates the aboveground portion of the cableways near the access road that passes directly in front of the launch support building.

Underground duct banks continue beyond the aboveground cableways, to extend cabled services to the launch pads and silos. The duct banks run approximately 2'4" below grade and are sloped as necessary.[236] A 4'-wide sidewalk runs along each of the cableways. Additional sidewalks provide access to the western-most survey monuments. Where these sidewalks intersect with the cableways, galvanized steel grating crosswalks span the cable trenches.[237]

The aboveground cableways vary in clear width, from 6'0" between transitions I and II, to 4'0" between transitions II and III. The 6'0"-wide runs accommodated two triple stacks of 1'6" cable trays; the 4'0"-wide runs carried just one triple stack of cable

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[234] "Drawing No. 01-17780-011"; Hilliard, electronic correspondence, 19 April 2008; Hilliard, electronic correspondence, 2 June 2008. Like the CZR camera mounts, the M-45 camera mounts supported camera operations at both pad 31A and 32A.

[235] Thomas Penders, electronic correspondence with Susan Enscore, 2 June 2008.

[236] "Drawing No. 01-17780-004"; "Drawing No. 01-17780-080."

[237] "Drawing No. 01-17780-008."

trays. Eight-inch-thick reinforced concrete walls are typical of cableways. The cableways are protected overhead by sheets of corrugated aluminum, industrial siding that once rested on removable aluminum wide-flanged beams. The bolt-washer-pad connections that once secured the siding to the cableways have been replaced by a series of rip rap sandbags that weigh the siding down.[238]

Each transition node has a chamber that varies in size. The chamber for transition I measures 12'0"-square in plan x 5'7 5/8" deep. It contains a cable rack, upper and lower cable trays, an access ladder near the northeast corner, and a sump pump to siphon water in the southeast corner. There were thirty-four cable ducts which entered transition I from each of the blockhouses. The chamber for transition II is a 9'0" cube and contains a 3'2" x 4'0" duct bank opening to the pad equipment rooms, an access ladder on the west side, a sump pump in the northwest corner, and pass-through cable trays on the south side. The chamber for transition III measures 6'0"-square x 9'0" deep in plan, and contains a duct bank opening to the silos, an access ladder on the north side, and a sump pump in the northeast corner.[239]

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[238] "Drawing No. 01-17780-080."
[239] Ibid.

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HISTORIC DRAWINGS

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Due to this stipulation, it is not possible to reproduce in this document the drawings used to gather information about the design, construction, and use of facilities at Launch Complex 31/32, CCAFS.

APPENDIX: FIGURES FROM DATA PAGES

Figure 2. Aerial of Cape Canaveral with use areas indicated, 1957 (National Archives and Records Administration [NARA]).

Figure 3. The Industrial Area at Cape Canaveral, 1962 (NARA).

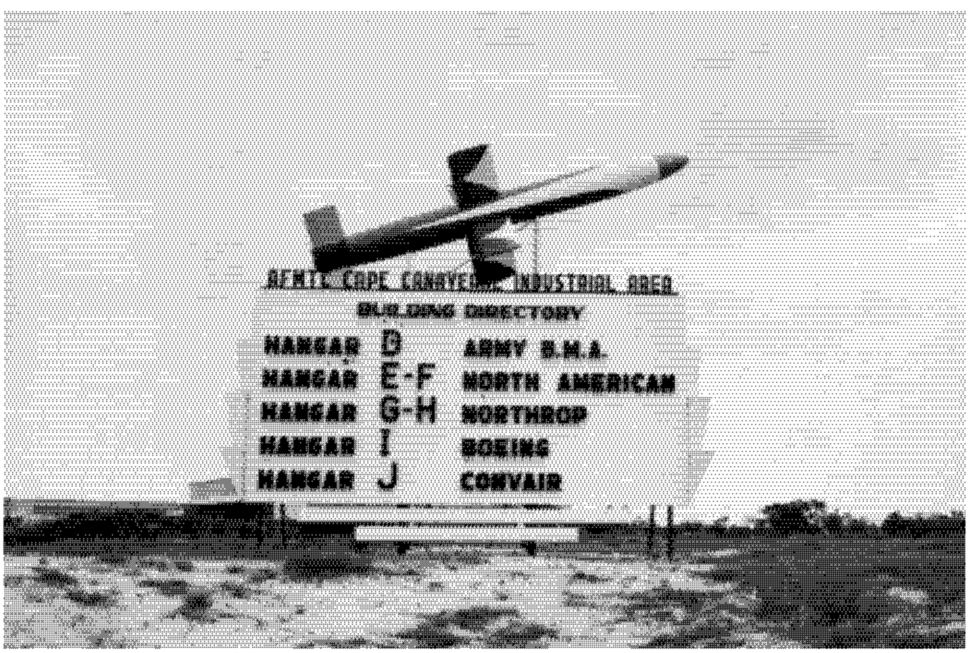


Figure 4. Hangar identification sign, 1957 (NARA).

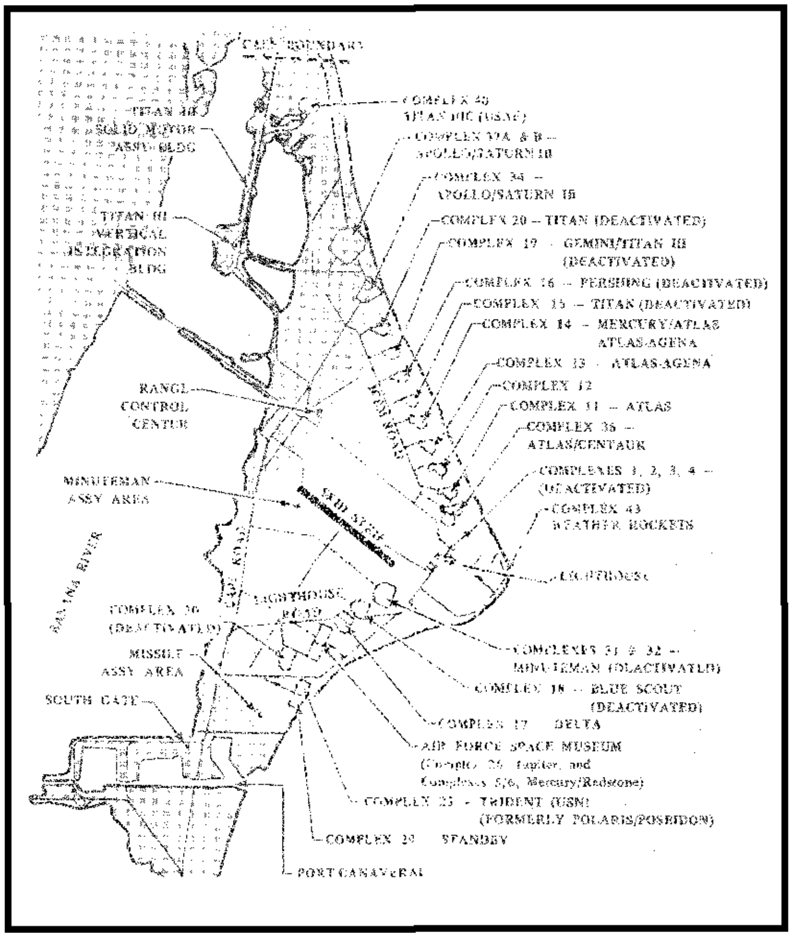


Figure 5. Map showing the many types of missile launches supported by CCAFS Complexes (USAF).

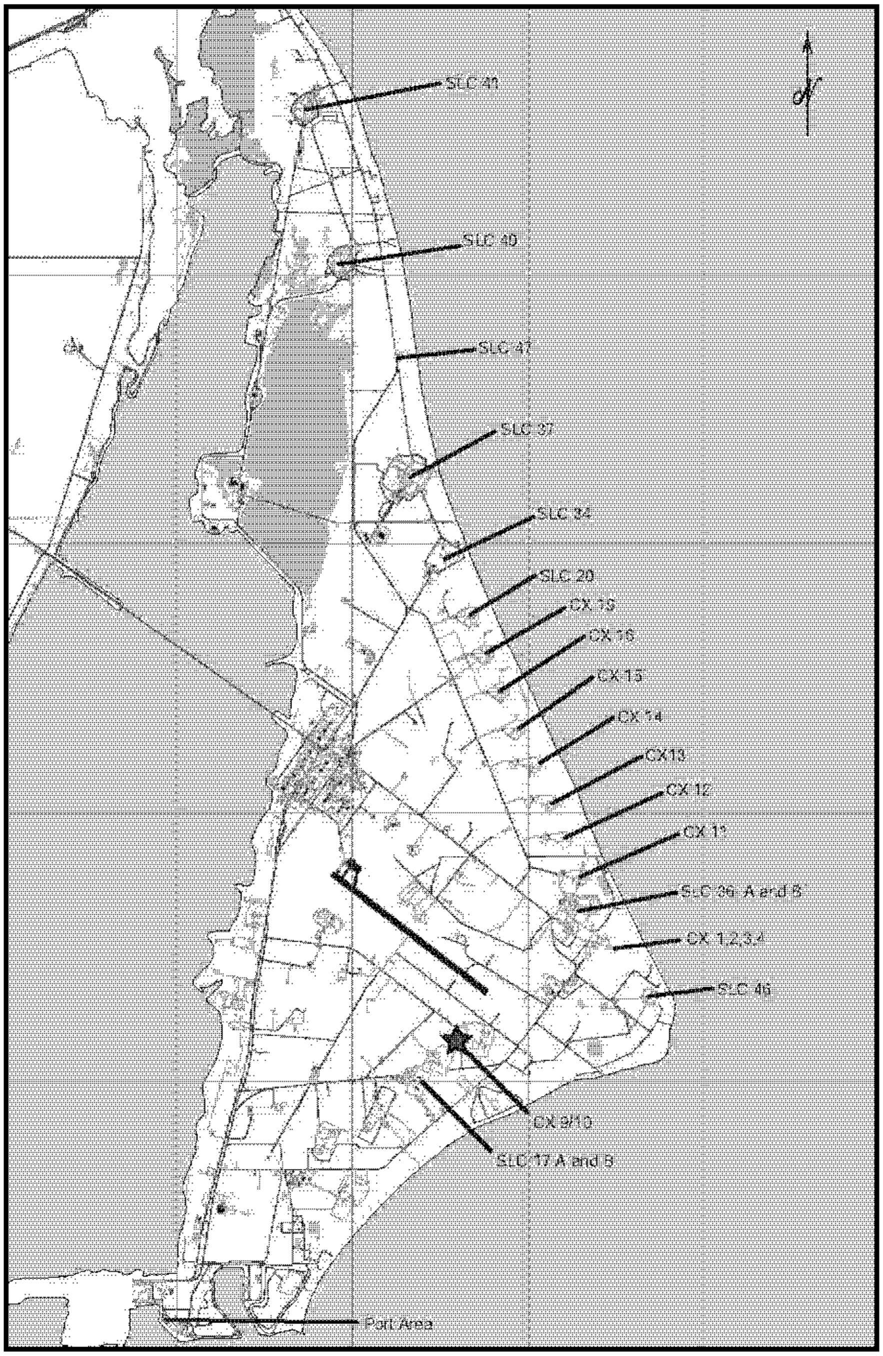


Figure 6. Location of Complex 9/10, CCAFS (USAF, 2003).

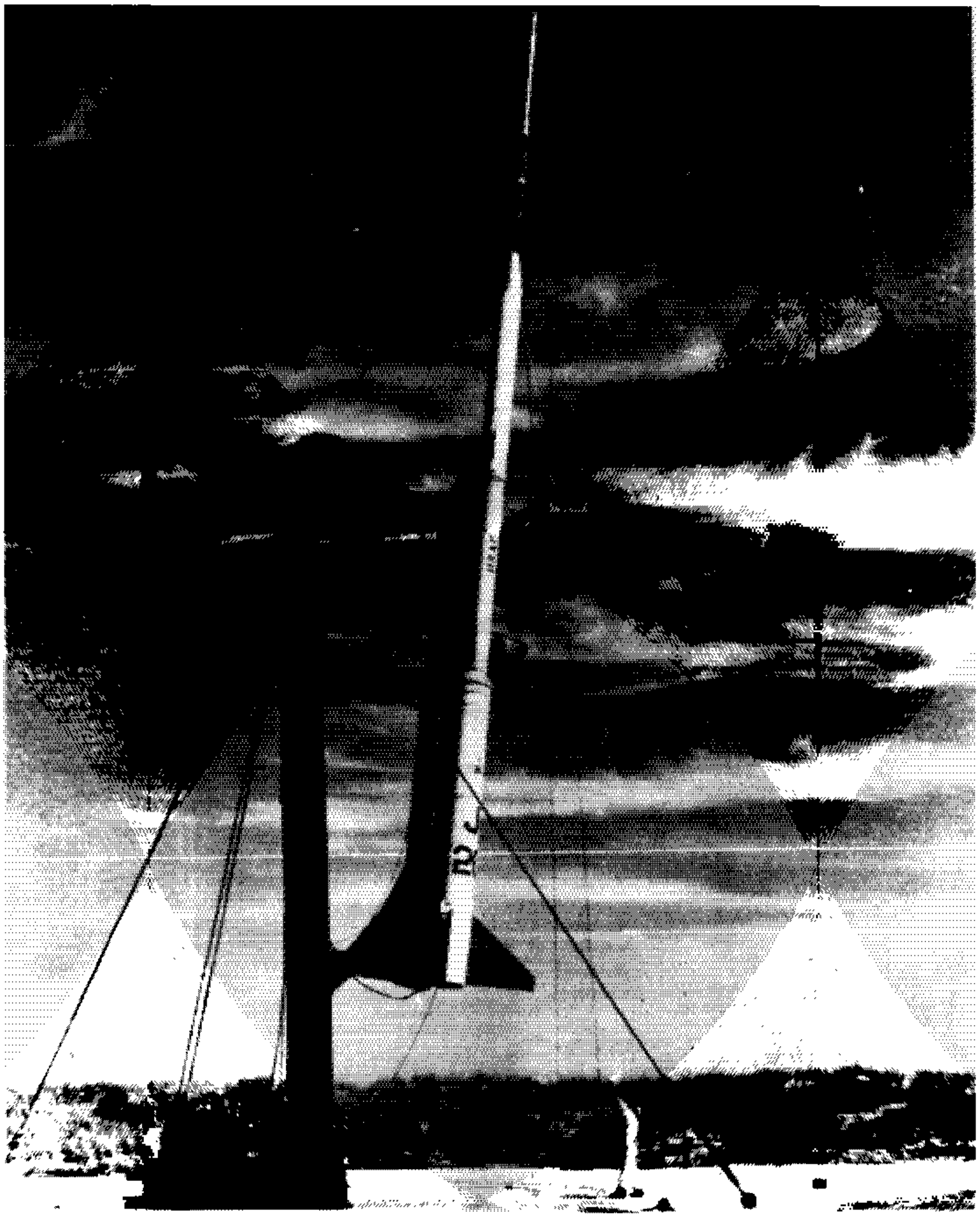


Figure 7. Jason sounding rocket, 1958 (NASA).

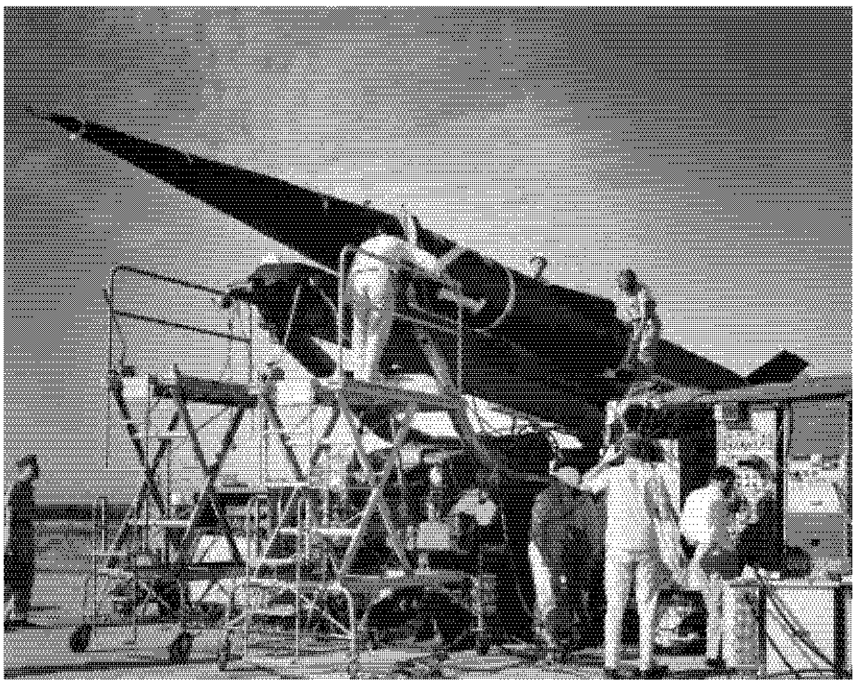


Figure 8. Alpha Draco and launcher on pad 10, 1959 (USAF).

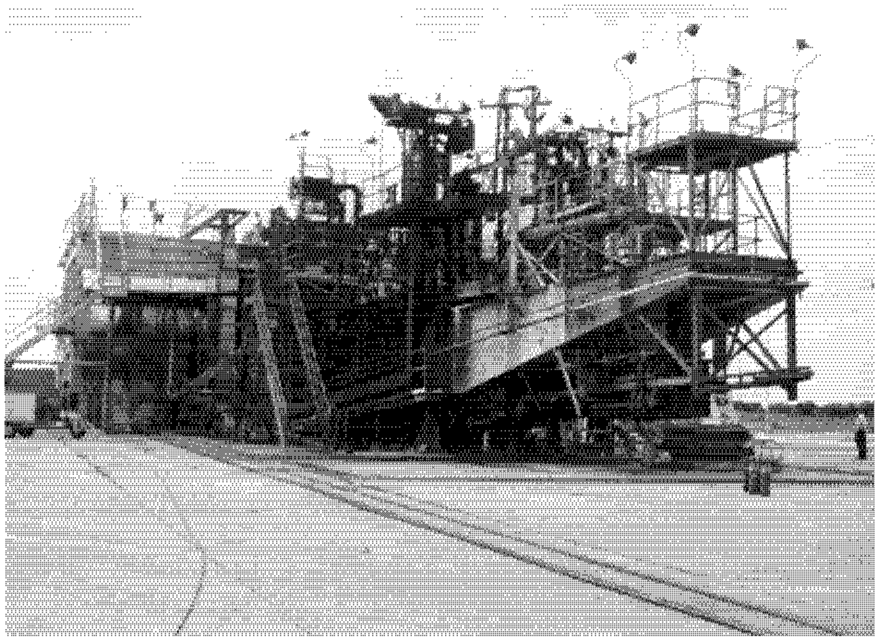


Figure 9. Navaho launch pedestal and gantry, 3 May 1957 (NARA).

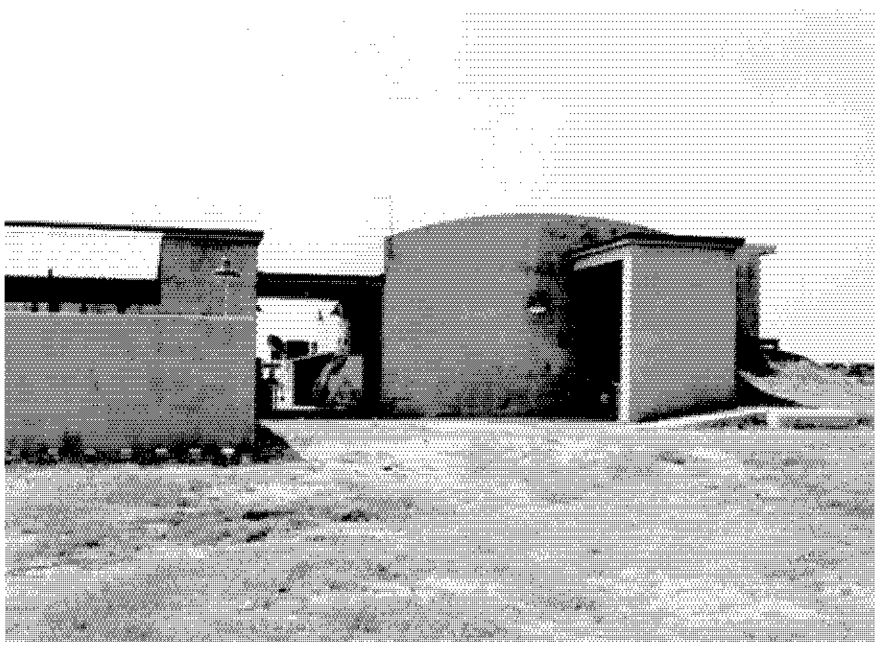


Figure 10. Blockhouse, transformer vault, and nitrogen shed at complex 9/10, 8 June 1956 (NARA).

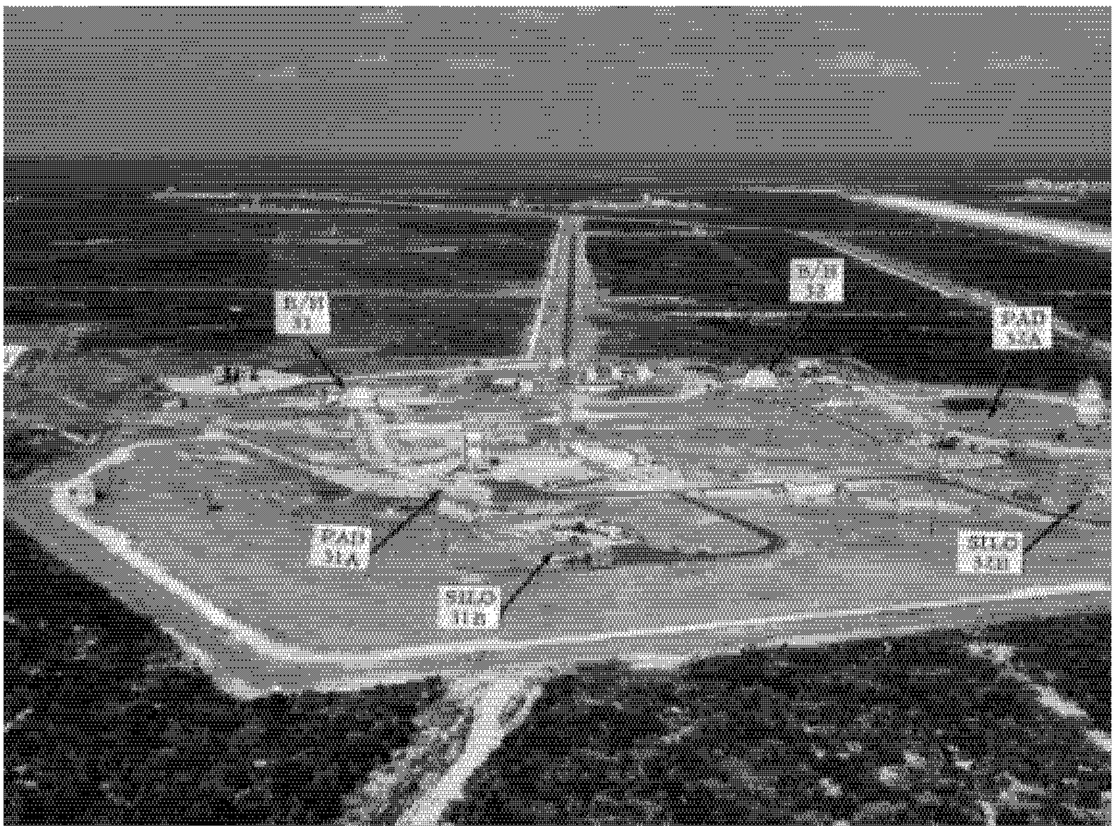


Figure 11. Aerial photograph of Launch Complex 31/32, 1960s (Air Force Space and Missile Museum).

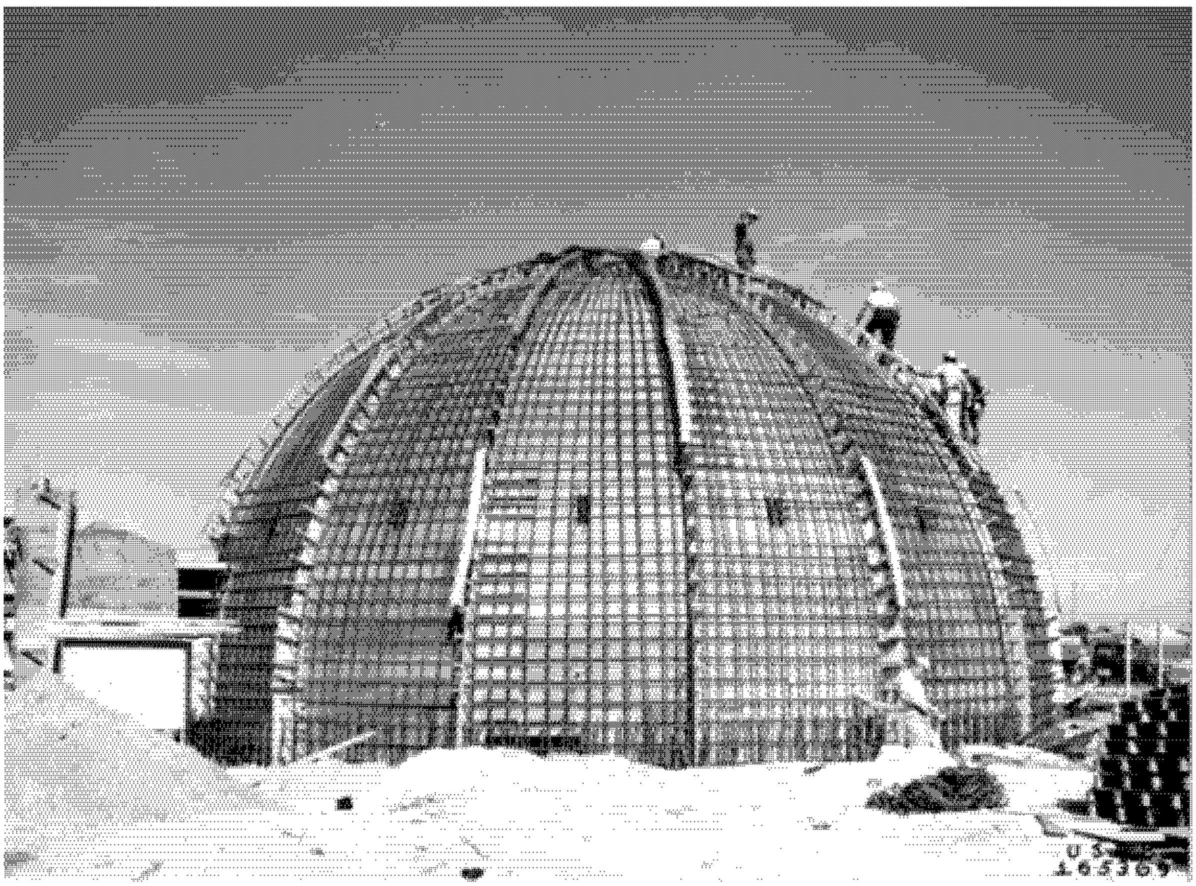


Figure 12. Reinforcing rods being put in place on Blockhouse 31, 30 October 1959 (NARA).

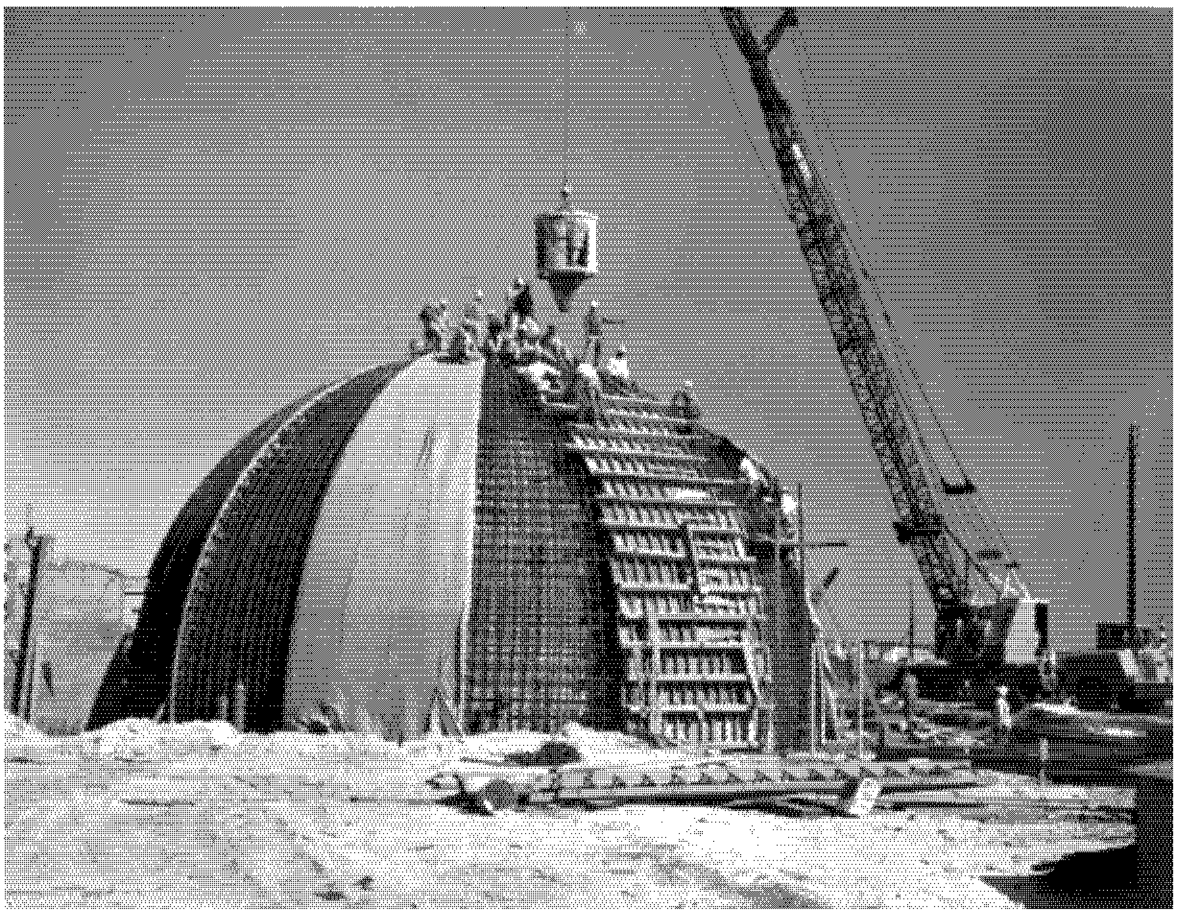


Figure 13. Pouring concrete for Blockhouse 31, 25 November 1959, (NARA).

Figure 14. Completed Blockhouse, 18 July 1960 (NARA).

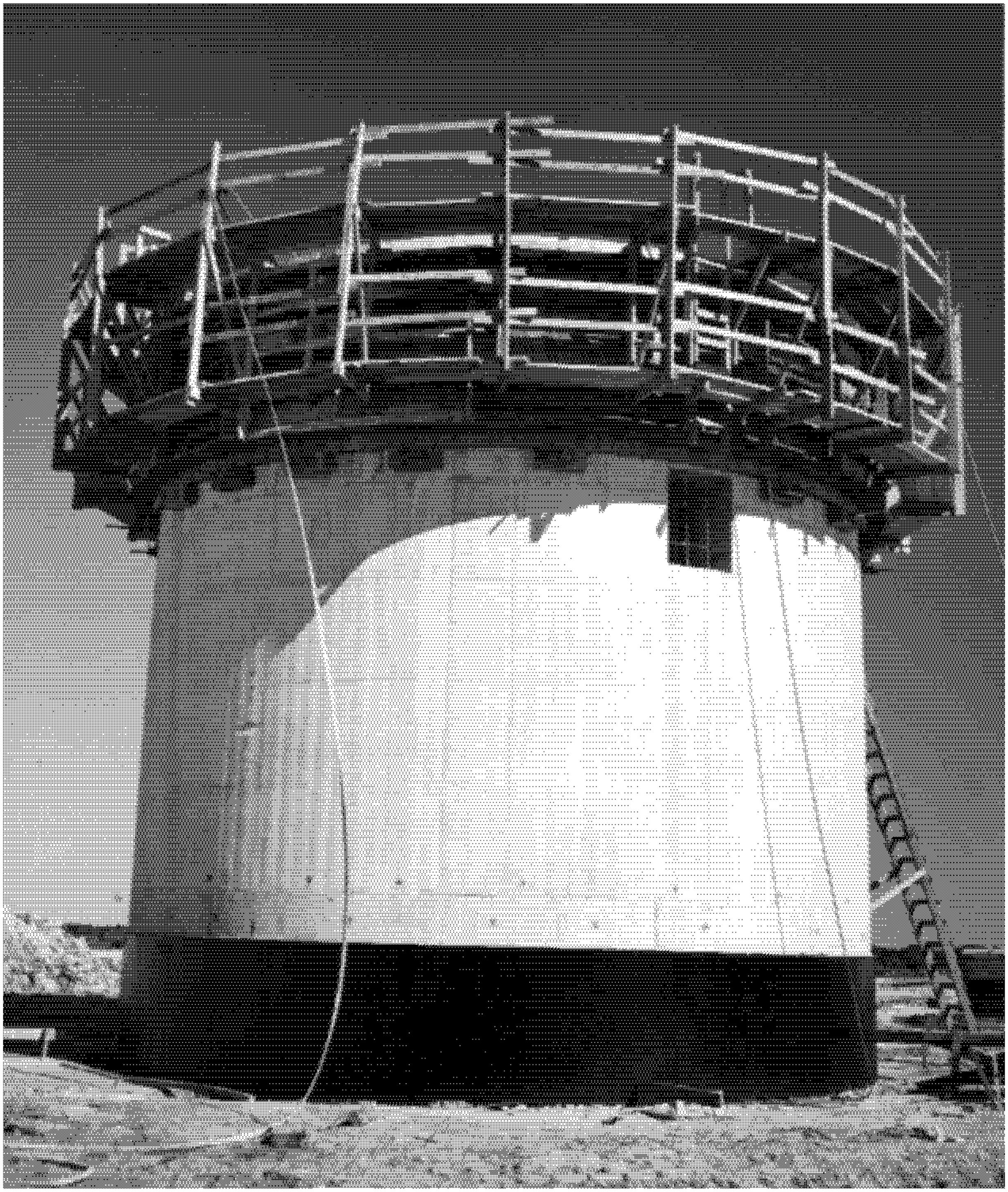


Figure 15. View of silo under construction at complex 31/32, 25 November 1959 (NARA).

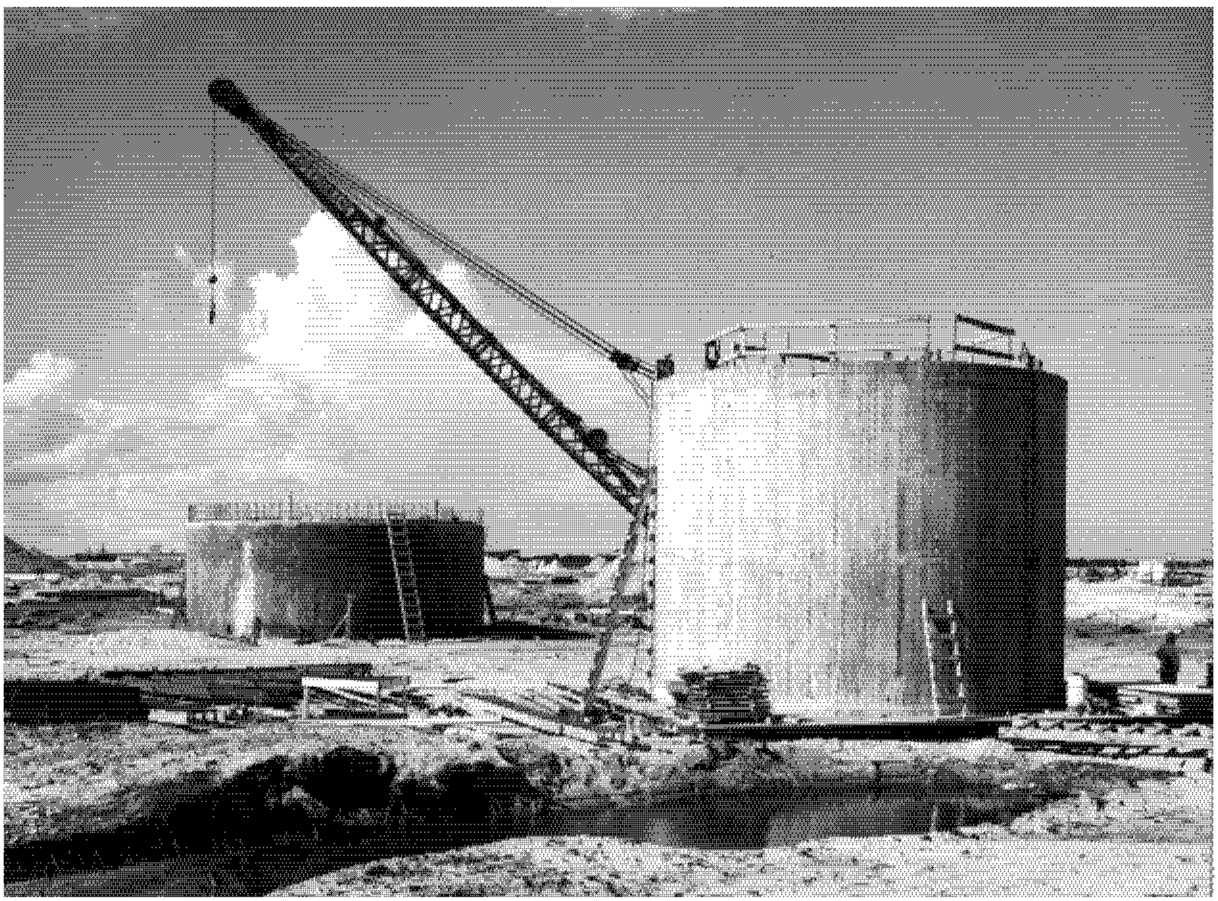


Figure 16. Construction of silo and R&D room, 30 October 1959 (NARA). Smaller concrete structure to the left may be the next ring to get stacked on the silo (right).

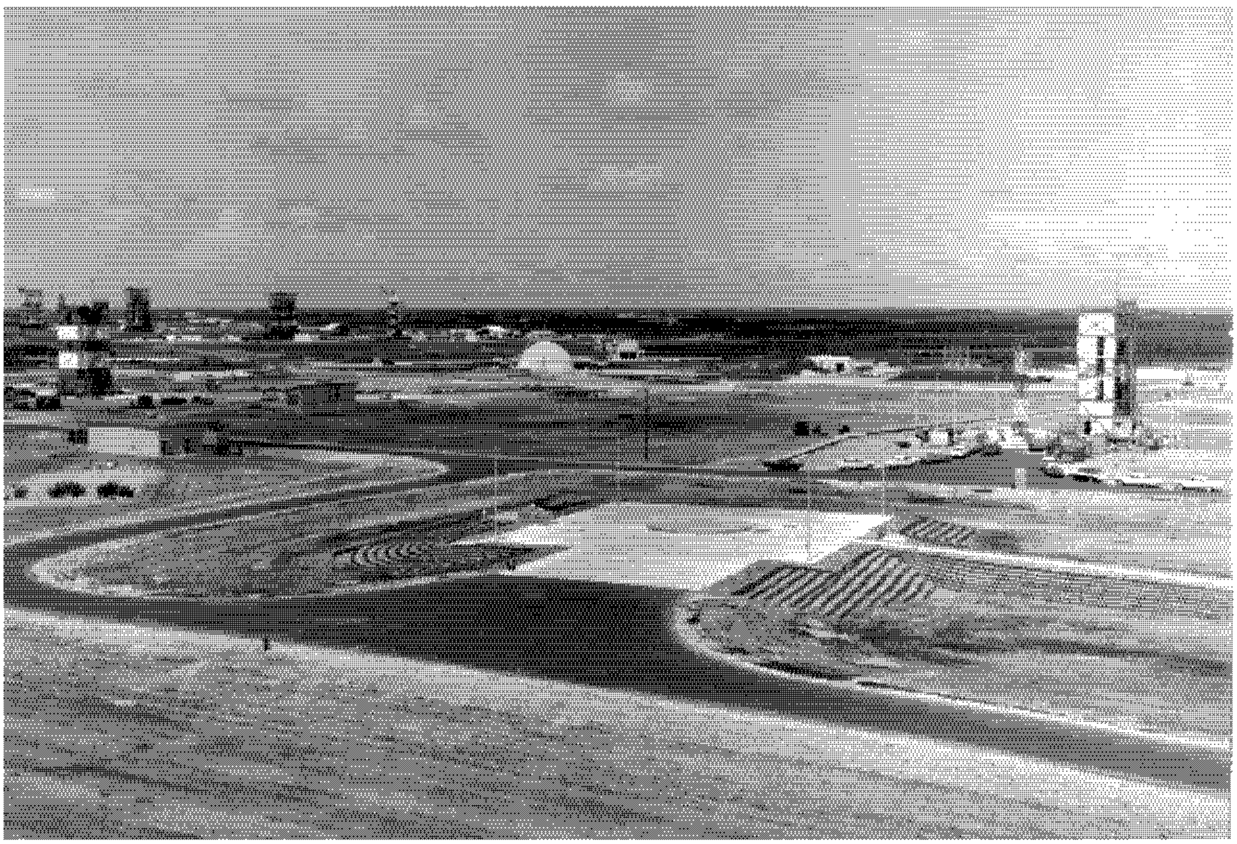


Figure 17. Completed silo 32B, 18 July 1960 (NARA).

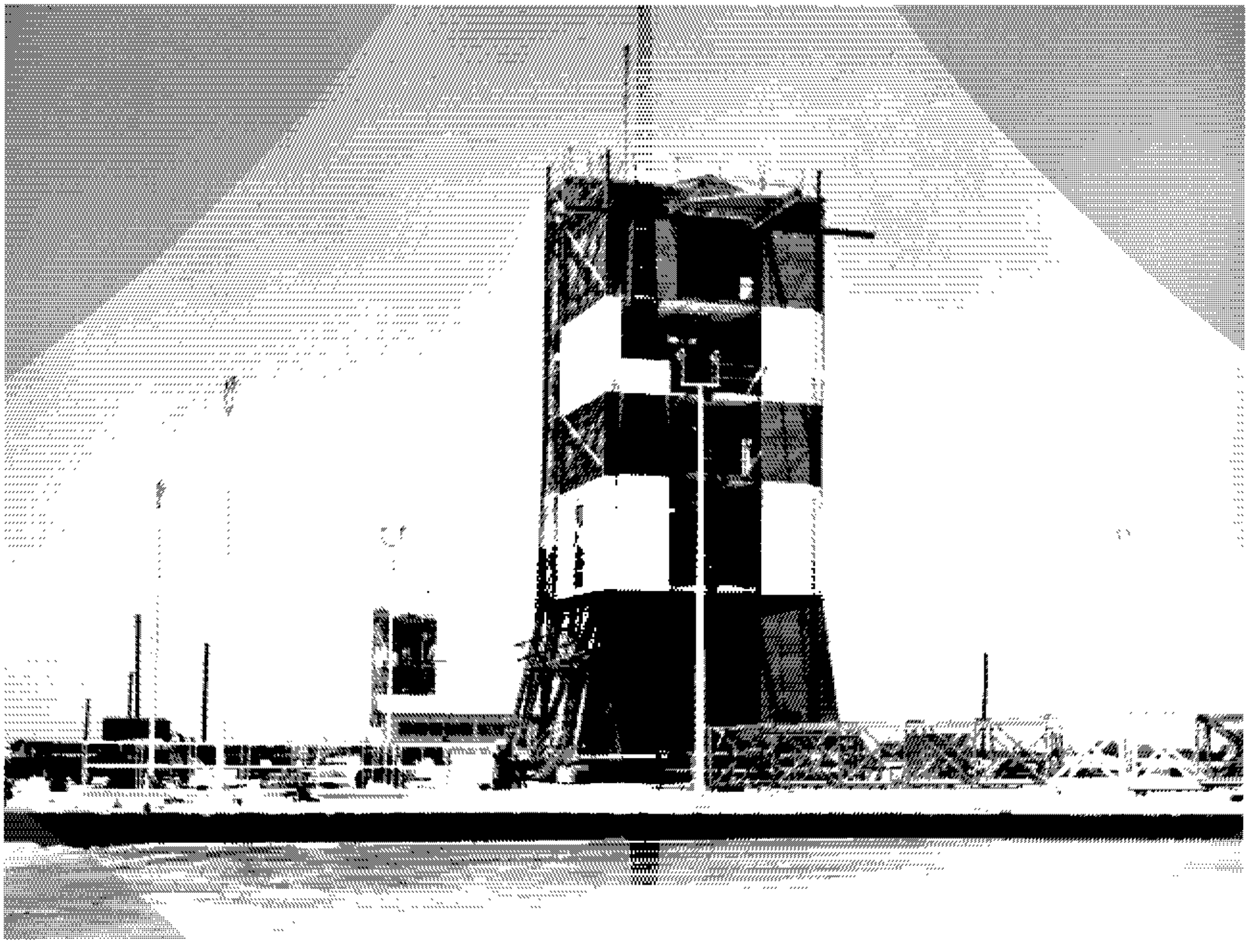


Figure 18. Completed mobile service tower for pad 31A, 29 July 1960 (NARA). The tower for pad 32A is visible in the background with an optical alignment building in between.

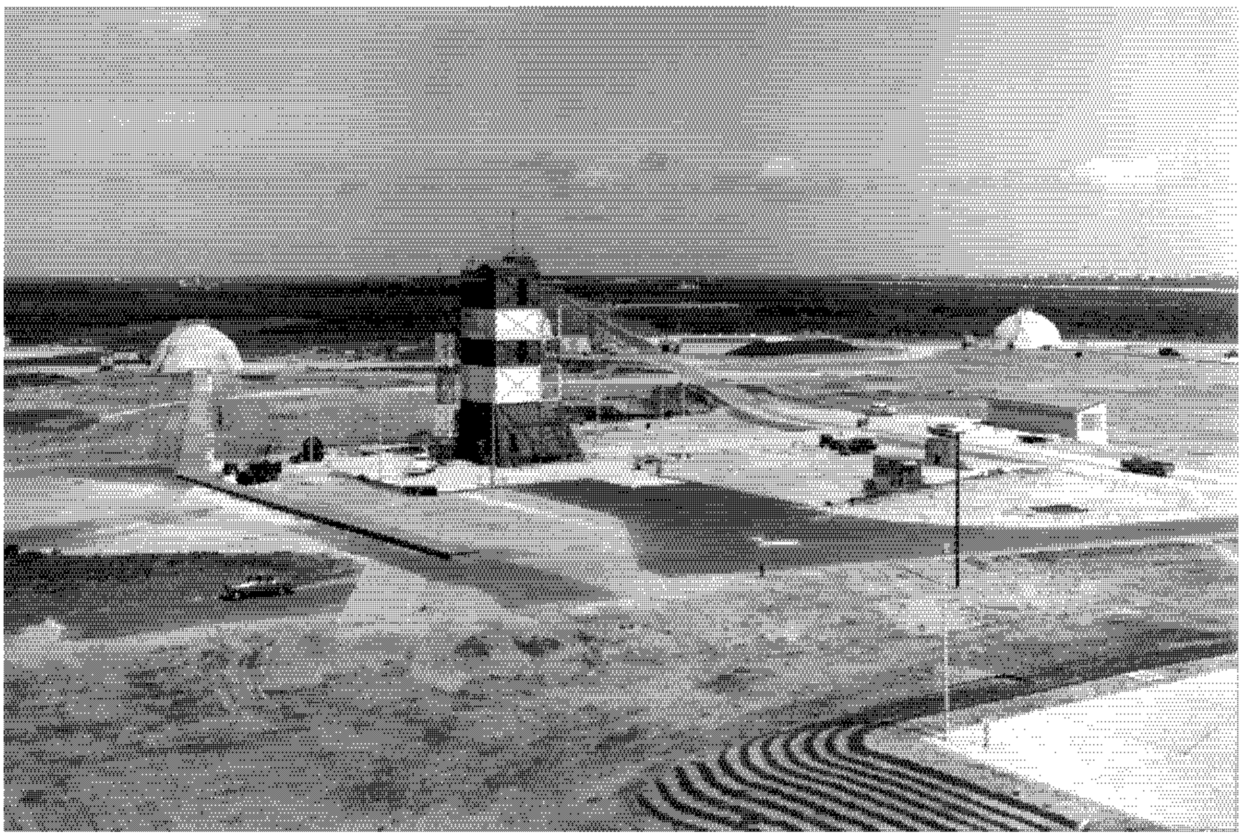


Figure 19. View of completed complex 31 with blockhouse to left, pad A in center, and silo B at near right, 18 July 1960 (NARA).

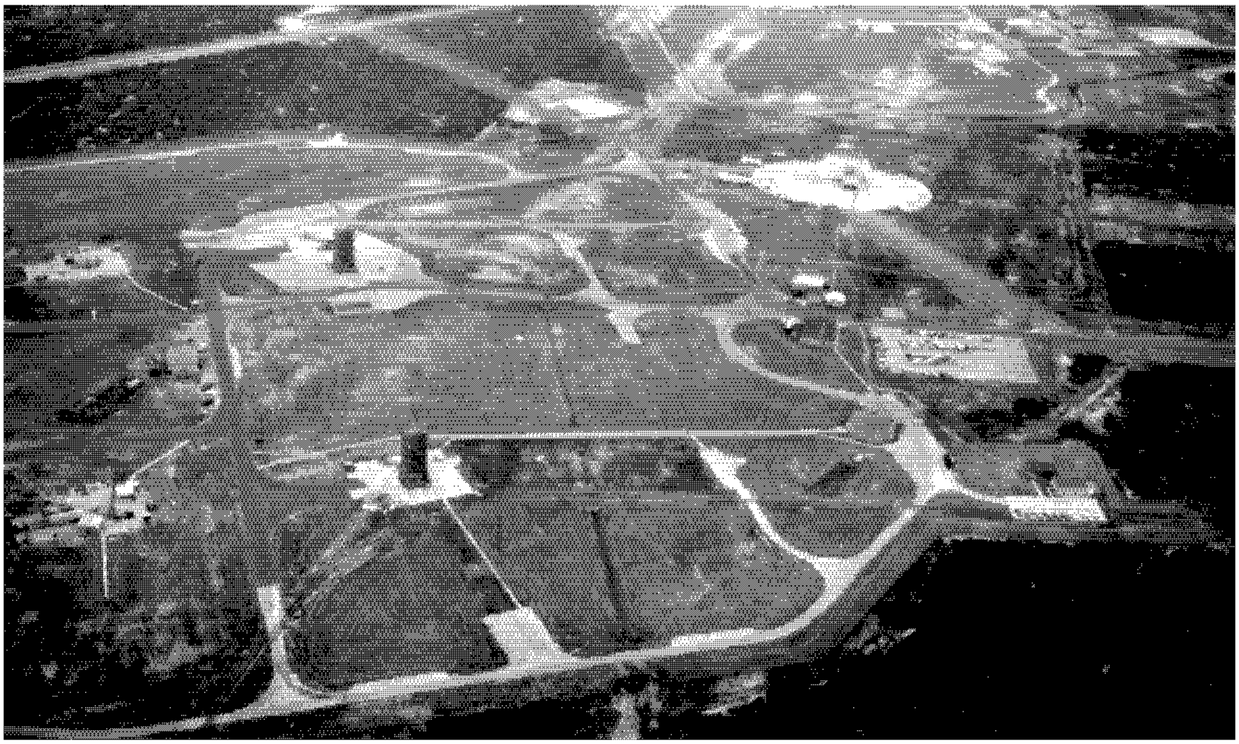


Figure 20. Aerial view of completed Complex 31/32 with silos at left, launch pads in the center, and blockhouses at right, October 1962 (NARA).

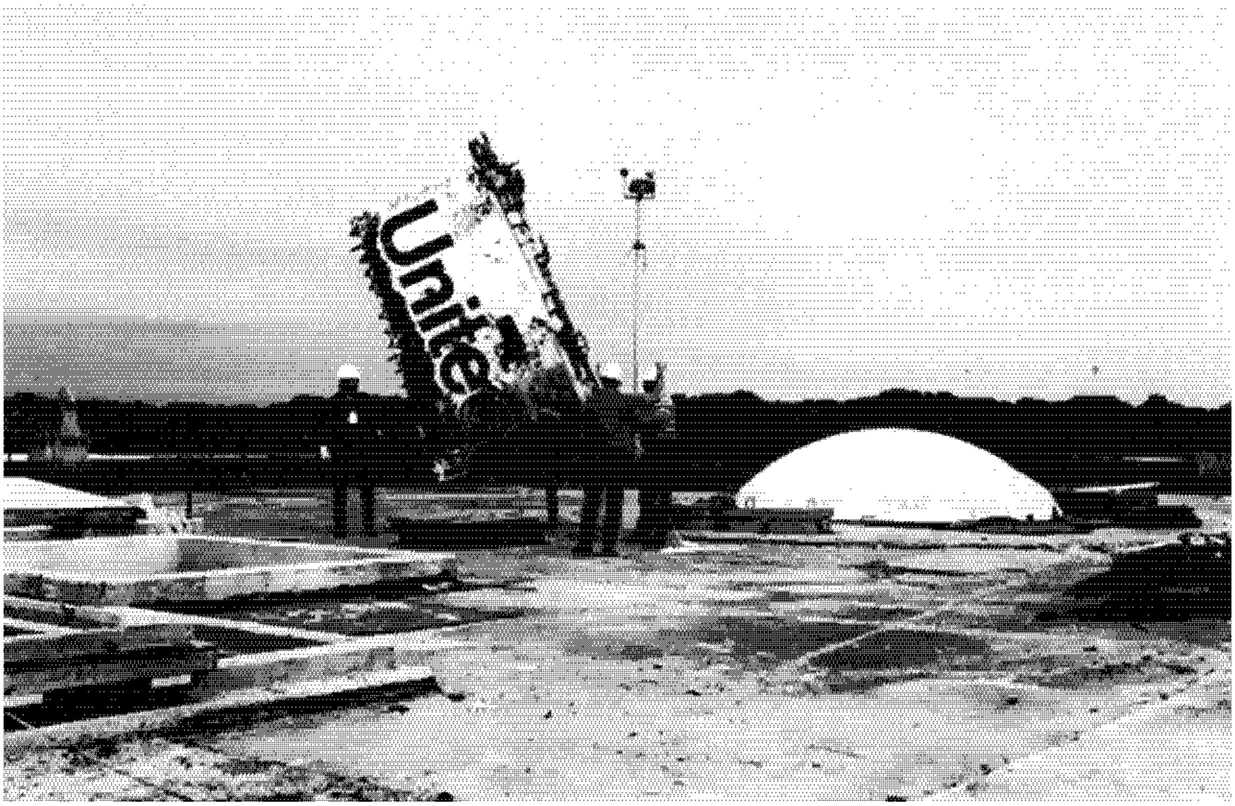


Figure 21. Storage of Space Shuttle Challenger debris, January 1987 (NASA).

Figure 22. Minuteman missile emerging from silo, 16 January 1964 (NARA).

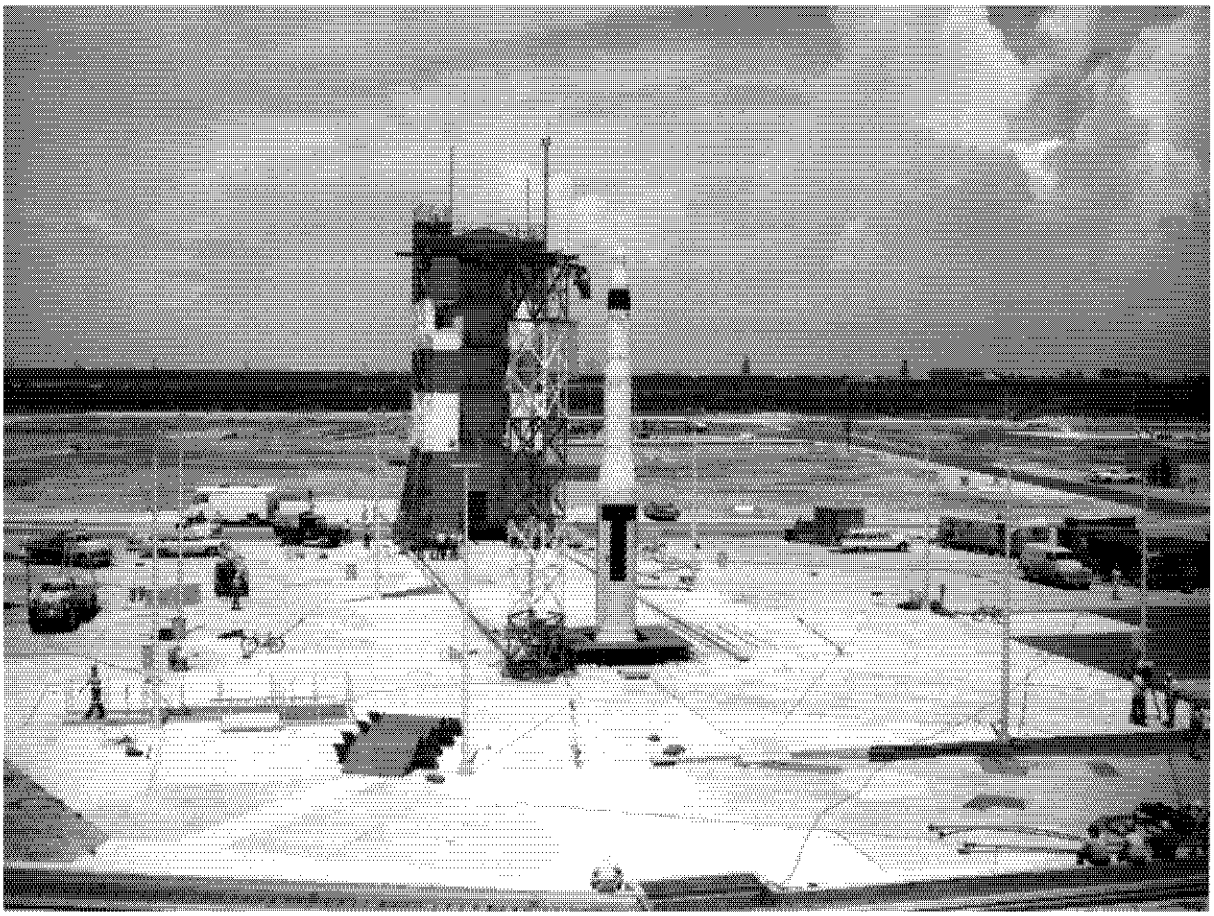


Figure 23. Activity around Launch Pad 31A leading up to the first Minuteman I launch, 18 January 1961 (NARA).

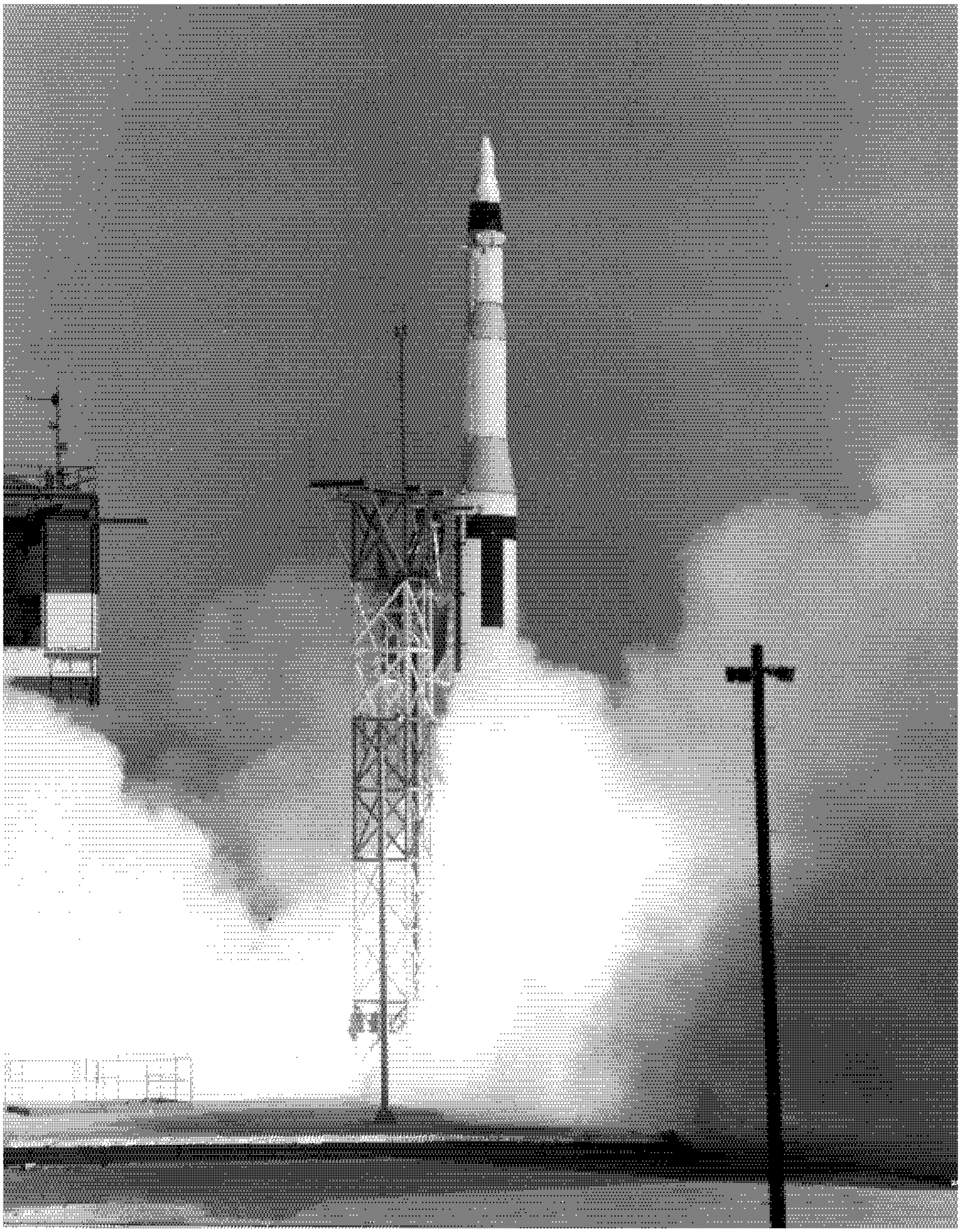


Figure 24. First Minuteman launch from Cape Canaveral, 1 February 1961 (NARA).

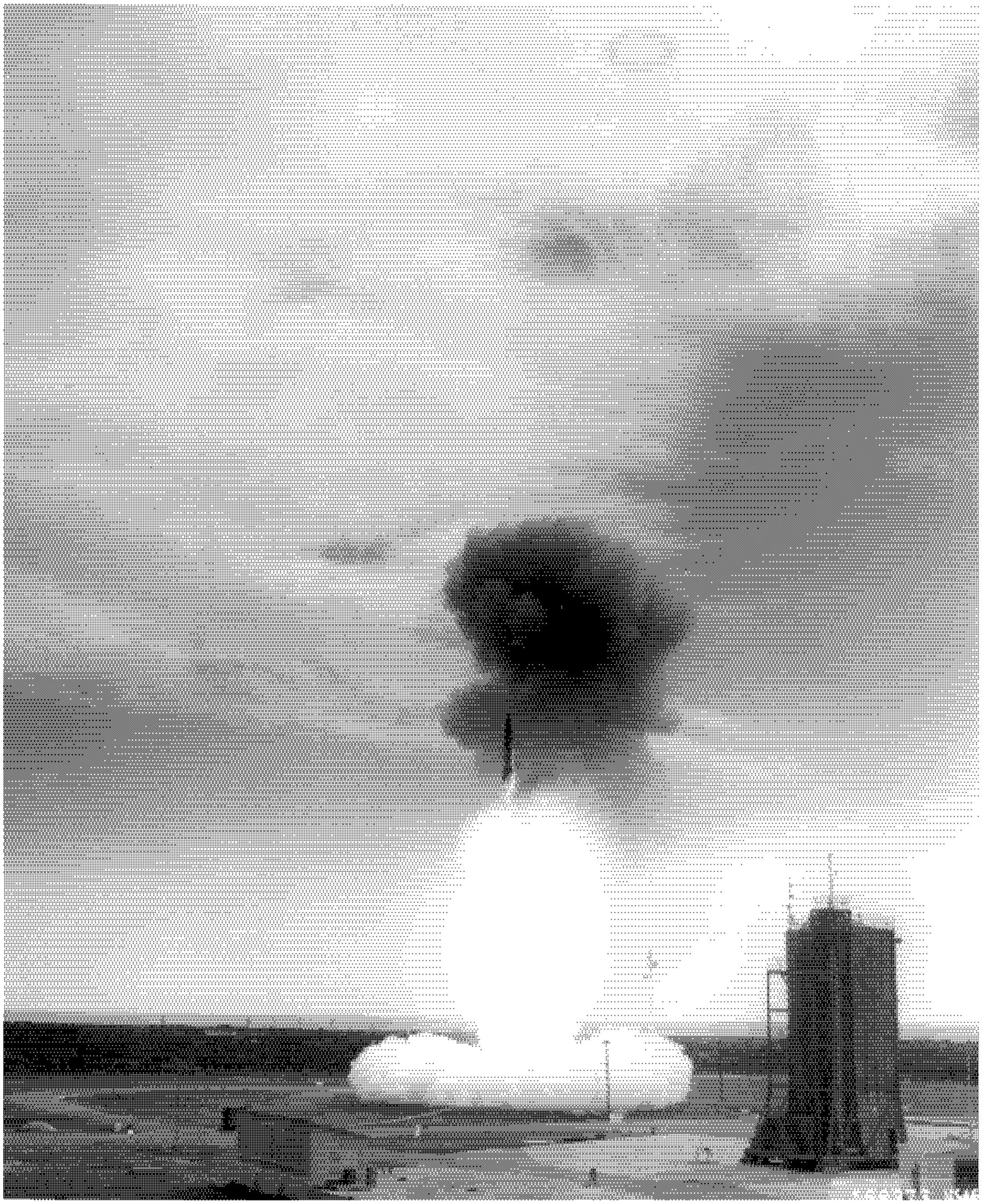


Figure 25. Minuteman I 31B silo launch, 19 November 1962 (NARA).

Figure 26. Explosion of Minuteman missile shortly after launch, 16 July 1963 (NARA).

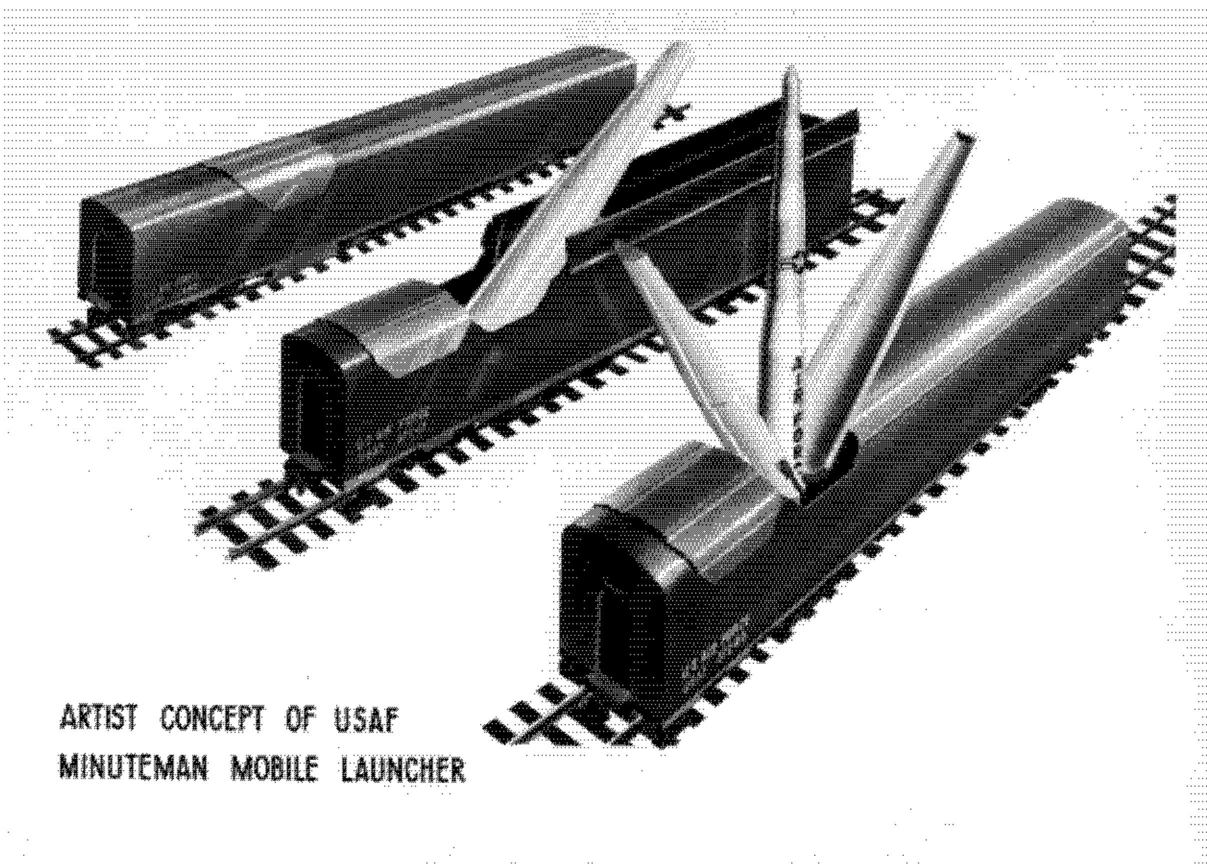


Figure 27. Concept drawing for mobile Minuteman launcher/train car, 1960 (NARA).

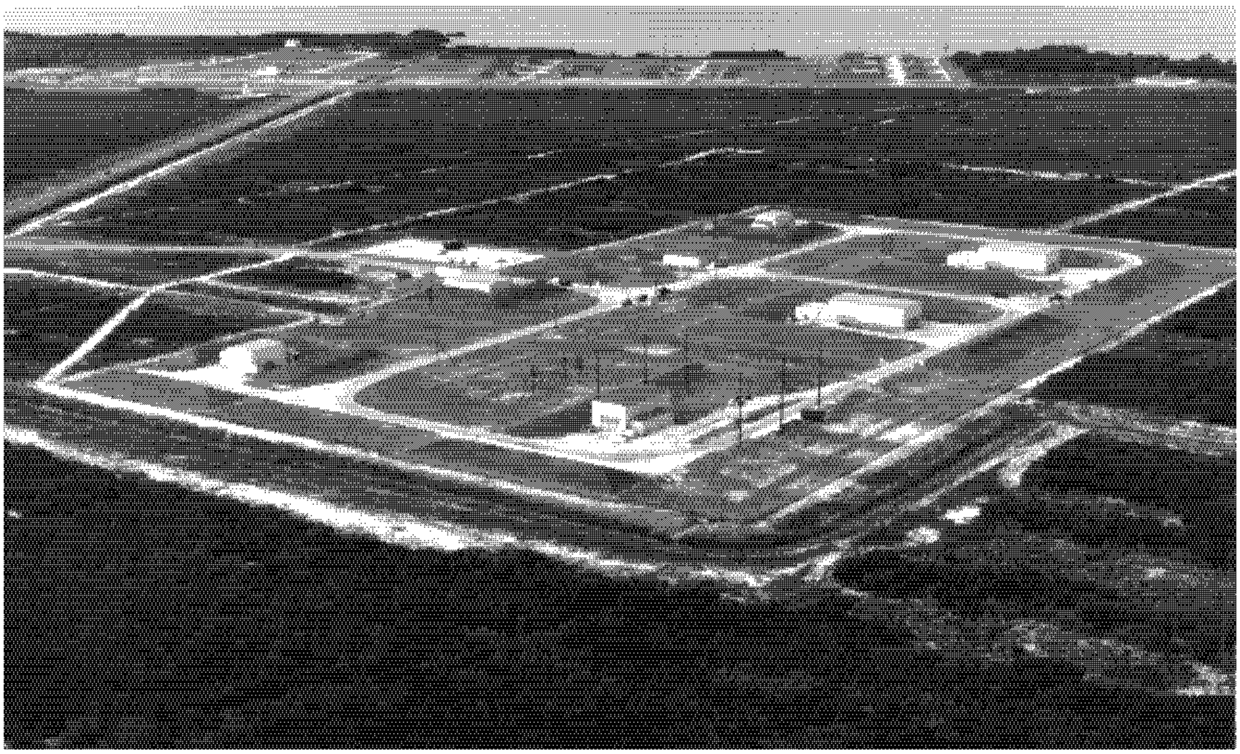


Figure 28. Minuteman missile assembly and testing area, Cape Canaveral, 31 December 1962 (NARA).

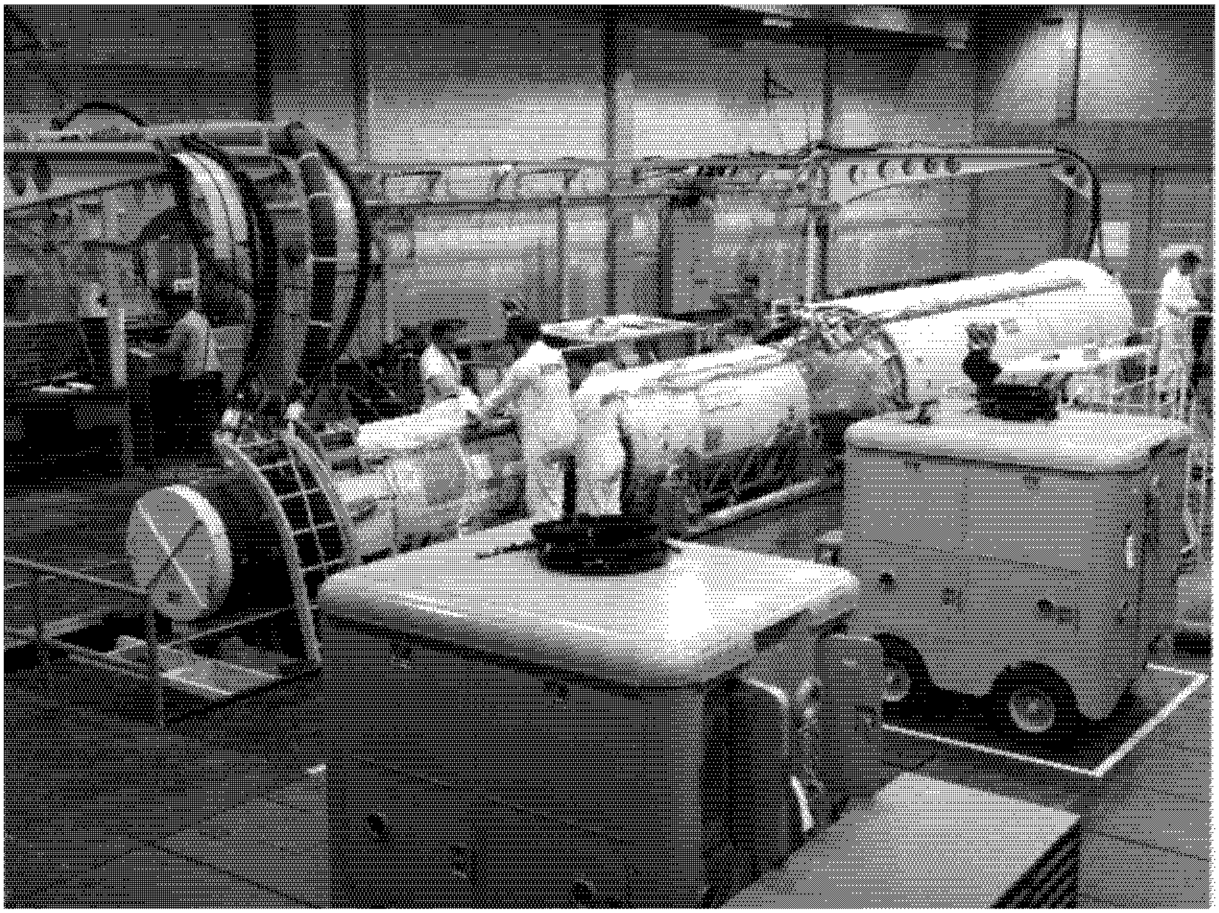


Figure 29. Boeing technicians perform missile assembly and checkout tasks in a Missile Assembly Building at CCAFS, 1 February 1963 (NARA).

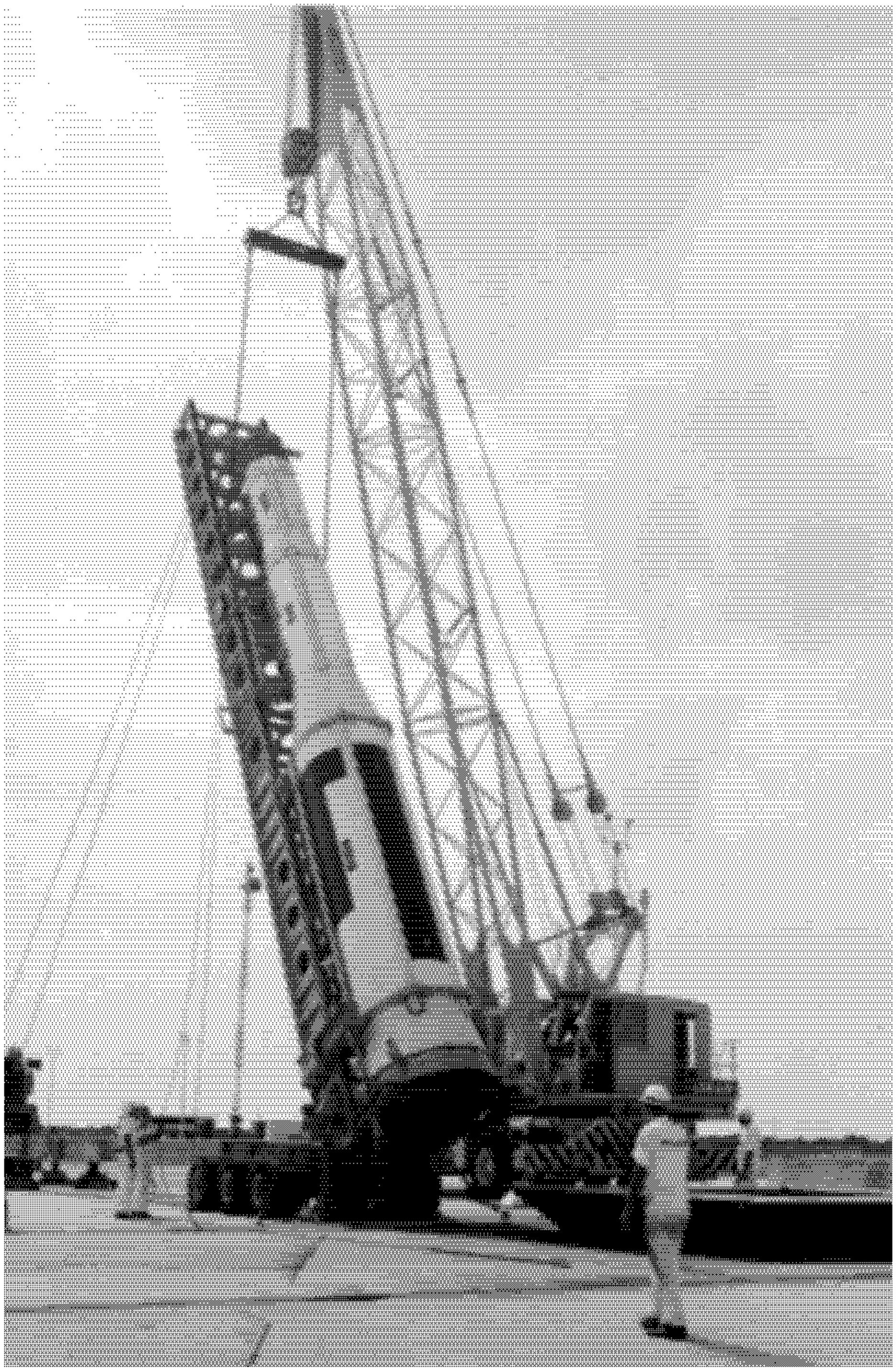


Figure 30. Minuteman I lifted by crane from transporter/erector to launcher, 12 May 1961 (NARA).

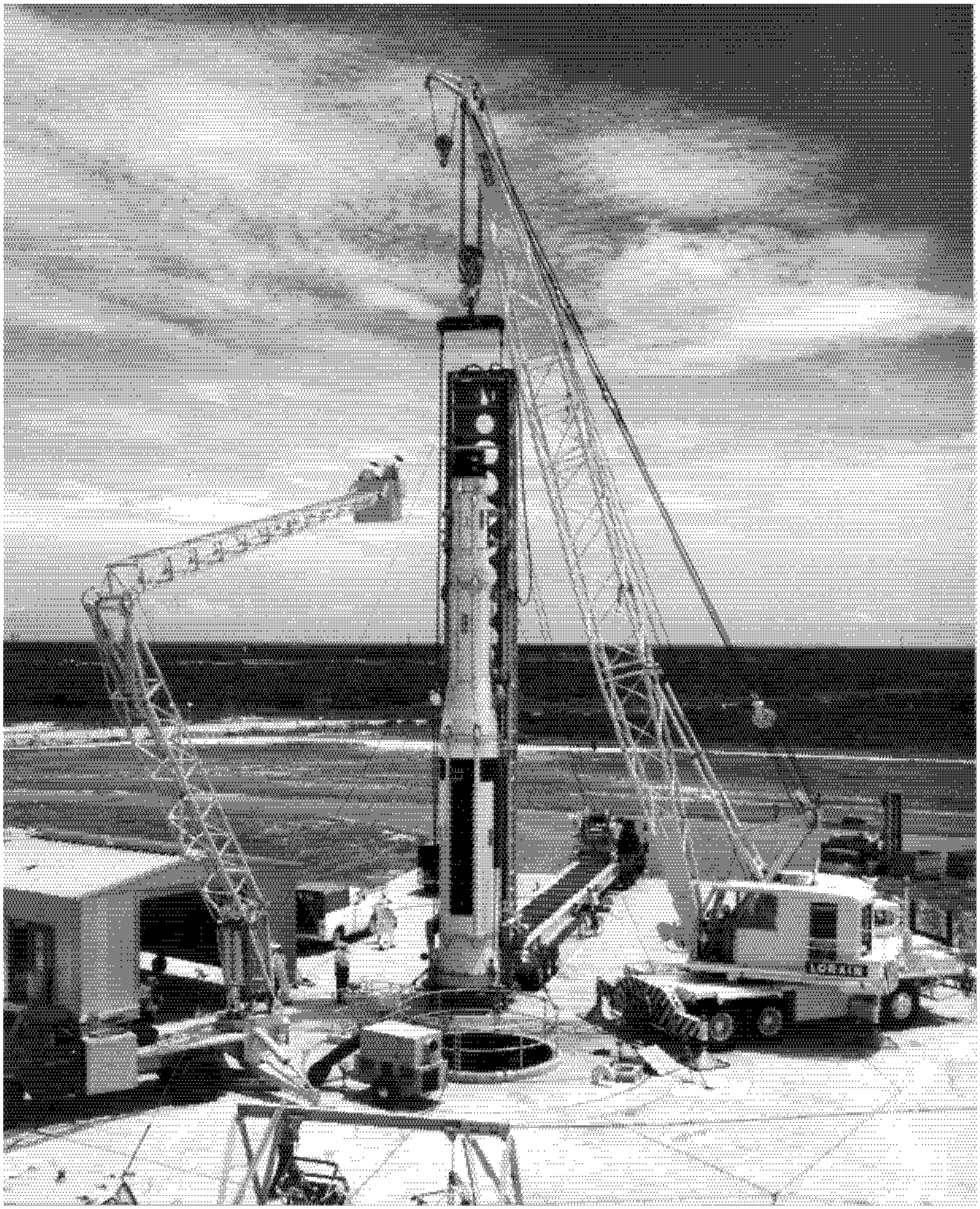


Figure 31. Minuteman I lifted from transporter/erector for lowering into silo (NARA).

Figure 32. Nose cone being positioned on Minuteman I missile on launch pad, 1961 (NARA).

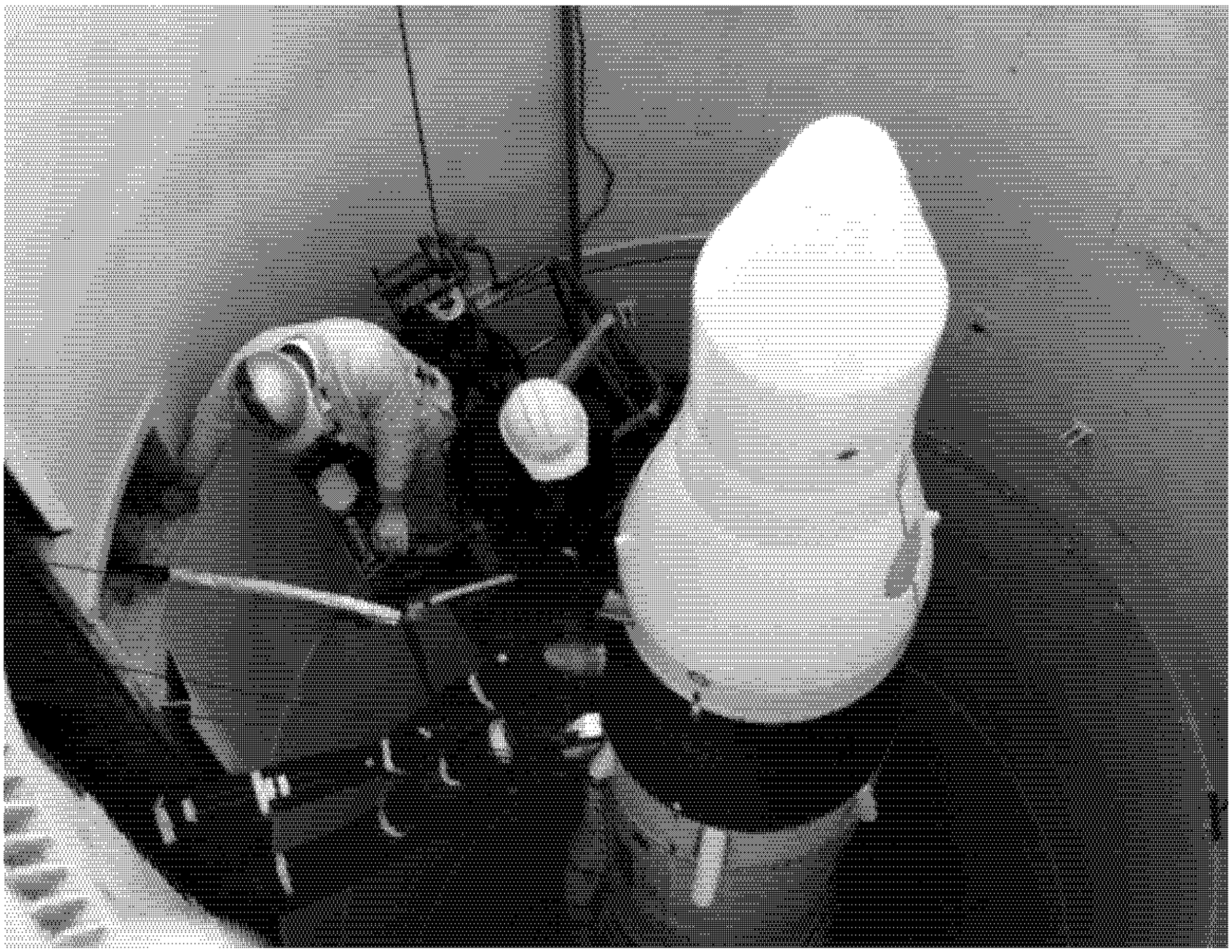


Figure 33. Boeing technicians preparing Minuteman I missile in silo, 19 November 1962 (NARA).

Figure 34. New transporter/erector for Minuteman, 1961 (NARA).

Figure 35. Transporter/erector in use for Minuteman III at silo 32B, 19 May 1970 (NARA).

Figure 36. Boeing technicians await count-down for the first Minuteman I launch, blockhouse interior, 1 February 1961 (NARA). The seated man on the left is chief of the Minuteman Weapons Branch; on his right is head of the Cape Canaveral Boeing team.

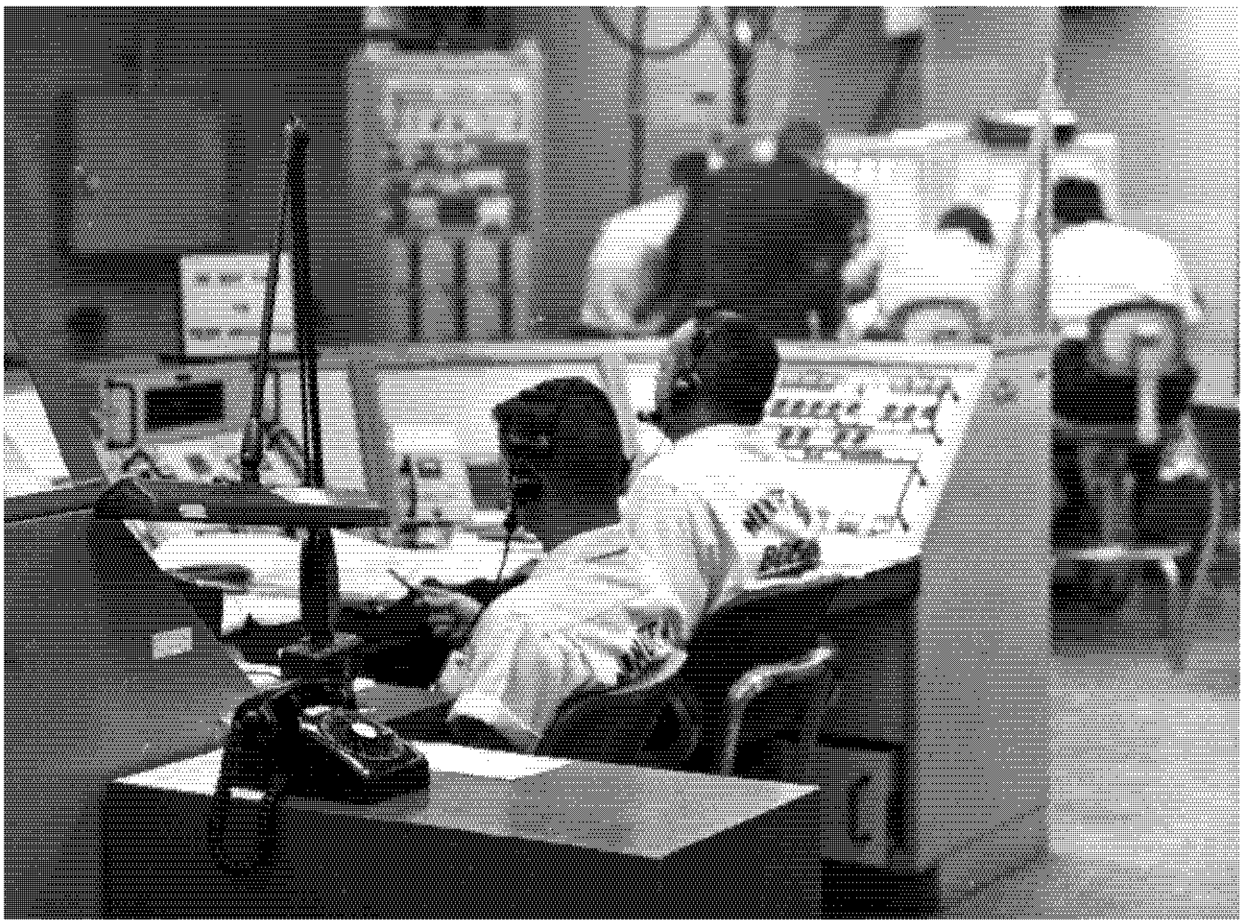


Figure 37. Boeing technicians check their equipment while waiting for the count-down to the first Minuteman I launch, blockhouse interior, 1 February 1961 (NARA).

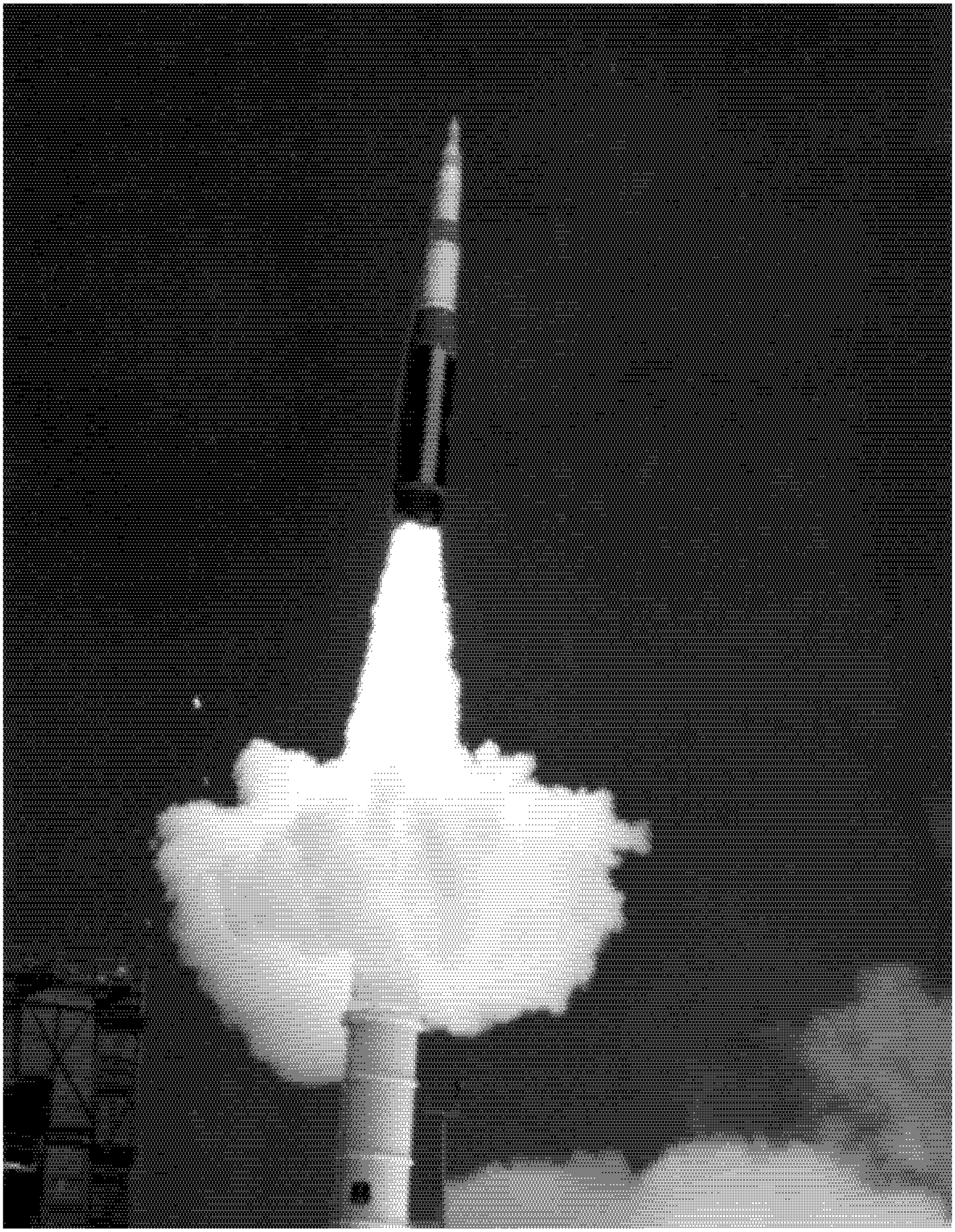


Figure 38. Final Minuteman II launch testing mobile tube, pad 31A, 14 March 1970 (NARA).

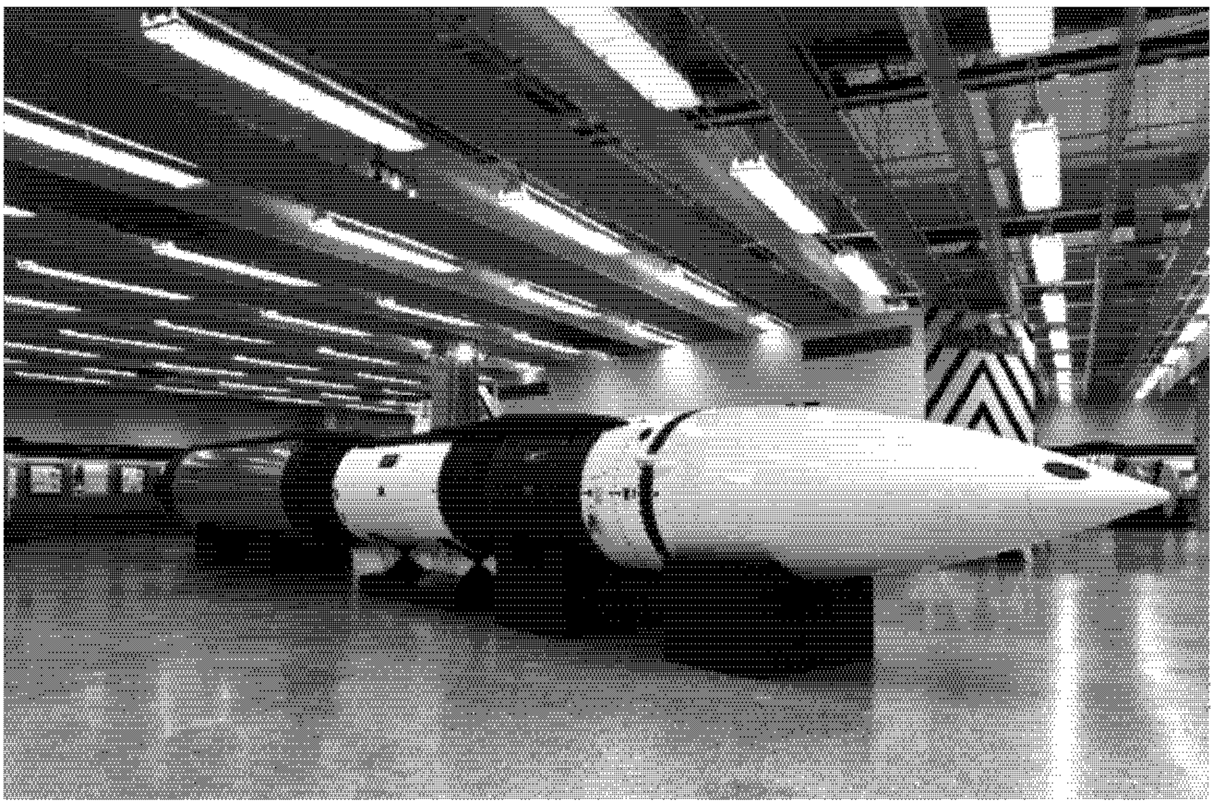


Figure 39. Mock-up of Minuteman III missile, 1968 (NARA).

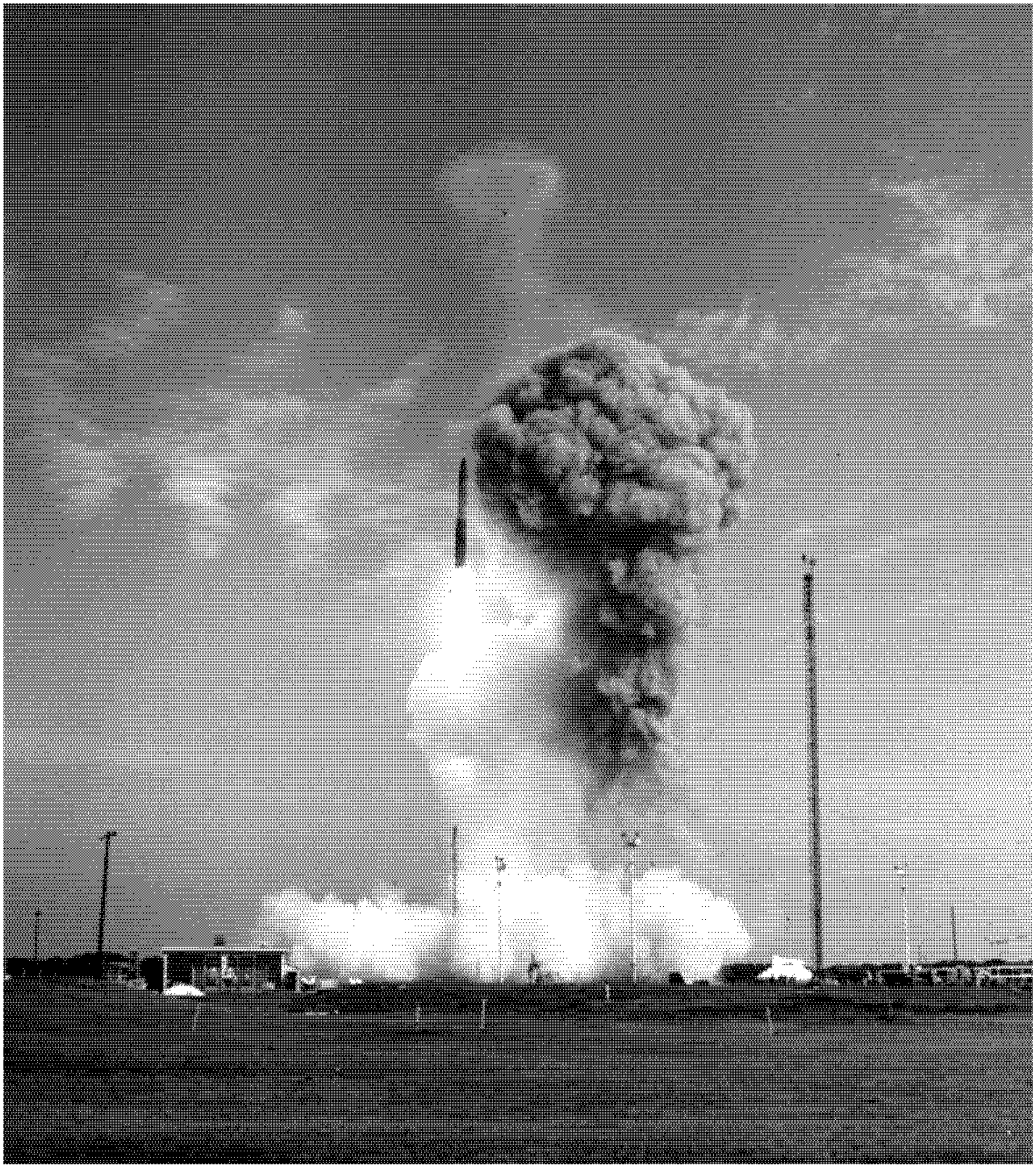


Figure 40. Final Minuteman launch (Minuteman III), pad 32B, 14 December 1970 (NARA).

Figure 41.Wide-angle view of final Minuteman launch, 14 December 1970 (NARA).

Figure 42. Navaho ramjet test pad at pad 31 (ERDC-CERL 2007).

Figure 43. Tent pads constructed near Blockhouse 32 (ERDC-CERL 2007).

Figure 44. Pad 31 firing pit covered with metal plates (ERDC-CERL 2007).

Figure 45. Pad 31 mobile service tower tracks (ERDC-CERL 2007).

Figure 46. Pad 31 showing umbilical tower, launch stand, Minuteman I, and mobile service tower (USAF).

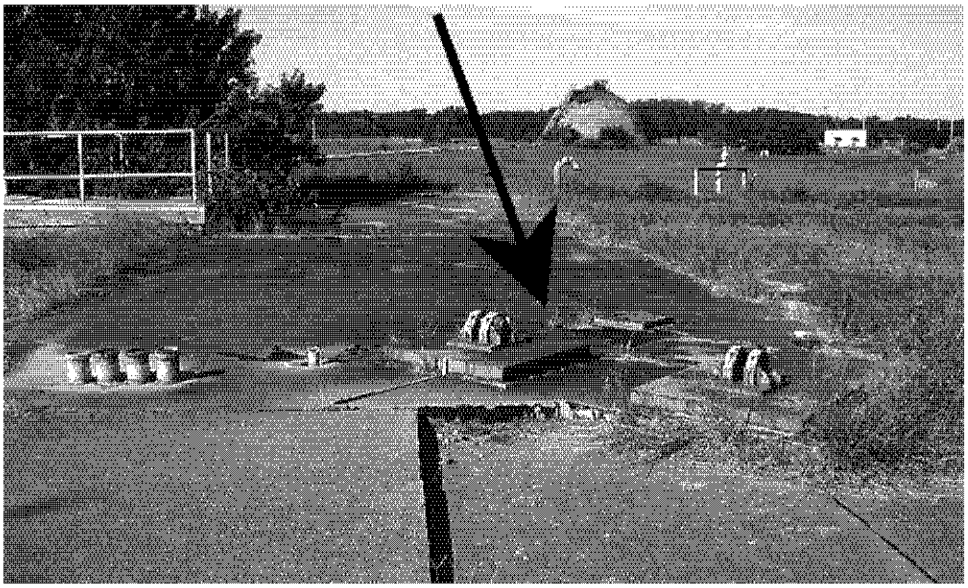


Figure 47. Pad 32 pad equipment room umbilical tower mounting (ERDC-CERL 2007).

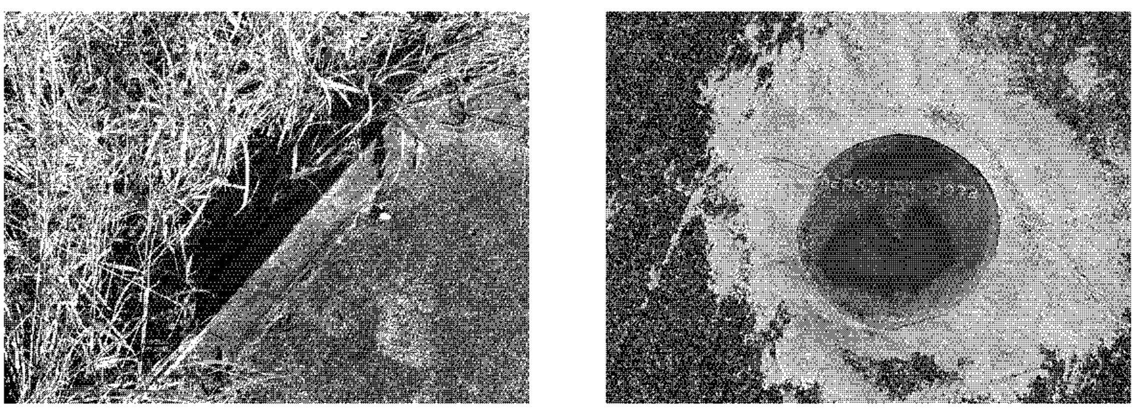
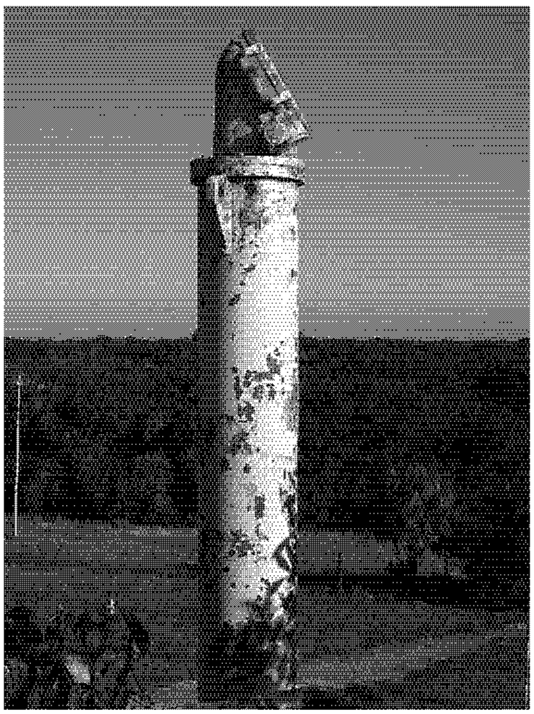


Figure 48. Edge of Alpha Draco flame deflector (left); 1972 Pershing benchmark (right) (ERDC-CERL 2007).



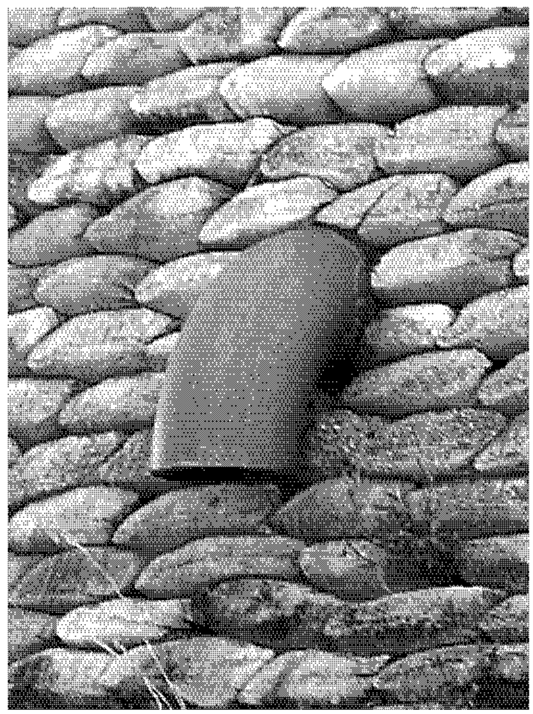


Figure 49. Blockhouse 32 periscope (left); toilet exhaust pipe (right) (ERDC-CERL 2007).

Figure 50. Blockhouse 32 upper level circular blast door (ERDC-CERL 2007).

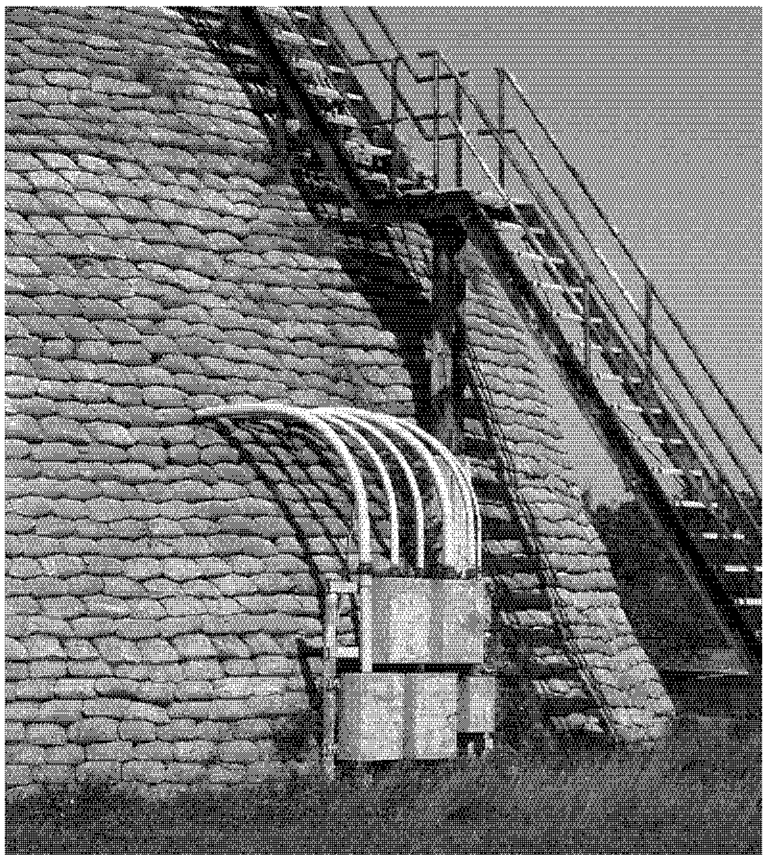


Figure 51. Blockhouse 32 electrical conduit sleeves and pull boxes (ERDC-CERL 2007).

Figure 52. Blockhouse 31 cooling tower walls (ERDC-CERL 2007).

Figure 53. Sliding doors in optical alignment building 32 (ERDC-CERL 2007).

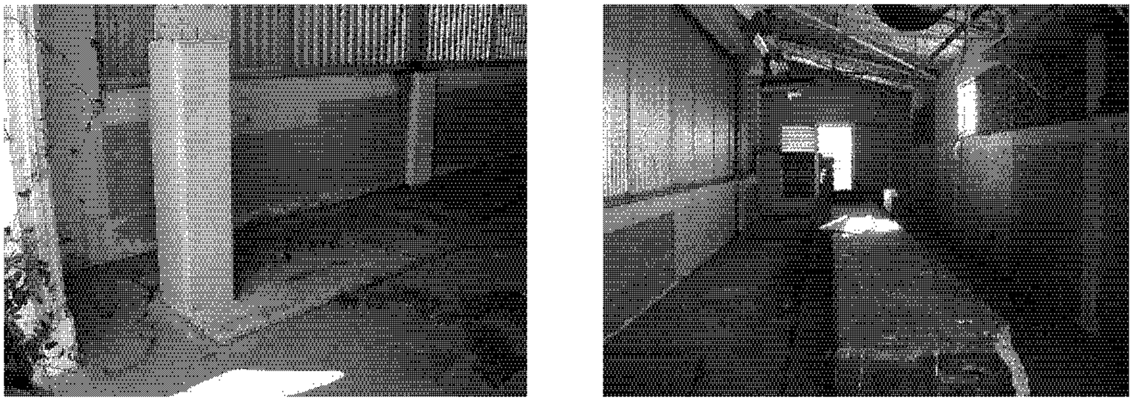


Figure 54. Optical alignment building 32 showing smaller pedestal with post (left) and larger pedestal (right) (ERDC-CERL 2007).

Figure 55. Interior of optical alignment building 32 showing roof joists and lighting (ERDC-CERL 2007).

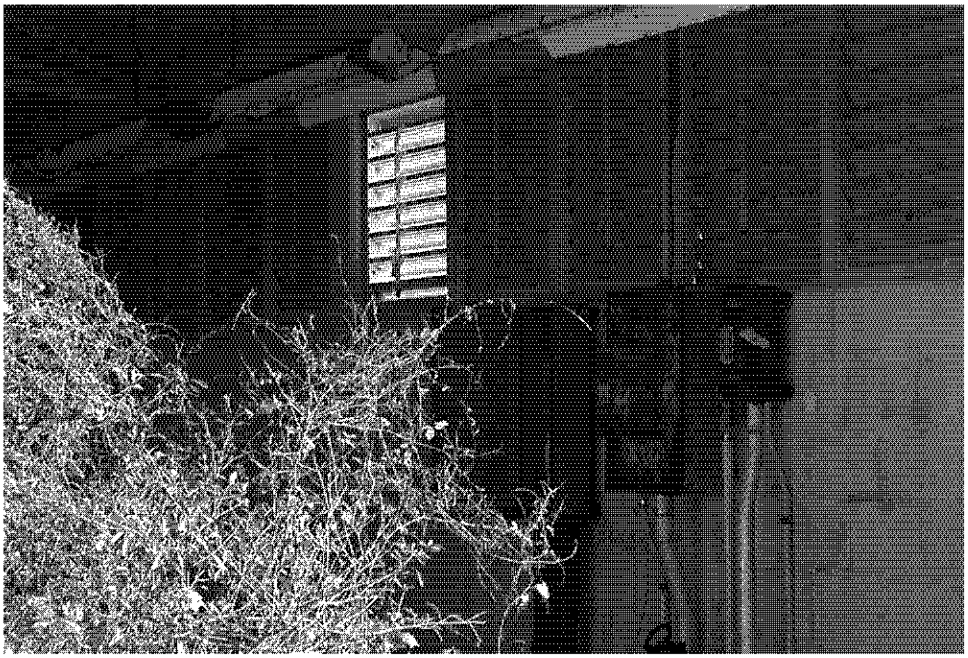
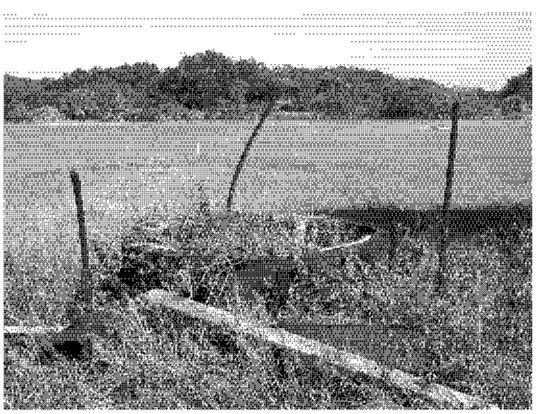


Figure 56. Interior of optical alignment building 31 showing louvered windows and electrical panels (ERDC-CERL 2007).



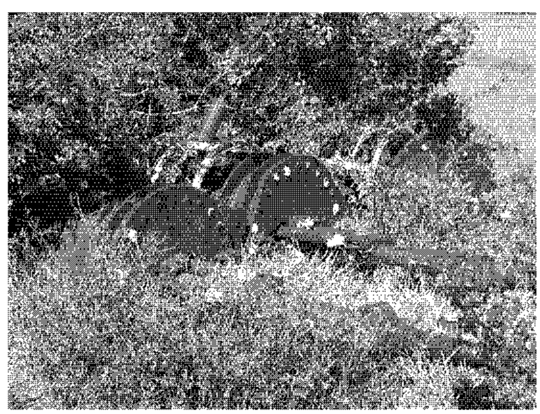


Figure 57. Silo 32B lift ring (left) and lift ring pulley mechanism (right) (ERDC-CERL).

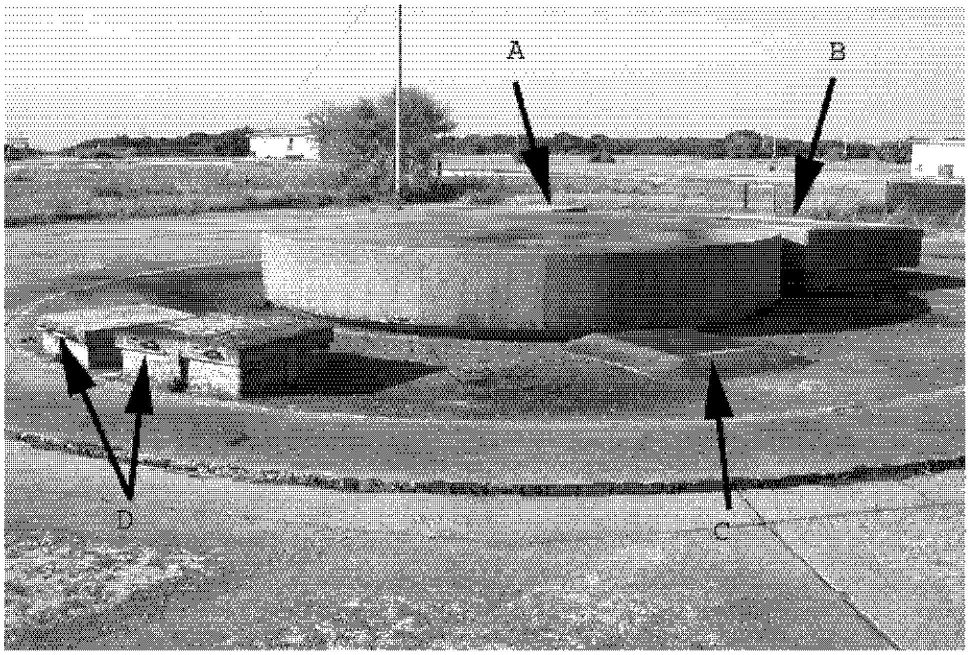
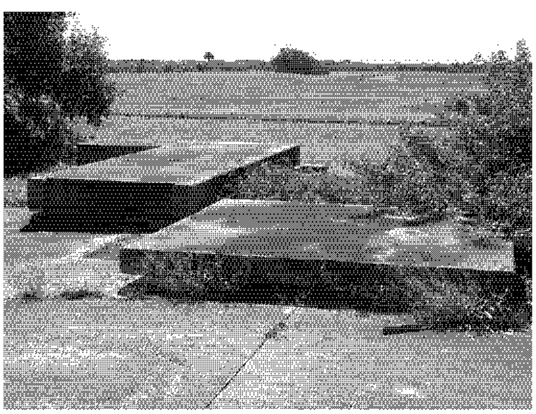


Figure 58. Silo 31B showing (A) guidance alignment notch, (B) personnel and equipment access hatch, (C) T-E jack point, and (D) junction-box openings (ERDC-CERL 2007).



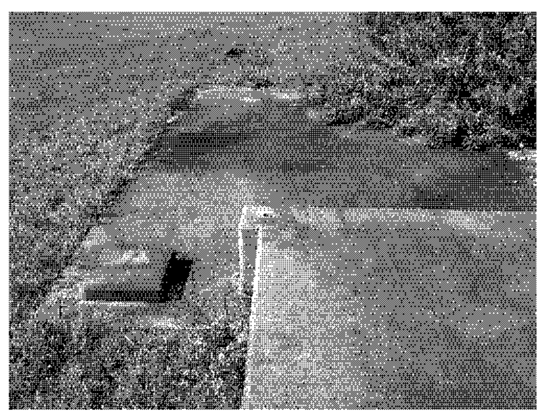


Figure 59. Removable concrete covers over Silo 32B R&D equipment room (left foreground) and subterranean staircase (left background; right foreground); concrete roof with corner exhaust vent of transformer vault (right background) (ERDC-CERL 2007).

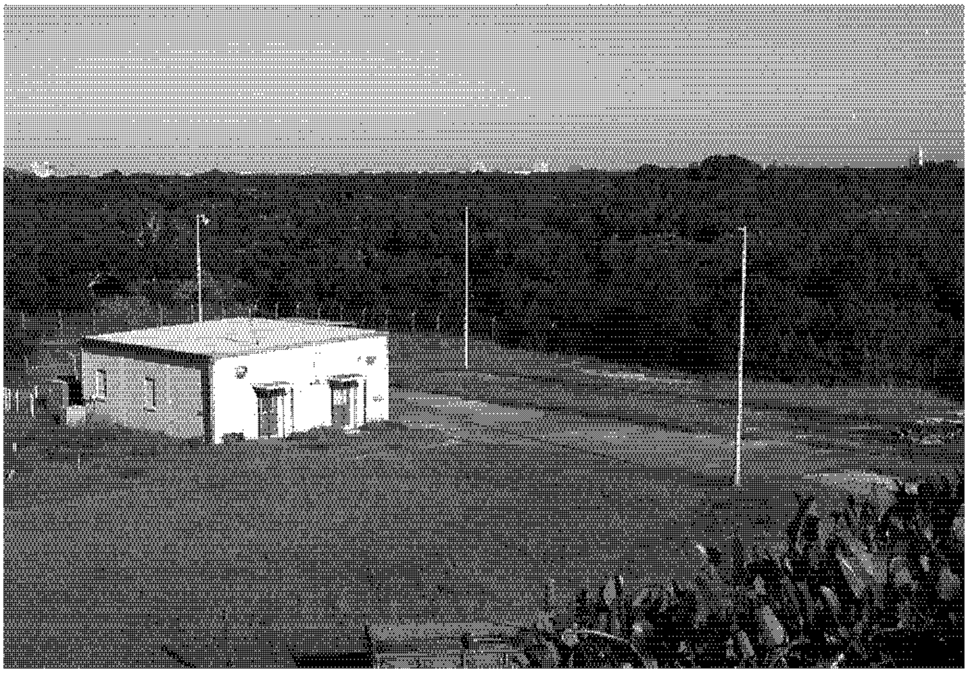


Figure 60. The MUSF support shop and its track bed (ERDC-CERL 2007).

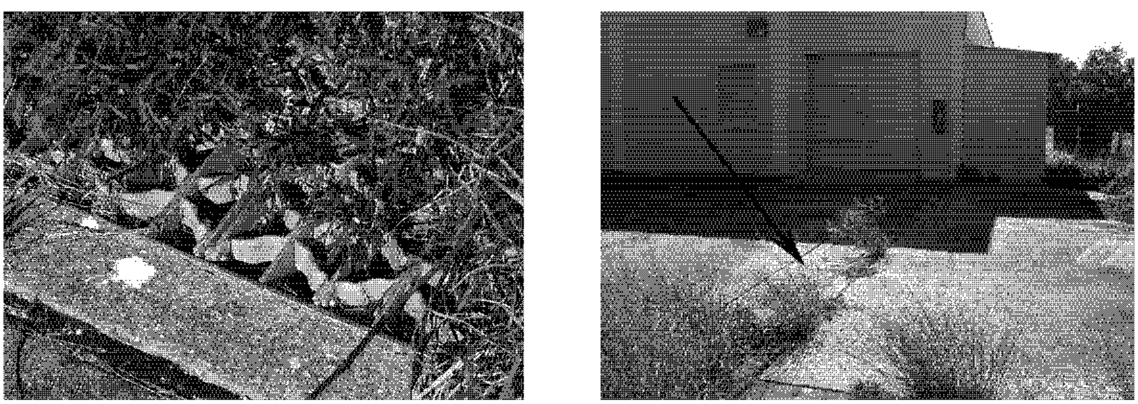


Figure 61. Riveted utility trench cover (left); north-south utility trench between MUSF support shop and track bed (right) (ERDC-CERL 2007).

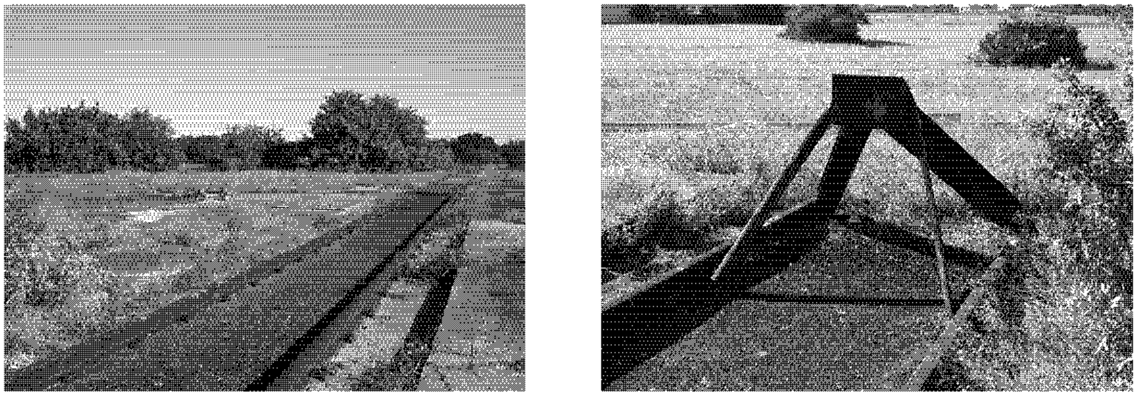


Figure 62. Pad 32 rail spur and bumper (ERDC-CERL 2007).

Figure 63. Launch support building eave and entry canopy (ERDC-CERL 2007).

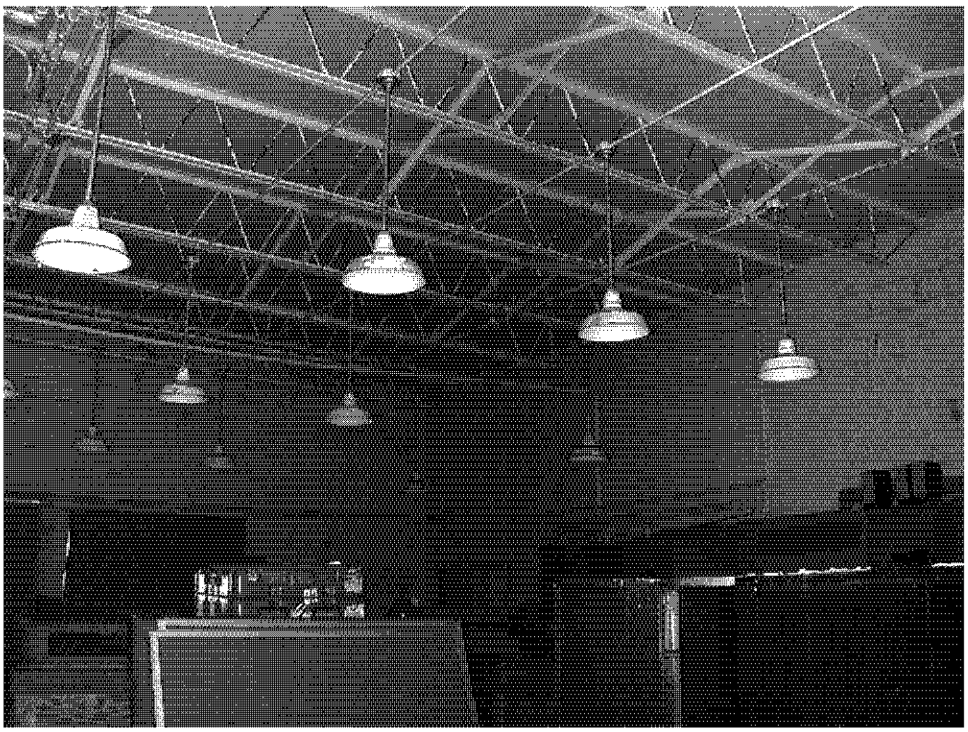


Figure 64. Launch support building store room (ERDC-CERL 2007).

Figure 65. Launch support building cooling tower walls (ERDC-CERL 2007).

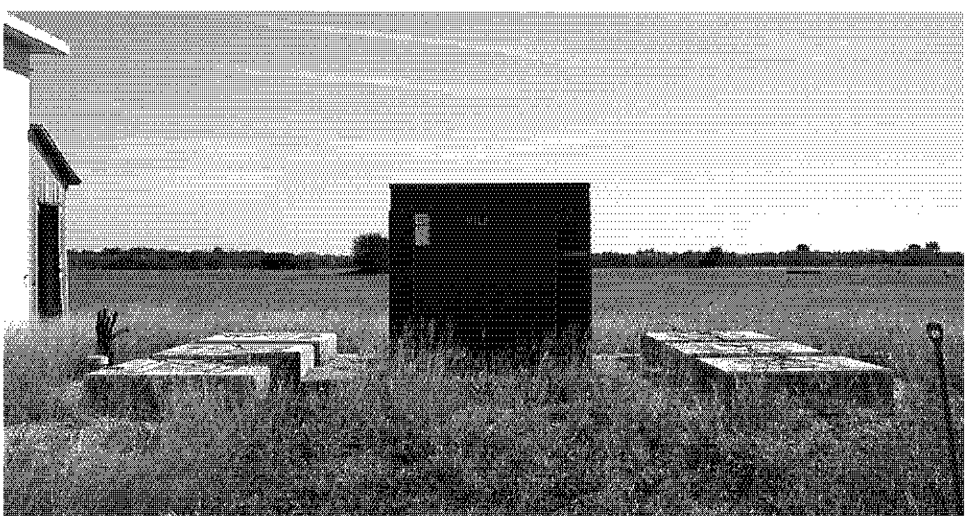


Figure 66. Launch support building transformer vault (ERDC-CERL 2007).

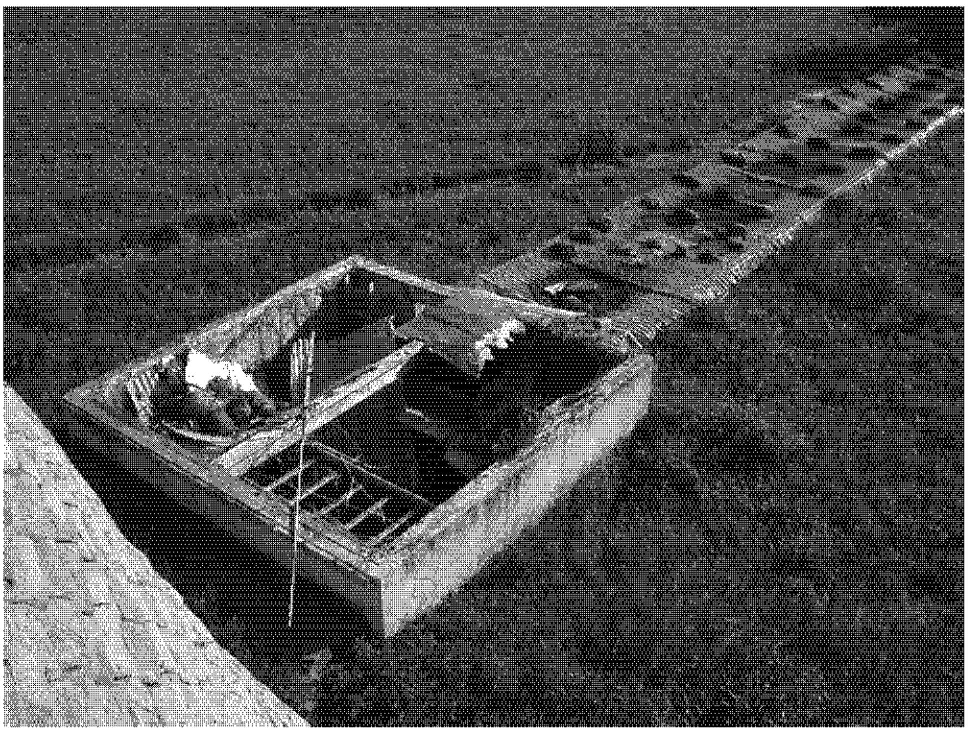


Figure 67. Cableway transition I behind blockhouse 32 (ERDC-CERL 2007).

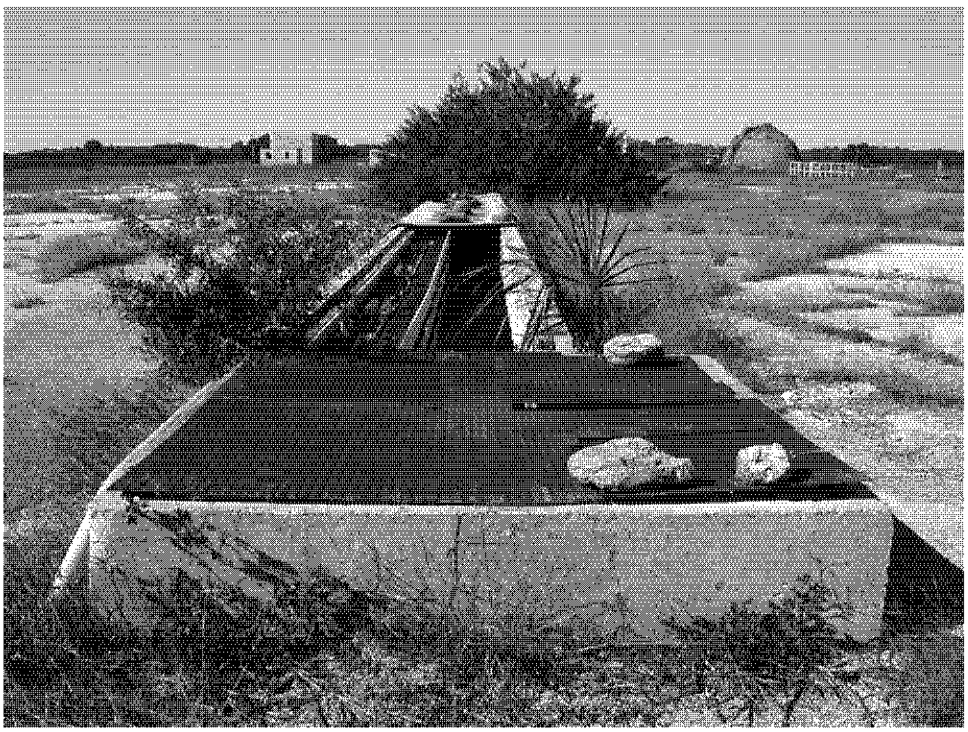


Figure 68. Cableway transition II near pad 31 equipment room (ERDC-CERL 2007).