HISTORIC AMERICAN ENGINEERING RECORD

of

SPACE LAUNCH COMPLEX 10
VANDENBERG AIR FORCE BASE, CALIFORNIA

For

30 CES/CEVP
Vandenberg Air Force Base
United States Air Force

By

US Army Engineer Research and Development Center
Construction Engineering Research Laboratory
Champaign, IL 61826

And

National Park Service
Midwest Regional Office
Omaha, NE 68102

January 2002

Introduction

Space Launch Complex 10 (SLC-10) is listed on the National Register of Historic Places and is considered a National Historic Landmark (NHL). SLC-10 was identified by the National Park Service (NPS) as one of the most endangered NHL in the United States. Emergency repairs and maintenance have been implemented and monitored by Mr. Donald J. Prichard, Director and Curator of the Vandenberg Air Force Base Space and Missile Heritage Center at SLC-10. These maintenance actions, separately and collectively, were considered "undertakings" which required State Historic Preservation Officer (SHPO) consultation. The SHPO consultation, conducted in 1995, included a long list of required repairs and maintenance actions that are still in process.

The following report contains historical, architectural, and photographic documentation to Historic American Engineering Record (HAER) Level II standards of Space Launch Complex 10 at Vandenberg Air Force Base, California. Although selected as a NHL in 1986, SLC-10 has not yet been the subject of thorough documentation. By providing historical, architectural, and photographic documentation of SLC-10, this report will serve as a valuable tool to assist Vandenberg Air Force Base in the management of one of its most important cultural resources.

This project was coordinated with Dr. James Carucci (30CES/CEVP), Architectural Historian / Cold War Specialist at Vandenberg Air Force Base. Mr. Donald J. Prichard (30SW/MU), Director and Curator of the Vandenberg Air Force Base Space and Missile Heritage Center, provided invaluable assistance by sharing his knowledge of SLC-10 activities and assisting in the collection of research materials. 2Lt. Brian Barnes and Mr. Aaron Frost also provided assistance in the collection of research materials.

United States Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) and the National Park Service, Midwest Regional Office (NPS-MRWO) personnel documented the complex during several field research trips in 2000-2001. Ms. Julie Webster, ERDC-CERL, served as Project Manager. Mr. Roy McCullough and Mr. Patrick Nowlan, Project Historians, researched and prepared the historical overview of Vandenberg Air Force Base and the history of Space Launch Complex 10. Ms. Sheila McCarthy, NPS-MWRO Project Manager and Architect, prepared the architectural description of the complex. Mr. Martin Stupich produced the current condition large format archival photographs.

Historical Documentation

Historical research focused on the acquisition and interpretation of primary documents relating to the Air Force’s mission, as well as the mission and construction history of SLC-10. Research and documentation procedures followed the standards established in the National Park Service HAER Guidelines “Preparing Written Historical and Descriptive Data” (May 1985).

Sources consulted and referenced include Real Property Records, engineering drawings, and reports located at Vandenberg Air Force Base, as well as historic records, newspaper clippings, and historic photographs from the Vandenberg Air Force Base Space and Missile Heritage Center and other archives.

Photographic Documentation

Photographic documentation for this project included representative current condition exterior and interior large-format (4” x 5”) archival photographs of the individual facilities at SLC-10 as well as archival quality photographs of existing engineering drawings.

VANDENBERG AIR FORCE BASE, SPACE LAUNCH COMPLEX 10
North end of Aero Road
Lompoc
Santa Barbara County
California

HAER No. CA-296

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

PHOTOGRAPHS

Historic American Engineering Record
Pacific Great Basin Support Office
National Park Service
Department of the Interior
Oakland, CA 94607

HISTORIC AMERICAN ENGINEERING RECORD

VANDENBERG AIR FORCE BASE
SPACE LAUNCH COMPLEX 10
HAER No. CA-296

Location:	Vandenberg Air Force Base Space Launch Complex 10 (SLC-10) North end of Aero Road Santa Barbara County Lompoc California USGS Casmalia Quadrangle, Universal Transverse Mercator Coordinates: Zone 10 718045/3849720 717180/3849040 718200/3849160 717040/3849190 717630/3849000 717220/3849620 717460/3849820
Date of Construction:	1958-1959
Engineer:	Douglas Aircraft Company
Present Owner:	United States Air Force
Present Use:	Vandenberg Air Force Base Space and Missile Heritage Center
Significance:	SLC-10 was nominated as a National Historic Landmark in 1986 as the "best surviving example of a launch complex built in the 1950s at the beginning of the American effort to explore space." SLC-10 is significant due to its direct contributions during the Cold War period to: 1) the Thor Intermediate-Range Ballistic Missile (IRBM) training program and subsequent Thor IRBM deployment to the United Kingdom under "Project Emily"; 2) Anti-satellite testing and training activities under Program 437; and 3) the Defense Meteorological Satellite Program.
Report Prepared by:	Roy McCullough and Patrick Nowlan US Army Engineer Research and Development Center Construction Engineering Research Laboratory Champaign, IL 61826 Sheila McCarthy, RA National Park Service, Midwest Regional Office Omaha, NE 68102
Date:	January 2002

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HISTORICAL OVERVIEW

Introduction

The first decades of the Cold War were characterized by a headlong race to research and develop new technologies and weapons. Among the most significant directions of this research were the development of weapons systems capable of delivering nuclear warheads and the development of launch vehicles to be used in the planned explorations of the new frontier of space. Vandenberg Air Force Base (VAFB) played a critical role in both these efforts, serving as a testing and training ground for the new weapon systems and as the launch site for space probes, and meteorological and military reconnaissance satellites. Space Launch Complex 10 (SLC-10) at VAFB played a key role in these developments by making significant contributions to the development of the Thor IRBM and to the early United States satellite and anti-satellite (AST) weapons programs.

This Historical Overview begins with a general discussion of the Cold War and the various research programs supported by VAFB. It continues with a discussion of the development of the Thor IRBM and its subsequent use as a booster in the United States space program. The treatment concludes with an examination of the important role played by Space Launch Complex 10 in these developments.

THE COLD WAR AND VANDENBERG AIR FORCE BASE

The Cold War[1]

With the end of World War II, relations between the Soviet Union and the West quickly deteriorated. Tensions between the Soviet Union and the United States reached a critical point in 1948-49 when the Soviet Union blocked access to West Berlin. A massive airlift campaign by the United States prevented war, but the incident revealed the strengths and weaknesses of both countries. The Soviets held a substantial military advantage in conventional forces while the United States was the sole possessor of the atomic bomb. Leaders in the United States, faced with post-war budgetary restrictions, soon came to view nuclear weapons as a relatively inexpensive and politically acceptable means to offset any Soviet advantage in conventional forces. Consequently, the United States began producing smaller, more powerful nuclear bombs while at the same time dramatically reducing its defense budget.

The nuclear policy of the United States in the 1950s and 1960s was greatly affected by a number of developments. The first was the Soviet detonation of a nuclear bomb in August 1949. This event ended the United States' nuclear monopoly and provided the impetus for the United States to develop the more powerful hydrogen bomb. Only a few months after the Soviet detonation, Mao Zadong's Red Army defeated the forces of Chiang Kai-shek, the United States' long time ally in China. Mao established the People's Republic of China the following year. When the Soviets consolidated their alliance with the Chinese, it appeared as if 500 million people had joined the enemy camp. These events led to a reassessment of United States defense policies.

A report prepared by the National Security Council (NSC), known as NSC-68, exerted a profound influence on this reassessment. NSC-68 portrayed the Soviet Union as a dangerous opponent, now armed with nuclear weapons and determined to achieve world domination. The report warned that the Soviet Union could have as many as 200 atomic bombs by 1954 and urged an immediate build-up of United States nuclear and conventional forces. The anxiety generated by the NSC-68 report was reinforced by the suspicion that the 1950 invasion of South Korea by North Korea was undertaken with Soviet approval. Fearing that the Korean development might be a prelude to similar action in Europe, Congress drastically increased the United States (US) defense budget.

While the US-dominated United Nation forces fought in Korea, United States efforts to develop a hydrogen bomb proceeded rapidly. American scientists detonated the world's first thermonuclear device at Eniwetok Atoll in November 1952, paving the way for the development of the hydrogen bomb. The explosion was 600 times more powerful than the bomb dropped on Hiroshima. For the moment, the nuclear balance shifted back in favor of the United States.

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[1]Much of the material in Part I has been adapted from the history provided in *Cold War Properties Evaluation - Phase I: Inventory and Evaluation of Launch Complexes and Related Facilities at Vandenberg Air Force Base, California* , (USACERL, 1996) by Sheila McCarthy, Patrick Nowlan and Roy McCullough.

Estimates suggested that only forty or fifty such bombs would be needed to destroy the Soviet Union.

Throughout the Cold War, however, advantages gained by either side tended to be short-lived. The Soviet Union detonated its first hydrogen bomb only ten months after the United States. With both sides now possessing the hydrogen bomb, the Cold War acquired a new, much more disturbing character. For the first time in history, two rival powers now possessed the means to destroy the entire human race.

Although both superpowers possessed the hydrogen bomb in the early 1950s, the United States maintained a strategic advantage in the form of a fleet of long-range bombers. These bombers, loaded with hydrogen bombs, could deliver their deadly payloads to Soviet targets within two hours. Soviet bombers of this period were not yet capable of threatening the United States mainland. American military planners used this to their advantage, reasoning that the best deterrent to a possible Soviet nuclear attack was the threat of a devastating retaliation visited upon targets within the Soviet Union. The Air Force Strategic Air Command (SAC) was the primary instrument for this policy of "massive retaliation." Soviet leaders, painfully aware of the American strategic advantage, initiated a massive military production campaign aimed at narrowing the strategic gap. It was not long before the Soviet Union was producing long-range bombers capable of reaching mainland United States targets with nuclear bombs.

Concurrent with the effort to produce a fleet of long-range bombers, the Soviet Union also began to invest heavily in the development of long-range missiles. By the mid-1950s, the Soviet's long-range missile program began to pull ahead of the United States' efforts. In August 1957, the Soviets announced the launching of a multi-stage long-range ballistic missile that had reached an "unprecedented altitude" and claimed that this accomplishment would "make it possible to reach remote areas without resorting to a strategic air force."[2] Further proof of the advanced state of the Soviet missile program came on 4 October 1957 when one of their rockets placed the world's first man-made satellite, Sputnik, into orbit (Figure 1). The Soviets quickly followed this launch with an even more impressive launch. In

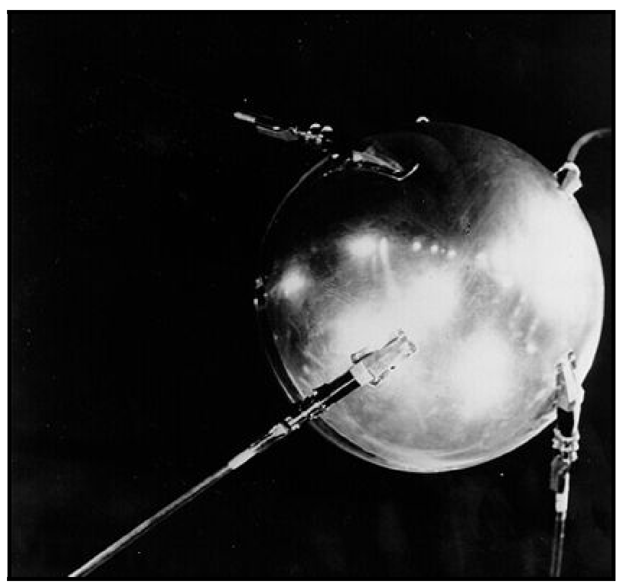

Figure 1: Soviet Sputnik Satellite

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[2]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.

November 1957, a Soviet rocket placed the 1,120-pound Sputnik 2 satellite, carrying a live dog, into orbit. This launch had tremendous strategic implications. A booster that could carry a payload that heavy into space would also be capable of delivering a nuclear bomb to targets within the United States. Leaders in both countries realized that such a development would effectively offset the US advantage in long-range bombers. The age of the missile had arrived.

Early US Long-Range Missile Program

At the time of the Soviet Sputnik launches, the United States was involved in its own long-range missile research and development efforts. These efforts began in earnest directly after World War II. Although the military experimented with some crude guided missiles during World War II, there had not been much interest in rocketry among United States military leaders until the Germans began firing their V-1 "buzz bombs" 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 the 3,500 mile-per-hour V-2. The German V weapons made it clear that missiles would revolutionize the future of warfare. Recognizing this, the different branches of the US 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 these scientists at Fort Bliss, Texas to conduct studies concerning 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 1951, the Army moved the team to the Redstone Arsenal in Huntsville, Alabama where they began to develop the Redstone missile.[3]

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. The Air Force (at that time still known as the Army Air Forces or AAF)[4] 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.[5] A fierce inter-service rivalry over control of guided missiles ensued as each service sought to define its role and mission. The ambiguous nature of guided missiles fueled the controversy.

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[3]The Army began testing its Redstone rockets at Cape Canaveral in 1953. The Redstone, with a range of approximately 300 miles and capable of carrying a nuclear warhead, was employed in West Germany by US troops in 1958 as part of the NATO arsenal. It was later employed as a booster during the nation's manned and unmanned space program.
[4]The National Security Act of 1947 divided the military services into the three separate departments of the Army, the Navy, and the Air Force.
[5]Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945-1960* (Washington, D.C.: Office of Air Force History, United States Air Force, 1990), 50-52.

Army officials, for example, claimed that ground-launched missiles were merely extensions of artillery and therefore the Army's responsibility. Air Force officials, on the other hand, claimed that missiles were simply "robot aircraft" or "pilotless aircraft" and therefore fell under the jurisdiction of the Air Force.[6]

In an attempt to clarify the roles of each service branch and to reduce duplication of effort, Secretary of Defense Louis A. Johnson initiated a review of the nation's missile programs in 1949. The review resulted in the creation of a priority list of missiles to be developed and the assignment of a separate missile test range to each service branch. More importantly, the Air Force emerged from the 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.[7]

The AAF first began funding long-range missile development studies in 1946. In January of that year, engineers from the Consolidated Vultee Aircraft Corporation (Convair) presented the AAF with two design proposals for a missile capable of carrying a 5,000-pound warhead over a range of 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 in April 1946.[8] Headed by the Belgian-born engineer Karel Bossart, the Convair effort became known as Project MX-774. In order to collect the necessary data, Bossart gained permission to build ten 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 flight test three vehicles. These flight tests, conducted at the White Sands Proving Grounds in New Mexico between November 1947 and May 1948, validated Bossart's design changes.[9] Later ballistic missile programs benefited from information gained during this project.

As a result of the drastic reductions in defense spending in the late 1940s, the Air Force was forced 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 grounds that this type could become operational sooner than the expected ten-year timeframe necessary for the development of an operational ballistic missile.[10] In the late 1940s and early 1950s, the Air Force began to invest heavily in the development of the Snark and Navajo cruise missiles.

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[6]Ibid., 82-93.
[7]Ibid., 55-56.
[8]Ibid., 45.
[9]Ibid., 48-49.
[10]Ibid., 48.

In the early 1950s, the Korean War prompted increased military spending and the Air Force began to fund another long-range missile study. This study, undertaken by Convair and designated Project MX-1593, later became known as Project Atlas. The Air Force began funding further studies of the Atlas ballistic missile design in 1952. This funding, however, remained at a very low level relative to the funds allocated to the Snark and Navajo cruise missile programs.[11]

When the United States' armed forces began developing long-range missiles after World War II, it soon became apparent that the nation's existing ranges were inadequate to support missile test flights that could at times extend for up to several thousand miles. Realizing this, in 1946 the Department of Defense (DoD) began searching for an adequate site for a long-range missile proving ground. A special selection committee eventually chose the Cape Canaveral area in Florida. The DoD established Cape Canaveral as a joint services long-range missile research and development facility in 1950. Cape Canaveral became one component of a missile test range that included administrative headquarters at nearby Patrick Air Force Base, launch sites at Cape Canaveral, and downrange tracking facilities extending out into the Atlantic Ocean. The Air Force, in charge of developing and administering the range, began extensive testing of its cruise type missiles at Cape Canaveral in 1950.

Several important developments in the early 1950s significantly altered the United States' approach to long-range missile development. Soon after the US detonated its first thermonuclear device in 1952, the Atomic Energy Commission (AEC) predicted that the production of smaller nuclear warheads with tremendous destructive potential would soon be feasible. Smaller, 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 the Soviet Union was making significant progress in the development of long-range missiles and in the development of its own thermonuclear warheads, prompted a reexamination of US strategic missile programs. In 1953, the Air Force convened a panel of leading scientists, later known as the Teapot Committee, to examine the Snark, Navajo and Atlas missile programs. The committee's report, submitted in February 1954, contained recommendations for relaxing performance requirements for long-range missiles (based on the new, lightweight, high yield thermonuclear weapons) and accelerating the development of the Atlas Intercontinental Ballistic Missile (ICBM).[12] These recommendations received the approval and support of high-ranking civilian and military leaders during the following months. Air Force officials, especially Trevor Gardner, Special Assistant for Research and Development, began to campaign vigorously to convince Congress and the President of the importance and urgency of ICBM development. These efforts paid off when President Eisenhower assigned the highest national priority to the ICBM development program in 1955. Eisenhower also supported the Air Force in its bid to gain control of ICBM development. Although budget cuts by the Eisenhower administration in 1956-57 temporarily slowed progress towards an operational ballistic missile, the launch of the Sputnik satellites in October and November of 1957 again focused attention on the US ICBM

[11]Ibid., 241.
[12]Ibid., 99-103.

program. Congress reacted by restoring national priority to the ICBM program and by increasing funds for ICBM development.[13]

Air Force Ballistic Missile Development

Air Force officials hoped to achieve operational capability with the Atlas ICBM by the end of the decade. As a hedge against failure in the Atlas program, however, in 1955 the Air Force initiated a second ICBM development program, designated Titan. By 1958, the Air Force began funding the development of yet another ICBM, the Minuteman. The Minuteman ICBM was to be a smaller, more effective, three-stage, solid-fueled ICBM that would be relatively "cheap" to produce.

As the pace of the Air Force ICBM program quickened, intelligence reports indicated that the Soviet Union would likely have a dangerous number of ICBMs armed with nuclear warheads operational by 1960. Fearing the US would not be ready to match that threat, DoD officials decided that an IRBM should be developed and deployed to 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 period of 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, and in direct competition with each other.[14]

In order to speed progress in its ballistic missile programs, the Air Force replaced the conventional sequential weapon system development pattern with an approach later known as "concurrency." The liquid-fueled Atlas, Titan and Thor missiles all would share many common components thereby reducing costs and speeding development time. Concurrency allowed Air Force personnel and contractors to develop and test different missile systems and different models of the same missile within a very narrow and overlapping timeframe. Research, development, testing, and production all proceeded simultaneously. The Air Force also worked towards readying missile sites, equipment, and crews concurrently with the development of the missiles.[15] As described by Brigadier General Harry E. Goldsworthy, then Director of Production and Programming, Deputy Chief of Staff, Systems and Logistics, Headquarters, United States Air Force, the concept of concurrency represented "a departure from the time proven sequence of development, test, and then production through a drastic compression of that cycle so that the basic steps in weapon system acquisition were done concurrently rather than sequentially."[16] Research projects conducted under this new concept pioneered not only new weapon systems,

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[13]Ibid., 133-135.
[14]Ibid., 143-148. The IRBM programs were assigned equal priority with the ICBM program in January 1956.
[15]Ibid., 122-23, 201.
[16]This discussion of the concurrency concept can be found in the Senate report by the Preparedness Investigating Subcommittee of the Committee on Armed Services. *Series of Explosions of Air Force's Atlas F Intercontinental Ballistic Missiles*, 88th Cong., 2nd Sess., 1964, 4.

but also a completely new means of acquiring those systems.[17] This same concept of concurrency also determined the approach to the construction of launch facilities. In practice, this meant their construction "had to be initiated before the first missiles had ever reached the test pads."[18]

As might be expected, this approach resulted in a number of difficulties for the construction engineers. Since the concept of concurrency "calls for the design and development of system support equipment and facilities in parallel with that of the missile", this meant the engineers often were "designing at best for an unproven element and at worst for an unknown element." [19] As Goldsworthy pointed out, the engineers may, for example, "have to design and build a Blockhouse before the quantity or configuration of the equipment that will have to go onto it is known."[20] As a result, the engineers were constantly required to change their construction plans to correspond with new and frequent developments in missile technology.

When the Atlas and Thor programs received top national priority, the Air Force initiated the construction of launch complexes at Cape Canaveral in preparation for the research and development portion of those programs (Figure 2). As research and development facilities, the complexes constructed at Cape Canaveral did not resemble the operational launch complexes that would be employed at field missile bases. Operational launch facilities needed to be less vulnerable to enemy attack while at the same time allowing for a quick launch reaction time. Since research and development facilities were not designed for this purpose, the Air Force began to search for a site that could serve as a testing base where missiles and their supporting ground equipment could be developed and tested under operational conditions. The Air Force also wanted a base where missile combat and maintenance crews could be trained. A special site selection board evaluated nearly 200 sites and, in June 1956, recommended Camp Cooke, California.[21]

[17]Ibid.
[18]Ibid.
[19]Ibid.
[20]Ibid.
[21]During World War II and the Korean War, Camp Cooke saw service as a training facility for a wide variety of units, including armored, infantry, anti-aircraft artillery, combat engineer and ordnance units. The Army deactivated Camp Cooke in 1953 with the end of fighting in Korea.

The Establishment of Vandenberg Air Force Base

Camp Cooke was an ideal location for an operational missile testing installation. Its advantages included its size, remoteness, year-round fair weather, its access to an ocean for use as a test range, its proximity to the aerospace industry of southern California, and its existing military infrastructure.[22] Camp Cooke also had another important feature. Its unique geographic situation is the only location in the United States that offers a direct, safe flight path for polar-orbiting satellites. This had important implications for the United States' military space program, as most surveillance and reconnaissance satellites require a polar flight path to provide optimum coverage of the earth.

Figure 2: Aerial View of "Missile Row" at Cape Canaveral, FL

In 1957, the Secretary of Defense directed the Army to transfer the northern 65,000 acres of Camp Cooke to the Air Force. The Air Force subsequently redesignated Camp Cooke as Cooke Air Force Base. The primary mission of this new West Coast missile facility was to provide training for ballistic missile units, to support operational weapon system testing and to serve as a temporary operational ICBM base until others became operational. As a secondary mission, the installation also supported space launches.[23]

The Air Force's Air Research and Development Command (ARDC) and SAC shared responsibility for conducting ballistic missile and space launches. ARDC, later known as Air Force Systems Command (AFSC), initially managed Cooke Air Force Base. ARDC established the 392nd Air Base Group in April 1957. In the following months, the Air Force activated the 704th Strategic Missile Wing and 1st Missile Division and assigned them to Cooke Air Force Base. The 1st Missile Division, later renamed the 1st Aerospace Division or "1 Strad", was responsible for training missile launch crews, supporting test launches, and maintaining tactical ballistic missile capabilities. When SAC took over as base host in January 1958, it acquired the three ARDC base organizations. Later that year, the Air Force Ballistic Missile Division (AFBMD), a division of ARDC, established a field office at Cooke Air Force Base. The Air

[22]Versar, Inc., *A Historical Significance Assessment and Effects Determination of Space Launch Complex 3. Vandenberg Air Force Base, California* (Columbia, Maryland: August, 1992), 3-12.
[23]William S. Reed, "Vandenberg Trains USAF Missile Crews," *Aviation Week.* 26 October 1959, 69.

Force Ballistic Missile Division (AFBMD) eventually evolved into the 6565th Test Wing (Ballistic Missiles and Space Systems). The 6565th Test Wing supported ballistic missile test launches and the space program at the installation.[24]

Groundbreaking activities at the new missile center began in May 1957 when VAFB was still known as Cooke Air Force Base. The Air Force committed over $178 million for the initial improvements to the installation. Over $120 million went towards the construction of launch complexes while more than $32 million was spent on repairs and modifications to base support buildings and an airfield.[25] Approximately $25 million was directed towards the construction of over 1800 Capehart homes to ease the severe housing shortage that developed as the base population increased.[26]

As Cooke Air Force Base prepared for its new mission, it was decided to rename the installation in honor of General Hoyt S. Vandenberg. General Vandenberg had been an early proponent of aerospace readiness and had served as the Air Force's second Chief of Staff. Since his death in 1954, the Air Force had been waiting for the opening of a base sufficiently important to bear his name.

Figure 3: Mrs. Vandenberg and her Son, Captain Hoyt S. Vandenberg Jr., at the Main Gate of Vandenberg Air Force Base (Ca. 1958)

On 5 October 5, 1958, the formal dedication ceremonies were held with over 1,400 individuals attending. The distinguished guest list included the governor of California, California Senators and Representatives from Congress, and several important

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[24]Dames & Moore, Inc., *Request for Determination of Eligibility. Atlas 576 G. Vandenberg Air Force Base, California* (Austin: Dames & Moore, Inc., 20 September 1993), 4; Jeffery Geiger, The Heritage of Vandenberg Air Force Base, (Vandenberg Air Force Base, California: 30th Space Wing History Office, n.d.).

[25] Prior to the construction of this airfield in 1959, all Vandenberg-related flight activities were forced to use the airport facilities in Santa Maria. See the "History of the 704th Strategic Missile Wing (ICBM) (1st Missile Division) for the period of 1 January through 31 December 1958," prepared by the Historical Division of the Office of Information, 1st Missile Division (15 May 1959). Copy on file at the Air Force Historical Research Agency, Maxwell Air Force Base.

[26]Versar, 3-13.

personages from the US Air Force, including the Commander of the Ballistic Missile Division, Major General Bernard Schriever. The President and Vice President were extended invitations to the event while the Secretary of the Air Force and the Chairman of the Joint Chiefs of Staff sent messages to be read at the dedication ceremony. The late General's wife, son and grandson also attended the ceremony with Mrs. Vandenberg presenting a portrait of her husband to the installation newly named in his honor (Figure 3). A Thor and an Atlas missile were placed next to the reviewing stand to reinforce the fact that the ceremony marked the dedication of SAC's first missile base. A performance by an acrobatic team in F-100 fighters and a flyover by a formation of B-52 bombers were intended to be part of the ceremony but heavy cloud cover forced the cancellation of the aerial aspects of the day.[27]

One year later, in 1958, the Army transferred the remaining southern portion of the former Camp Cooke, including Point Arguello, to the Navy. The Navy christened the new installation the Naval Missile Facility at Point Arguello (NMFPA). This new acquisition led to the establishment of the Navy-controlled Pacific Missile Range. Planned as the nation's largest range, the Pacific Missile Range stretched for 500 miles along the California coast and extended out to sea for 250 miles. The Naval Air Missile Test Center, located at Point Mugu, controlled both the Pacific Missile Range and the NMFPA. The Navy began conducting Terrier surface-to-air missile training exercises on slopes located in the northwest corner of the NMFPA in July 1958. While the Terrier training proceeded, the Navy awarded construction contracts in 1958 and 1959 for a radiosonde launching facility, a two-pad launch complex for the AEC, and an Air Force Atlas space booster launch complex (later designated SLC-3). The Navy awarded three more construction contracts in 1961 for an additional Air Force Atlas booster complex (later designated SLC-4), a probe launch complex (PALC-C), and a complex for the National Aeronautics and Space Administration's (NASA) Scout launch vehicle (later designated SLC-5).[28]

Although administered independently, the NMFPA and VAFB cooperated in many areas of missile research. The Air Force conducted extensive space launch programs at Point Arguello (from Navy-built complexes) while NMFPA personnel had access to many of the facilities at VAFB, including the housing resources.[29] In addition, the Navy provided command and control for all launches from both the NMFPA and VAFB until 1964.

In November 1963, the DoD announced plans to consolidate ICBM and satellite test ranges under the single management of the Air Force. As a result, the DoD ordered the Navy to transfer the real estate and logistical support functions of the NMFPA to the Air Force. When the Navy

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[27] The details relating to the dedication ceremony can be found in various letters and memos recently acquired by the Vandenberg Air Force Base Space and Missile Heritage Center.

[28] NASA opened a test facility at the NMFPA in 1960.

[29] Warren S. Howard, *History of the 1st Strategic Aerospace Division and Vandenberg Air Force Base, 1962-63*, (Vandenberg Air Force Base, California: Historical Division, Directorate of Information, 1st Strategic Aerospace Division, February 1964), 21.

completed the transfer in July 1964, the former NMFPA was absorbed into VAFB and became known as South VAFB. At the time of the transfer, the Air Force also assumed responsibility for the Pacific Missile Range, renaming it the Western Test Range.[30] As a result of this transfer, the size of VAFB increased by 20,000 acres.

Before the acquisition of the former NMFPA, the Corps of Engineers had been engaged in steady construction activity on what would become known as North VAFB. Having already gained valuable experience in missile base construction at Cape Canaveral, the Corps of Engineers became the supervising construction agency responsible for converting the former Camp Cooke into a modern missile and space center. The Corps of Engineers worked closely with the AFBMD at Inglewood, California, and with civilian contractors, to rapidly complete VAFB's missile and support facilities.[31] Initial construction at what is now referred to as North VAFB included seven Thor pads and six Atlas pads. By mid-1966, the Corps of Engineers had overseen the construction of eleven Atlas pads, four Titan I silos, three Titan II silos, fourteen Minuteman silos, and two launch facilities for Bomarc missiles at North VAFB.[32]

Overview of Research Programs at Vandenberg Air Force Base

The initial mission of VAFB was to produce an operational Thor weapon system and to train Thor IRBM combat crews from Great Britain's Royal Air Force (RAF).[33] The Thor program was carried out with a sense of extreme urgency as the Air Force raced to produce an operational weapon system that would temporarily offset a perceived Soviet lead in ICBM production. As the Air Force began conducting initial Thor IRBM R&D test launches at Cape Canaveral in 1957, the Corps of Engineers began construction of seven launch pads and three Blockhouses for the Thor missile near Purisima Point at VAFB. Completed in 1958, these facilities made up the complexes known today as SLC-1 (75-3), SLC-2 (75-1) and SLC-10 (75-2).

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[30]The organizational arrangement of the Western Test Range (WTR) changed several times over the years. In 1970, the WTR was inactivated and its function absorbed by the newly created Space and Missile Test Center (SAMTEC). The 6595th Aerospace Test Wing (ATW) was assigned to SAMTEC. SAMTEC and the 6595th were subsequently inactivated in 1979 with some elements of the 6595th reassigned to the newly created Western Space and Missile Center. Several other command and name changes occurred over the next few years. Today the range is known as the Western Range and is designated as the 30th Space Wing (ITT Federal Services Corporation, *Land-based Instrumentation Handbook. 30th Range Squadron*, Vandenberg Air Force Base, 1994, 1-3, 4).

[31]The Corps of Engineers was responsible for the "brick and mortar" part of the launch complexes at VAFB (e.g. the construction of gantries, silos, and other technical facilities). Individual contractors and in some cases, Air Force personnel, installed the instrumentation at new launch facilities.

[32]The Bomarc was an anti-aircraft cruise missile built by the Boeing Company. Beginning in 1966, the US Navy launched Bomarc missiles from VAFB for use as high-speed targets for surface-to-air and air-to-air missile practice off the Southern California coast.

[33] A more detailed account of the IRBM program at VAFB is provided in Part II.

The first operational Thor IRBM arrived at VAFB in August 1958. That same month, the first RAF students arrived at VAFB to begin Thor integrated weapon system training (IWST).[34] In September, the Air Force activated the 392nd Missile Training Squadron (MTS) to conduct VAFB's Thor program. While the first RAF students completed their classroom training, the 392nd MTS conducted the first launch from VAFB. The demonstration launch, Operation "Tune Up", occurred on 16 December 1958.[35] The following March, the 392nd MTS began conducting the "hardware" portion of the RAF IWST program at complexes 75-1 and 75-2.[36] The first Thor launch conducted by an all-RAF crew occurred on 16 April 1959 during Operation "Lion's Roar."

The Thor IWST program continued at VAFB until 1960. When the program ended, SAC's 392nd MTS had trained approximately 1,250 British missilemen and several hundred American servicemen as well.[37] Although the Thor IWST program ended in 1960, Thor IRBM launches continued at VAFB until 1962. Since England did not have a suitable training area where Thor IRBMs could be test fired, RAF crews and Thor IRBMs stationed in England began returning to VAFB in 1960 and 1961 for additional combat training launches (CTLs). CTLs gave RAF crews a chance to demonstrate their skills and ensured that the Thor IRBMs in England were combat-ready.[38] The final RAF Thor CTL launch occurred in June 1962 (Figure 4).

Besides acting in their capacity as nuclear-armed weapon systems, the United States' long-range missiles also had great potential as boosters for both military and civilian purposes. Only days after the Soviets launched the first Sputnik satellite, an Air Force Scientific Advisory Board urged the development of second-generation ballistic missiles for use as space boosters as well as weapon systems. The committee established high priorities for the development of military satellite systems and the development of the Thor and Atlas satellite booster systems.[39]

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[34] IWST incorporates "hands-on" experience with the launching facilities and ground support equipment. It is interesting to note that the first classes at VAFB commenced before the launch facilities were completed. This created a certain degree of frustration among RAF personnel, including the RAF representative in Washington, DC. For details, see "History of the 704th Strategic Missile Wing (ICBM) (1st Missile Division) for the period of 1 January through 31 December 1958," prepared by the Historical Division of the Office of Information, 1st Missile Division (15 May 1959). Copy on file at the Air Force Historical Research Agency, Maxwell Air Force Base.

[35] Berger and Howard, 20.

[36] Ibid., 24.

[37] Howard, 23-25.

[38] Berger and Howard, 26.

[39] Roger A. Jernigan, *Air Force Satellite Control Facility: Historical Brief and Chronology, 1954-Present* (AFSCF History Office, 1982), 2.

Figure 4: Launch Complex 75-1 (1963)

Once the reliability of the Thor and Atlas missiles was established in test flights, they were pressed into service in the military and civilian space programs. The same held true for the Titan ICBM. While the weapon system aspect of these programs continued to evolve, modified missiles were used to place military and scientific payloads into orbit beginning in 1958. The first launch vehicles were merely modified ICBMs. Improved and standardized launch vehicles (SLVs) were eventually developed to increase performance and payload capacity. These improved SLVs enabled scientists to develop and deploy increasingly heavier and more sophisticated satellite systems. The Air Force and NASA developed a wide variety of standard upper stages for the Thor, Atlas, and Titan boosters including Able, Agena, Delta, Centaur and Burner (I and II).

Satellite reconnaissance played a key role during the Cold War. Speaking before a small group in March 1967, President Johnson stated:

> "[W]e have spent thirty-five or forty billion dollars on the space program. And if nothing else had come out of it except the knowledge we've gained from space photography, it would be worth ten times what the whole program has cost. Because tonight we know how many missiles the enemy has and, it turned out, our guesses were way off. We were doing things we didn't need to do. We were building things we didn't need to build. We were harboring fears we didn't need to harbor."[40]

President Johnson's statement illustrates the exceptionally important role satellites have played and continue to play in the United States' military strategic efforts. Satellites were used extensively by both the United States and the Soviet Union for military purposes during the Cold War. Of the 3,174 satellites orbited between 1957 and 1985, about 75 percent were launched to support or enhance the performance of nuclear and conventional weapons on earth.[41] With the massive political changes in the former Soviet Union, the United States' military satellites continue to play a vital role in monitoring and preparing for developing international crises.

The early Vanguard and Explorer launches represent early efforts to place the first scientific satellites into orbit. As a result of these early efforts, the DoD gained valuable experience in satellite launch techniques and 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 focus of the DoD was directed towards 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 that posed 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. A study by the Research and Development Corporation (RAND) in 1956, partially sponsored by the Central Intelligence Agency (CIA), recommended that the Air Force undertake "at the earliest possible date completion and use of an efficient satellite reconnaissance vehicle as a matter of vital strategic interest to the United States."[42]

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[40]William E. Burrows, *Deep Black: Space Espionage and National Security* (New York: Random House, 1986), preface.
[41]Jasani Bhupendra and Toshibomi Sakata, *Satellites for Arms Control and Crisis Monitoring*, New York: Oxford University Press, 1987), 25.
[42]Burrows, 83.

In response to RAND's study, 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 imagery 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 Air Force awarded the Lockheed Corporation a contract to develop both types of satellites in October 1956. The project became known as WS-117L (Weapon System-117L).[43]

By 1958, the National Security Council assigned highest priority status to the development of an operational reconnaissance satellite. In November of that year, the DoD announced plans for its WS-117L program, revealing that it would consist of three separate systems: Discoverer, Sentry (later Satellite and Missile Observation System, SAMOS), and Missile Defense Alarm System (MIDAS). The first two were reconnaissance systems and the latter was a surveillance system.[44] All of these programs used VAFB (and NMFPA) launch complexes.

The Discoverer program was publicized as an effort to conduct biomedical experiments with mice and small primates, including placement in orbit, re-entry and recovery. Its main objective, however, was to serve as a cover for Project Corona, a classified effort to develop, test and operate a photographic reconnaissance satellite employing a recoverable capsule system.[45] The Air Force managed the Discoverer program while the CIA controlled Project Corona. Discoverer satellite launches, utilizing the Thor-Agena booster, began at VAFB (at SLC-1) in February 1959.

The Air Force conducted the first thirteen Discoverer launches to test the feasibility of recovering a capsule ejected from a satellite. Discoverer XIV, launched on August 18, 1960, was probably the first US satellite to be equipped with operational photographic reconnaissance equipment[46] (Figure 5). It was also the first mission in which a capsule ejected by a satellite was successfully recovered in mid-air.[47] This was accomplished by a C-119 Flying Boxcar aircraft on

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[43]Ibid., 84. The WS-117L project was code-named Pied Piper.
[44]Jeffrey T. Richelson, *America's Secret Eyes in Space: The US Keyhole Spy Satellite Program*. (New York: Harper & Row, 1990), 26-29. In terms of technical intelligence collection "reconnaissance" and "surveillance" are not synonymous terms. Generally, reconnaissance involves pursuing specific information while surveillance entails passively and systematically watching for something to happen, such as a missile being fired. However, the terms are often used interchangeably.
[45]Richelson, 27-30.
[46]Ibid., 41.
[47]The capsule ejected from Discoverer XIII, launched on August 10, 1960, was actually the first man-made object recovered from orbit. Discoverer 13's capsule was successfully recovered by a Navy frogman after it splashed down in the Pacific Ocean on August 11, 1960. President Eisenhower was presented the flag carried by the capsule (Richelson, 39-40).

August 19, 1960. The capsule contained the first satellite photos of the Soviet Union, ushering in the age of spy satellites.[48] The Discoverer program continued until April 1964 and included a total of seventy-eight launches.[49]

The Air Force began the SAMOS reconnaissance satellite program soon after the Discoverer program began producing images of the Soviet Union. SAMOS featured satellites that carried equipment capable of relaying images to the surface. It was envisioned that these satellites would eventually be able to provide maximum coverage of the Soviet Union with a quick transmission time.[50] In reality, however, image resolution was always a problem and some have argued that the pictures obtained by the SAMOS satellites were of questionable value.[51] The SAMOS program did, however, pave the way for the later development of sophisticated real-time reconnaissance satellites.

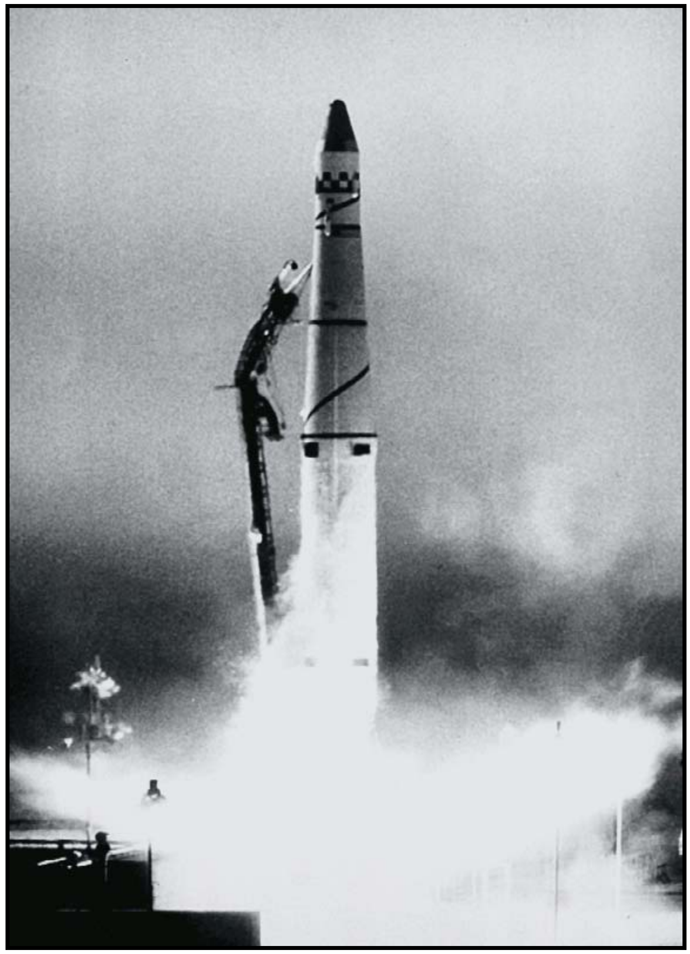

Figure 5: Discoverer / Corona Launch

The first SAMOS launch, attempted in October 1960 from PALC-1 (later SLC-3) at the NMFPA, was a failure. SAMOS 2 was successfully launched from PALC-1 in January 1961. Subsequent SAMOS missions were conducted under increasingly tight secrecy.[52] The SAMOS program concluded in November 1963 after thirty launches.[53]

The MIDAS program involved placing satellites equipped with infrared scanners into a polar orbit. This satellite was designed to detect Soviet missile launches and sound the alarm in case of attack. The first two MIDAS launch attempts, conducted in February and May 1960 at Cape

[48]Richelson, 43. Discoverer's camera photographed a suspected ICBM base at Plesetsk.
[49]Ibid., 59.
[50]Ibid., 53.
[51]Burrows, 92.
[52]Richelson, 52.
[53]Burrows, 91.

Canaveral, ended in failure. The third launch attempt, conducted at PALC-1 at the NMFPA in July 1961, was a success. As a surveillance rather than a reconnaissance system, MIDAS became the first US ballistic missile early warning satellite system. The DSP-647 satellite system, equipped with superior sensors, replaced MIDAS in the 1970s and 1980s.[54]

United States surveillance and reconnaissance satellite activities 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 US reconnaissance satellites down, officials in the Kennedy administration decided to drastically curtail any official publicity concerning the United States' military satellite programs. By 1962, all military launches were classified as secret.[55] Government officials hoped that this would make it much harder for the Soviets to pick out the military satellites from among the various other non-military satellites the United States was launching.[56] 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 the United States' satellite reconnaissance activity.[57]

Part of the new security arrangements implemented by the Kennedy administration included a new designation system for reconnaissance satellite systems. KEYHOLE became the code name used to refer to all such satellites. The various camera systems used on the satellites also became distinguished by Keyhole (KH) designations (e.g. KH-1 for Keyhole-1). The SAMOS cameras were retroactively designated KH-1, KH-2 and KH-3 while the camera used in Project Corona was designated KH-4.[58] KH satellites have become increasingly sophisticated over the years, utilizing top-secret cutting-edge technology. Whereas the SAMOS satellites yielded resolutions of from twenty to about five feet, resolutions from today's KH-12 satellites, developed in the 1980s, may possibly be as a low as fifteen centimeters or less.[59] The KH-12 satellites also carry electronic equipment developed to monitor Soviet communications.[60]

By the mid-1960s, reconnaissance satellites were yielding a regular supply of photographs to officials in the military services and the CIA, allowing them to stay abreast with the latest Soviet military developments. In addition, by revealing that the Soviets did not have as many ICBMs

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[54]DSP-647 satellites had the combined capabilities of space-borne missile launch detection, nuclear test detection and meteorological functions for use exclusively by the military. DSP-647 satellites were launched between 1971 and 1982. See Burrows, 195-198 and R. Cargill Hall, "Missile Defense Alarm: The Genesis of Space-Based Infrared Early Warning," manuscript on file at the Vandenberg Air Force Base Space and Missile Heritage Center.
[55]After the launch of SAMOS 5 in December 1961, officials would no longer even admit the existence of the SAMOS project (Richelson, 53).
[56]Richelson, 65.
[57]Burrows, 142.
[58]Richelson., 66. William Burrows claims that the SAMOS satellites were only designated as KH-1s and that there is no record indicating the existence of KH-2s or KH-3s (see Burrows, 137).
[59]Jasani and Sakata, 28.
[60]Ibid.

deployed as US officials had previously thought, reconnaissance satellite photographs were greatly responsible for dispelling fears of the much publicized "missile gap." [61] 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).[62]

In addition to reconnaissance and surveillance satellites, the United States has launched several 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 NAVSTAR Global Positioning System (GPS) program. All but the DMSP and GPS satellites have been launched from Cape Canaveral or the Kennedy Space Center. The DMSP and the GPS satellites have utilized VAFB complexes.

The DMSP and GPS satellite programs help address the perennial problems of weather and navigation. The DMSP system provides meteorological data to the entire DoD. First developed in the 1960s, these weather satellites have been continuously improved over the years. At any one time there are normally two DMSP satellites, launched from VAFB, positioned in polar orbits about 450 miles above the earth. The DMSP system has allowed for much more accurate global forecasting, including the detection and tracking of tropical storms. The up-to-date weather data they provide supports military operational planning. The DoD also regularly supplies DMSP weather data to the National Oceanic and Atmospheric Administration (NOAA).[63]

The GPS program provides navigation and positioning information to the military and to other users all over the world. Equipment installed in ships, planes, ground vehicles and now even in portable hand-held units, allows users to receive signals from satellites that pinpoint their position on the earth. Testing of the GPS began in 1978 and 1979 when four NAVSTAR satellites carrying special equipment were launched from SLC-3 at VAFB. Full-scale development of the system began in August 1979.[64] Completed in 1995, the NAVSTAR program now consists of twenty-four satellites.[65]

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[61] President Kennedy used the "missile gap" argument as a major 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, 349).
[62] 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.
[63] *Space and Missile Systems Organization: A Chronology, 1954-1979*, 11-12.
[64] Ibid., 12.
[65] *USAF Fact Sheet: Navstar Global Positioning System* (October, 1999).

THE THOR: INTERMEDIATE-RANGE BALLISTIC MISSILE AND "WORKHORSE OF THE SPACE AGE"

Background

On 1 December 1955, President Eisenhower assigned the highest national priority to the development of the Thor and Jupiter IRBMs, placing them on equal footing with the ICBM development program (Figure 6). The IRBM research was conducted concurrently with that for the ICBM, but the less restrictive performance requirements of the IRBM meant the missile could be developed and rendered operational more quickly than the larger, more complex ICBM. Intelligence reports indicated that the Soviet Union had made significant advances in their IRBM research, a situation that posed a serious threat to the security of the United States' allies in Western Europe. The IRBM was intended as a temporary, emergency weapon system to be based in Europe until ICBMs could be developed and deployed.[66]

The Douglas Aircraft Company was awarded the research and development contract for the Thor IRBM on 27 December 1955. Several contractors were associated with Douglas on the project, and all were placed under the overall direction of the Ballistic Missile Division of the ARDC. These included the Rocketdyne division of North American Aviation Corporation (propulsion system), the A.C. Spark Plug Division of General Motors Corporation (guidance system), General Electric Company (re-entry vehicle), and Sandia Corporation (warhead). The Douglas Aircraft Company was responsible for fabricating the airframe, developing the ground-support equipment, and integrating the system components.

Figure 6: The Thor IRBM

To expedite the development of the weapon system and to compress the time required for the system to become operational, the program was conducted under the concept of "concurrency." This provided for the development of support equipment and

[66] Plans were also drawn up for a Thor deployment in Alaska although this was never implemented. See the report "History of the Directorate of Civil Engineering, DCS/O, 1 January 1959 to 30 June 1959" prepared for the Air University Historical Liaison Office (now the Air Force Historical Research Agency) by the Administrative Branch, AFCCE. A copy is on file at the Air Force Historical Research Agency, Maxwell Air Force Base.

facilities while the weapon itself was still under development.[67] This approach resulted in a remarkably rapid development process and on 26 October 1956, just 10 months after the original contract was signed, the Douglas Aircraft Company delivered the first Thor missile.[68]

Early Thor Testing

On 25 January 1957, only 13 months from the initial contract award, the first Thor stood ready for launch at the Air Force Missile Training Center (AFMTC), Cape Canaveral, Florida. This initial launch (of Thor #101) proved disappointing. Just seconds after liftoff, the liquid oxygen start tank ruptured and the missile burned up on the pad. Subsequent tests proved equally disappointing: the second launch (#102) resulted in the missile being destroyed by the Range Safety Officer; the third missile (#103) blew up on the pad; and the fourth missile (#104) blew up after 92 seconds of flight. But with each failure valuable information was obtained that aided scientists and engineers in their preparations for subsequent launches. On 20 September 1957, the launch of Thor #105 marked the first completely successful flight.[69] The testing continued, and by 1958, the Research and Development phase of the testing had come to a close. On 5 November 1958, the Initial Operational Capability (IOC) program began with the first launch attempt of the DM-18A Thor missile.[70] This launch aborted but the next IOC launch, on 26 November 1958, was a success.

Up to this point, all launches had been conducted from the Air Force Missile Test Center, Cape Canaveral, over the Atlantic Missile Range. On 16 December 1958, however, the Thor became the first ballistic missile to be fired from the newly established missile facility at Vandenberg Air Force Base, California. This date also marked the first CTL of a Thor by an Air Force SAC crew.

As part of the plan to base Thor IRBMs in Europe until ICBMs could be deployed, RAF personnel soon joined Douglas Aviation and United States Air Force personnel in conducting IOC and CTL launches at VAFB. CTLs conducted by RAF crews trained and supported by Douglas and United States Air Force (USAF) personnel achieved excellent results, scoring 16 successes out of 18 launches. Eventually, launch operations were performed exclusively by approximately 50 RAF personnel.[71] These CTL launches continued through 1961, registering a

[67] For a description of the concept of concurrency, see Part I.
[68] *The Thor History*, Douglas Report SM-41860, Douglas Missile & Systems Division, Douglas Aircraft Company, Inc., Santa Monica, CA (February, 1964). A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.
[69] Mark C. Cleary, *The 6555th: Missile and Space Launches Through 1970* (45th Space Wing History Office, 1991). See also Julian Hartt, *The Mighty Thor: Missile in Readiness* (New York, 1961).
[70] Various designations were used to identify the Thor missile its stages of development. "DM-18", for example, stands for "Douglas Model-18." The Air Force referred to the DM-18 as XSM-75, for "Experimental Strategic Missile-75." The later Air Force designation SM-75 refers to "Strategic Missile-75," the operational version of the Thor missile. See *The Thor History*, 8, note #1.
[71] *The Thor History*, 12.

remarkable one hundred percent success rate and proving the reliability of the Thor weapons system.[72]

IRBM Deployment Overseas: "Project Emily"[73]

On 22 March 1956, Headquarters USAF assigned responsibility for Thor IOC jointly to the ARDC and SAC. The initial plan called for the deployment of one IRBM wing of eight squadrons, to be supported from three bases in the United Kingdom (Figure 7). Each base would have four complexes containing five launchers each, for a total of 20 launchers. The overall IRBM force would consist of 120 missiles and 60 launchers. Initial planning called for the first ten Thor IRBMs to be combat ready by October 1958, with the entire 120-missile force ready by 1 July 1959. SAC was responsible for the selection and construction of the IRBM bases and the overseas deployment of the operational units.[74]

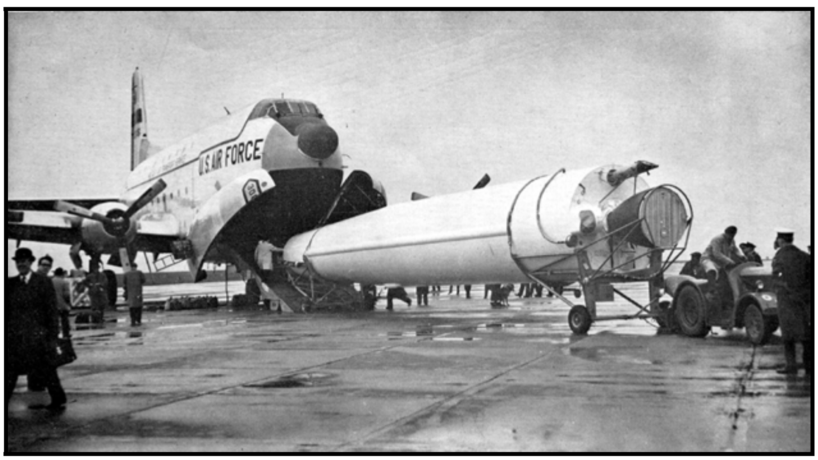

Figure 7: Thor Arrival in the United Kingdom

Like every missile program before it, the Thor development program underwent a series of changes. On 28 March 1957, Eisenhower approved a revised Thor IOC, calling for 60 missiles (divided into 4 squadrons of 15 missiles each, each squadron having five launch positions and three launchers at each position). This force was first scheduled to become operational by July 1959, with the entire force to be ready by July 1960.[75] After the striking success of the Soviet Union's Sputnik I launch, however, this plan was revised yet again. On 30 January 1958, a new plan called for the deployment of four 60-missile Thor squadrons, the first to be operational by 31 December 1958.

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[72] Ibid., 17.
[73] An interesting discussion of Project Emily, focusing primarily on the human element and not on technical issues, can be found in the April 1960 edition of *Airview News* ("Project Emily: 1958-1960"). *Airview News* was a monthly newsletter published by Douglas for its personnel working in the United Kingdom. A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.
[74] Neufeld, 160.
[75] Ibid., 162.

In accepting the deployment of US IRBMs on their soil, the British government had to contend with skeptical officials and a suspicious British public. Negotiations between US and British officials began in 1956 and, on 25 March 1957, President Dwight D. Eisenhower and British Prime Minister Harold Macmillan issued a joint communiqué announcing a general agreement on Thor IRBM deployment. On 22 February 1958, after 18 months of negotiations, a formal agreement was reached on the deployment of four Thor IRBM squadrons to England (Figure 8).

Figure 8: RAF Thor on Alert in England

This program of overseas deployment, known as "Project Emily," has been called "one of the most difficult tasks of all time."[76] It was a huge undertaking, involving the establishment of four complete Thor squadrons dispersed across the English countryside. To accomplish this task, the United States Air Force contracted with the Douglas Aircraft Company for the Thor installation program in the UK. Douglas provided the design blueprints and equipped the launch complexes as they were completed. The British undertook the "brick and mortar" construction. Work included the installation of liquid oxygen and fuel storage and transfer systems, missile shelters, launch control trailers, erecting mechanisms, and maintenance and testing facilities. The first missiles began to arrive in the UK in September 1958, along with a contingent of 400 Douglas personnel to assist the British with construction and base operations.

Four RAF sites were selected to house the arriving Thors (Feltwell, Hemswell, Driffield and North Luffenham). The 705th Strategic Missile Wing (SMW) was activated on 20 February 1958 at Lakenheath Royal Air Force Station, United Kingdom, to monitor the Thor IRBM program in the UK and to provide technical assistance to the four RAF Thor squadrons.[77]

On 22 June 1959, the 77th RAF Strategic Missile Squadron (SMS) at Feltwell, England became the first UK-based Thor IRBM squadron to reach operational status. On 11 September and 22 December 1959 the second and third UK-based Thor IRBM squadrons (at Hemswell and Driffield) were declared operational and assigned to the RAF. The fourth and final squadron (based at North Luffenham) was turned over to the British on 24 April 1960. Although the

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[76] *The Thor History*, 10.
[77] Shortly thereafter the Air Force transferred the 705th SMW to South Ruslip and merged it with Headquarters, 7th Air Division.

squadrons had been turned over to the RAF, SAC retained control over the squadron's nuclear warheads and assigned a detachment to perform four functions: (1) retain custody and control over, and provide maintenance for, reentry vehicles and warheads; (2) receive and initiate US warhead release orders; (3) operate USAF communications facilities; and (4) provide training to the Royal Air Force.[78]

The Thor presence in the UK was relatively short-lived. In May of 1962, Secretary of Defense Robert S. McNamara told the British Minister of Defense that the United States would not provide logistical support for the Thors after 31 October 1964, prompting a British decision to phase out the IRBMs. On 29 November 1962 the first Thor came off alert at the 98th Royal Air Force SMS in Driffield. Nine months later, on 15 August 1963, the last fifteen Thor IRBMS were declared non-operational. The phaseout of the British Thors was completed on 20 December 1963.

The Thor Space Booster: "Workhorse of the Space Age"

Even before the Thor was operational as an IRBM the decision had been made to make the Thor the first "double-programmed" system, intended to produce both missiles and boosters having long-range and space capabilities.[79] Although its role as an IRBM was relatively short-lived, the Thor boosters continued to make significant contributions to the United States missile and space program.

The first such contribution was made in 1958, when a series of Thor boosters were mated to Able second stages (a liquid propellant propulsion system developed by the Aerojet) in support of re-entry vehicle testing for the Atlas ICBM program at Cape. The launch of Thor-Able 119 from the Atlantic Missile Range on 9 July 1958 marked the first successful launch of a ballistic vehicle that attained an altitude of nearly 1,000 miles, traveled to a target more than 6,000 miles away, and managed to survive the blazing heat of reentry.[80]

The Thor-Able combination was also used in a space probe program initiated by the USAF and operating under the DoD Advanced Research Projects Agency (ARPA) (Figure 9). On 17 August 1958, the four-stage Thor-Able I was launched in an attempt to achieve a lunar orbit. It is interesting to note the timing of this attempt relative to the progress of the IRBM program. As one historian notes, "[They] had not yet been able to complete testing of a Thor IRBM that could fly with accuracy from the UK to behind the Iron Curtain, over distances ranging from 300–1500 nautical miles. Yet a Thor was going to boost into space a vehicle that would travel 240,000 miles to the moon."[81] Unfortunately, this ambitious attempt met with failure. Thor's first real

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[78] *From Snark to Peacekeeper: A Pictorial History of Strategic Air Command Missiles* (Offutt Air Force Base, NE: Office of the Historian, Headquarters Strategic Air Command, 1991), 57.
[79] *The Thor History*, 6.
[80] Hartt. The reentry vehicle was unfortunately lost.
[81] Hartt.

contribution to the space program came on October 1958 when a Thor-Able lifted the Pioneer I spacecraft into a 78,000 nautical mile space probe, confirming the existence of the Van Allen radiation belt.

Figure 9: Launch of Thor-Able

Modifications of the Thor-Able configuration were used in many subsequent programs. A Thor-Able II configuration was used in the launch of TIROS-1 (Television and Infra-Red Observation Satellite), a meteorological payload developed by the Radio Corporation of America for weather observation experiments sponsored by NASA (1 April 1960). A Thor-Able III launched the "Paddlewheel" payload that allowed pictures of Earth to be taken from orbit (1959). A Thor-Able IV (a 3-stage configuration) was used to launch a space probe that achieved a heliocentric orbit between the Earth and Venus, transmitting data over a record distance of 22,500,000 statute miles from the Earth. This was the longest direct radio transmission ever achieved up to that time (11 March 1960).[82]

Another configuration, the Thor-Ablestar, was used by the United States Navy. On 13 April 1960, a Thor-Ablestar launched a navigational satellite and, on 22 June 1960, a Thor-Ablestar system was responsible for a space milestone, when it placed two satellites in orbit simultaneously. On 4 October 1960, another Thor-Ablestar launch placed a communications satellite in orbit that was used to relay a message from President Eisenhower to Secretary of State Christian Herter, at the United Nations.[83]

After the Thor-Able and Thor-Able I launchings, Douglas entered the Military Satellite program in 1959 with the Thor-Agena A, the Agena A second-stage being provided by Lockheed (Figure 10). The purpose of this program, named Discoverer, was to provide a satellite capable of first gathering scientific data and then ejecting a recoverable research capsule.[84] The Thor-Agena A launchings continued from 28 February 1959 to 13 September 1960. The payload used in the launch of 10 August 1960, was the first known payload to have its data capsule recovered from orbit.[85] A modified configuration, the Thor-Agena B, was launched on 12 November 1960, with

[82] *The Thor History*, 20.
[83] Ibid., 20.
[84] Ibid., 14.
[85] Ibid.

the ejected research capsule being recovered in mid air by an airplane equipped with a special hook for that purpose.[86]

Yet another configuration was the Thor-Delta. The first launch of a Thor-Delta, on 13 May 1960, carried a communication satellite (Echo). The satellite failed to achieve orbit, but a second launch on 12 August 1960 successfully placed the Echo I satellite in orbit. The Thor-Delta successfully launched a series of other satellites including TIROS A-2, Explorer X, TIROS A-3, Explorer XIII, TIROS A-4, and the Orbiting Solar Observatory, or OSO.[87] This configuration has evolved continuously and is still in use today. Its considerable success has established the Delta as one of the United States' most reliable boosters.[88]

Figure 10: Thor-Agena Launch (1959)

The Defense Meteorological Satellite Program

The impressive litany of Thor's contributions to the space program continued with the DMSP. The DMSP played a crucial role in military intelligence gathering during the Cold War and the success of the program had both strategic and tactical implications. Photo-reconnaissance satellites (such as those launched in the Corona Program) depended on accurate and timely meteorological forecasts, particularly those of the Sino-Soviet landmass. Cloud cover could severely limit the utility of such satellites. Program proposals to develop a system that could assist these reconnaissance satellites by providing accurate meteorological forecasts were first developed in 1961.

From the beginning, these early attempts were plagued with problems. The early system relied upon the use of a Scout booster and launches at VAFB on 25 April and 23 May 1962 were unsuccessful because of the Scout booster failure.[89] A launch of 23 August 1962 was successful, but the Lockheed ground-control team failed at first to track the weather satellite. Two months later, in October 1962, however, weather pictures of the Caribbean returned by this same vehicle proved of crucial importance during the Cuban Missile Crisis.[90] Subsequent launches resulted in

[86] Ibid., 25.
[87] Ibid., 23.
[88] Steven J. Isakowitz, *International Reference Guide to Space Launch Systems* (Washington, DC: American Institute of Aeronautics and Astronautics, 1991).
[89] "Weather Reconnaissance: The Defense Meteorological Satellite Program," 3. Author and date unknown. A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.
[90] "Weather Reconnaissance", 4.

a number of failures because of the unreliable NASA Scout booster. Five launches in two years had yielded three Scout booster failures and, on 7 October 1963, the Air Force cancelled its contract with NASA.[91]

A search began for a replacement booster that could provide increased reliability with no loss in lift capacity. A few months earlier, a number of liquid-propellant Thor and Jupiter IRBMs had been withdrawn from England and Turkey as part of a deal struck with the Soviets during the Cuban Missile Crisis. When combined with a solid rocket motor then being tested in Redlands, California by a firm called Rocket Lab, it was determined that this combination would be able to do the job. Designated the Burner I, this combination possessed almost double the total impulse power of the Scout motor and burned and accelerated extremely rapidly. This increased power, however, subjected the weather satellites to 25g loads. As a result, work began on an improved solid-propellant upper stage, eventually resulting in the Thor-Burner II. This combination, which eventually used an additional solid-propellant third stage to increase lift capacity continued to be used in the program until the early 1980s, when it was replaced by the Atlas booster.[92]

Two Thor-Agena vehicles, the same vehicle used to launch Corona satellites, were also used in the DMSP. Although larger and more expensive than was needed for the DMSP, this vehicle could carry two satellites into orbit simultaneously. Thor-Agena launches occurred on 19 January and 17 June 1964, placing a total of four DMSP satellites into orbit.

It would be difficult to overestimate the importance of these DMSP satellites, both strategically and tactically. At the strategic level, beginning in 1965, two DMSP polar-orbiting, sun-synchronous weather satellites continually functioned in circular orbits 450 miles above the Eurasian landmass providing daily observations of cloud distribution and organization. The tactical value of these satellites became first apparent in 1964. In November of that year, DMSP satellites furnished weather data over central Africa to the Military Airlift Command, data that proved crucial to the successful airlift of Belgian paratroopers from Europe to Stanleyville, in the Congo, where they freed hostages that were seized in an uprising.[93] DMSP satellites also played a key role in supporting operations in Vietnam by providing weather data for planned air strikes and in support of clandestine operations. Tactical data of this sort proved so useful, and so improved the timeliness and accuracy of weather forecasts in Southeast Asia that, in October 1965, the military services cancelled all daily, routine aerial weather-reconnaissance sorties and relied entirely on data provided by the DMSP satellites.[94]

DMSP satellite launches continued throughout the subsequent decades. Modifications and improvements to the satellite configuration eventually increased the payload weight to 1,792 pounds. This was too heavy for the Thor-Burner booster combination and, in 1980, after 16

[91] Ibid., 5.
[92] Ibid., 6
[93] Ibid., 9.
[94] Ibid., 10.

months of indecision, an improved version of the General Dynamics Atlas ICBM was chosen as the new launch vehicle for DMSP satellites.[95] The last launch of a DMSP satellite atop a Thor-Burner vehicle occurred on 15 July 1980 at SLC-10W, Vandenberg Air Force Base. For the first time in many years, the Thor-Burner combination failed. The second and third-stage solid rockets did not separate and the satellite fell into the South Pacific.[96]

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[95] Ibid., 19.
[96] Ibid., 20.

SPACE LAUNCH COMPLEX 10

Space Launch Complex 10 is one of three Thor launch complexes built near Purisma Point at North VAFB in the late 1950s. The Douglas Aircraft Company began construction of the complex in January 1958 and turned the site over to the Air Force the following October. The Air Force designated the original three pads at the complex as 75-2-6, 75-2-7 and 75-2-8. These designations changed over the years. 75-2-6 became known as LE-6 (for Launch Emplacement 6), then 4300 B-6, and finally SLC-10 West (SLC-10W) (Figure 11). The Air Force redesignated 75-2-7 as LE-7 and then SLC-10 East (SLC-10E). 75-2-8 became known as LE-8.

The first launches and training activities at SLC-10 (from 1959-1962) contributed to the development of the Thor IRBM and, more specifically, to the training of RAF crews and the eventual overseas deployment of these missiles to the United Kingdom. Later activities supported crew training associated with anti-satellite research under Program 437 (1963-1975) and military meteorological satellite launches under the DMSP (1965-1980). The details of these activities are discussed below.

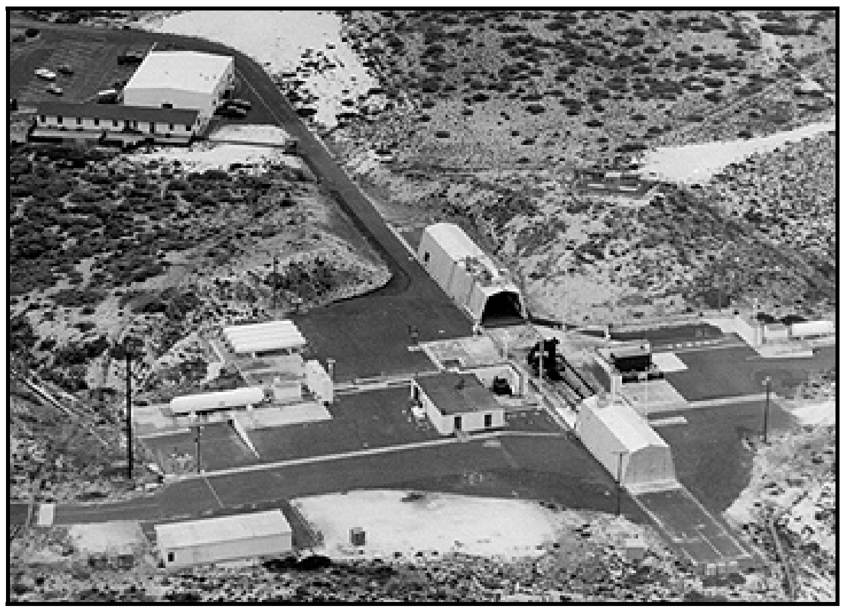

Figure 11: Aerial View of SLC-10 West

IRBM Training for the Royal Air Force

The three original pads at SLC-10 initially supported the Air Force's RAF Thor IRBM training program. Construction of Thor launch facilities in the United Kingdom began in 1958. RAF airmen were initially sent for individual training to the plants of the contractors who had developed the Thor missile. Douglas Aircraft set up a facility in Tucson, Arizona for this purpose. After receiving instruction at these plants, the RAF personnel were then sent to VAFB to complete an 8-week training course. Other RAF men learned on the job in the UK as the launch complexes were being built and then came to VAFB for actual firings.[97]

The first RAF students, men from the 77th and 97th Strategic Missile Squadrons, arrived at VAFB in August 1958. Six months later, in February 1959, thirty-five launch crews (271 men),

[97] Hartt.

173 maintenance men, 30 maintenance supervisors and 14 staff officers from the two RAF squadrons had received their training and returned to England. During this same period, 255 American servicemen also received training in Thor operations.[98]

The first launch conducted by an RAF crew at VAFB took place at SLC-10 on 16 April 1959. Designated Operation "Lion's Roar", this training exercise took place at the 75-2-8 pad. RAF training launches from 75-2-7 and 75-2-6 followed on 16 June 1959 ("Rifle Shot") and August 14, 1959 ("Short Skip") respectively. The launch from 75-2-6 was the only RAF Thor training launch conducted at that pad. RAF crews continued to conduct Thor IRBM training launches at 75-2-7 and 75-2-8 over the next three years. Pad 75-2-7 witnessed six launches between 16 June 1959 and 19 March 1962 while seven launches took place at Pad 75-2-8 between 16 April 1959 and 18 June 1962.

Operation Dominic, Program 437, and the DMSP at SLC-10

While the Thor IRBM training proceeded at VAFB, international developments were taking place that ultimately impacted the fate of SLC-10. By early 1961, intelligence reports indicated that the Soviet Union was preparing to resume its nuclear testing program, breaking a 34-month voluntary moratorium by the two superpowers. In response, the AEC began readying plans to resume its nuclear testing program.

Designated Operation Dominic, the AEC effort ultimately involved 36 nuclear detonations in the Pacific, including air-drops and high-altitude missile-launched shots.[99] For the high-altitude portion of Operation Dominic, the AEC planned four DoD launchings of nuclear-armed Thor IRBMs from Johnston Island (a small island located southwest of Hawaii). These high altitude tests using the Thor booster were collectively nicknamed the Fishbowl program. To support the Fishbowl launches, the Air Force dismantled and transported the 75-2-6 pad at VAFB to Johnston Island in early 1962. The rebuilt pad became known as LE-1. Meanwhile, the RAF Thor training program continued at SLC-10's two remaining pads.[100]

The first launch attempt in the Fishbowl program, designated Bluegill, occurred on 3 June 1962 from LE-1. Unfortunately, the range safety officer was forced to destroy the warhead 13.5 minutes after lift-off when the missile tracking system on Johnston Island malfunctioned. Later investigations revealed that the missile had actually followed its proper course. The Bluegill attempt would be the first of several failures in the Fishbowl program. The second launch attempt in the program, conducted on 19 June and designated Starfish, also ended prematurely. The range safety officer, when informed that the missile had exploded, sent a destruct order to the missile 65 seconds after lift-off. Finally, on 9 July, the first successful launch in the Fishbowl program lifted off LE-1. Code-named Starfish Prime, the shot culminated with a 1.4-megaton

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[98] Berger and Howard, 23.
[99] Chuck Hansen, *US Nuclear Weapons: The Secret History* (New York: Crown Publishers, 1988), 81-89.
[100] The last RAF Thor IRBM training launch at SLC-10 occurred on June 18, 1962 at the 75-2-8 pad.

nuclear explosion about 248 miles above Johnston Island.[101] The world's first high-altitude nuclear explosion produced spectacular results and several unintended effects, including knocking out electrical systems in Hawaii, 715 miles away. More importantly, electromagnetic pulse effects from the blast seriously damaged the solar panels of three orbiting satellites even though they were not in the line of sight of the nuclear detonation. The radiation effects lingered in the earth's magnetic fields and affected satellites that followed an orbital path through the detonation area. Electronic components were destroyed and continued exposure to radiation trapped in the Earth's magnetic fields degraded the life of affected satellites.[102] This impressive demonstration of the affect on satellites of a high dose of radiation laid the groundwork for a future anti-satellite program, Program 437.[103]

The fourth attempted launch in the Fishbowl program, Bluegill Prime, was conducted on 25 July. This launch, a repeat of the ill-fated 3 June attempt, was the worst failure in the program. A faulty liquid oxygen valve prevented the Thor missile from developing sufficient thrust to lift off. When the Thor's main engine failed to achieve full thrust, the range safety officer on duty made an error in judgment. Instead of merely shutting down the Thor's engines, he initiated the destruct sequence and the missile exploded on the LE-1 pad. The ensuing explosion severely damaged the pad and scattered radioactive particles around the complex and island. This caused a two-month delay in the Fishbowl program while massive decontamination efforts at Johnston Island were undertaken. As the clean up proceeded, preparations were made to transport the other two Thor pads at SLC-10 to Johnston Island to support the remaining Fishbowl launches. The Thor IRBM training program had ended at SLC-10 the previous June, making the two pads available for use in the Fishbowl program.

By October, with the clean-up effort completed and the two former VAFB pads transported to, and rebuilt at Johnston Island, the DoD was ready to resume the Fishbowl launches. The first launch after the Bluegill Prime incident, designated Bluegill Double Prime, took place on 15 October. Unfortunately, the Thor booster once again failed and had to be destroyed 156 seconds after lift-off. Three subsequent attempts in the series, however, were highly successful. The launches, nicknamed Bluegill Triple Prime, Kingfish, and Tightrope, occurred on 25 October, 1 November, and 4 November respectively. The Tightrope shot successfully concluded the Dominic series of nuclear tests.

When Operation Dominic ended, the Air Force already had plans for the next use of the two Thor pads at Johnston Island. In February 1962, the Air Force had begun developing a plan to deploy a direct-ascent anti-satellite (ASAT) system utilizing ground computer-guided Thor missiles armed with nuclear warheads. Excess SM-75 Thor IRBMs previously on alert in

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[101] Hansen, 84, 86-87.
[102] Chun, Clayton K. S. *Shooting Down A Star: Program 437, the US Nuclear ASAT System, and Present-Day Copycat Killers* (Maxwell AFB: Air University Press, 2000), 4. The damaged satellites included two classified Air Force satellites and Ariel, a joint US-British satellite.
[103] Chun, 4.

England (and later shipped back to the United States) would be refurbished to serve as the booster for the Air Force ASAT system.[104] An operational ASAT system would give the United States the capability to destroy hostile orbiting objects, such as military satellites or orbiting bombs. Such a system was seen as a necessity to offset the ominous and increasingly plausible possibility of the Soviets implementing an orbital nuclear weapon system (known as Fractional Orbit Bombardment System, or FOBS).[105] The top-secret Air Force effort, eventually known as Program 437, was initially planned as an emergency standby system. The program eventually evolved into an operational ASAT system on permanent 24-hour alert.[106]

The proposed program was not without its critics. The CIA in particular expressed reservations about the project, arguing that no foreign country's satellites posed a major space threat. President Kennedy did not share this opinion and directed McNamara to develop an ASAT system at the 'earliest practicable time.' In 1963, Program 437 received the highest priority.[107]

The operational concept for Program 437 incorporated two bases – VAFB and Johnston Island. Johnston Island was selected because it was thought that its particular location would allow the Air Force to intercept a hostile satellite before it reached the continental United States (Figure 12). Two Thor ASAT boosters at Johnston Island would be placed on continuous alert, while VAFB provided the support and training facilities for the Johnston Island crew.[108] The original staffing concept called for 178 personnel. Three launch teams would rotate from VAFB to Johnston Island. A small, permanent detachment at Johnston Island would maintain the launch pads.[109] Additional crew could be deployed from VAFB if required.

If an enemy satellite was detected, the launch crew would count down both Thor missiles (one acting as a backup in case of a mishap with the first). Once launched, the Thor's warhead would close in on the enemy satellite in space and a nuclear explosion would effectively destroy it. Final approval for Program 437 was obtained on 11 January 1963, with a plan for IOC on 1 May 1964. The DoD initially authorized a four-launch feasibility demonstration schedule for Program 437 with test launches slated to begin in early 1964.[110]

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[104] After the Air Force shipped the SM-75 Thor IRBMs back to the United States from England where they had stood on alert, Douglas aircraft refurbished some of them for Program 437 by installing new guidance system, command-destruct, and telemetry components. These refurbished Thors were designated as Launch Vehicle 2D or LV-2D.

[105] Curtis Peebles presents an excellent discussion of the Soviet threats of deploying orbital nuclear weapons and the range and extent of their actual programs in his book *Battle for Space* (New York: Beaufort Books, 1983), 51-76.

[106] Peebles, 85-88.

[107] Chun, 6.

[108] Ibid., 10.

[109] Ibid., 15.

[110] The Army's ASAT effort, designated Program 505, was actually the United State's first operational ASAT. Program 505 utilized Nike-Zeus missiles and, for a time, directly competed with the Air Force's Program 437. Army personnel carried out several Program 505 ASAT test launches in 1964 from a Nike-Zeus ASAT site at Kwajalein Atoll in the Pacific. The site had originally been built for ABM test flights. Although the Nike-Zeus had

Figure 12: Johnston Island

In 1963, Douglas Aircraft Corporation modified the two Thor pads at Johnston Island to support Program 437. Douglas Aircraft also completely rebuilt the 75-2 pad at VAFB at its original site using equipment from dismantled Thor IRBM sites previously located in England. This construction took place between May and October of 1963.[111] The rebuilt 75-2-7 pad, first designated LE-7 and then later SLC-10E, supported Program 437 crew training exercises. The rebuilt 75-2-6 pad, first designated 4300 B-6, then LE-6, and finally as SLC-10W, was initially intended to support Thor IRBM testing. Afterwards, the Air Force modified the pad to support its Thor-Burner I series of DMSP satellite launches.

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a faster reaction time, the Army missile could not compete with the altitude of the Thor. Defense Secretary Robert McNamara finally ordered Program 505 to be phased out in May 1966 (Peebles, 82-85).

[111]Lemmon, "History of Space Launch Complex 10."

The 75-2-8 pad was also rebuilt and designated as LE-8. Although LE-8 was available for space launches, the Air Force never utilized the complex for any mission. In the early 1970s, the pad was decommissioned and its equipment salvaged for use at other VAFB locations.[112]

Program 437 was initiated during the height of Cold War tensions between the Soviet Union and the United States. Two weeks after the original Program 437 working plan was published, Air Force Chief of Staff General Curtis LeMay recognized the effort having top priority status among defense programs.[113] Air Force Systems Command (AFSC) was originally given the responsibility for rendering the Thor ASAT operational in the event of an emergency while Air Defense Command (ADC) personnel worked on the development phase of the system. Many of the men assigned to Program 437 had extensive experience with the Thor. By November 1963, the Air Force had assigned full responsibility for Program 437 to ADC. ADC went on to form the 10th Aerospace Defense Squadron (10th ADS) to man the ASAT effort.[114]

The initial crew training for Program 437, consisting of realistic mock launch exercises, began at SLC-10E in mid-1963.[115] As this training proceeded, contractor crews working at Johnston Island conducted the first Program 437 test launches on 14 February, 1 March, and 23 April 1964.[116] All of the simulated warheads carried by the Thor missiles during these launches passed close enough to their targets to be considered successful interceptions. 10th ADS personnel conducted the final research and development flight in the series on 28 May. Despite a flawless performance by the crew, the Thor malfunctioned and went out of control. Despite this failure, the system was declared operational. By early June, two nuclear-armed Thor missiles, manned by a 10th ADS crew, were on 24-hour alert at Johnston Island.[117]

The initial plan was to conduct three Combat Training Launches (CTLs) per year from Johnston Island. Each of the three rotating crews would serve for 90 days at the Johnston Island facility and be responsible for conducting one CTL. The first CTL was conducted on 16 November 1964. Funding shortages, resulting from a diversion of resources caused by the Vietnam War, and a shortage of available Thors created obstacles to the successful execution of this initial plan.[118] The second CTL did not take place until 5 April 1965. Secretary of Defense McNamara was eventually persuaded to authorize the purchase of 16 additional boosters for the program to be used from 1966-1971.

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[112] Eric Lemmon, phone interview by Patrick Nowlan, 3 March 1995. The exact date of the decommissioning and dismantlement of LE-8 is unclear because many of the Real Property records of the complex from that period cannot be located.
[113] Peebles, 87.
[114] Ibid., 88.
[115] The rebuilt SLC-10E pad supported only launch training exercises. It never supported an actual missile launch.
[116] These launches were given the interesting designation “Squanto Terror.”
[117] Chun, 18.
[118] Ibid., 17.

In addition to the launches at Johnston Island, a series of training exercises were taking place at SLC-10E. During these exercises, 10th ADS crews performed and were evaluated on all tasks required in a live launch situation up to the point of a simulated lift-off.

Up to this point, the scope and extent of the Thor ASAT program had been kept secret from the American press and public. When Republican presidential hopeful Barry Goldwater, in a campaign speech in 1964, accused President Johnson of ignoring the threat of Soviet military space systems and weapons, Johnson refuted the claim by disclosing for the first time the existence of the Air Force Thor ASAT. It soon became common knowledge that the United States could destroy almost any enemy satellite.[119] The existence of Program 437, however, remained classified until 1974.

As Program 437 activity continued at SLC-10E and Johnston Island, the 4300 Support Squadron was busy with the Air Force Thor-Burner I satellite program at the modified SLC-10W. After initially being rebuilt in its original IRBM configuration with materials salvaged from Thor sites in England, SLC-10W had subsequently been modified to support DMSP launches. The pad resembled a Thor IRBM pad in many respects except for the addition of a retractable extension on the Missile Shelter to shield payloads during launch preparations and the addition of an electronic equipment facility. At Thor IRBM sites this electronic equipment was generally mounted on trailers. Other modifications at SLC-10W included the addition of a water deluge and fire suppression system, high-intensity floodlighting, closed-circuit television, payload air conditioning, gaseous nitrogen distribution, and high-capacity electrical distribution.

The Thor-Burner I was a 2-stage space booster that used a modified Thor IRBM as the first stage and a solid rocket motor as the second stage. To prepare for the Burner I program, the 4300th Support Squadron rebuilt the dismantled SLC-10W site with excess equipment returned from England, modified the launch emplacement to support a Burner I configuration, oversaw the necessary modifications of six Thor IRBMs, and processed six newly designed and untested second stages. They followed up these activities with a series of six successful Thor-Burner I launches. The first of these, nicknamed "Astral Lamp," took place at SLC-10W on 19 January 1965. This launch also marked the first time a space launch was conducted by an all "blue suit" (all military) crew. The last Thor-Burner I launch took place at SLC-10W on 31 March 1966.[120]

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[119] Peebles, 90.
[120] "Chronology of the 4300 Support Squadron, 1963-1967" (Vandenberg Air Force Base, California). A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.

The 4300th Support Squadron was also responsible for the subsequent series of Thor- Burner II launches. The Thor-Burner II was also a 2-stage space booster that used a modified Thor IRBM as the first stage. The second stage consisted of a solid rocket motor and incorporated an inertial guidance system. The first launch of the Thor-Burner II configuration took place at SLC-10W on 16 September 1966. Like the majority of the Thor-Burner launches, this first launch, nicknamed "Irish Duke", supported the DMSP. The following spring, the Air Force merged the 4300th Support Squadron with the 10th ADS to form the 10th Aerospace Defense Group (10th ADG) under the Aerospace Defense Command (ADCOM). The 10th ADG formally took over the space launch responsibilities at SLC-10W on 1 April 1967 (Figure 13). Over the next twelve and half years, ADCOM crews launched ten Thor-Burner II, eight Thor-Burner II-A, and four Block 5D-1 payloads from SLC-10W. All of these launches supported the DMSP.[121]

Figure 13: Thor-Burner II at SLC-10W ("Deer Foot" launch of 29 June 1967)

When the 10th ADG was formed and its crews took over operations at SLC-10W, the group implemented a new crew rotation schedule. Three separate launch crews rotated every three months between Johnston Island, SLC-10W and SLC-10E. The crew assigned to Johnston Island conducted CTLs and served on alert duty, the crew at SLC-10W conducted space launches, many supporting the DMSP, and the crew at SLC-10E engaged in Program 437 training exercises. This strenuous arrangement remained in place for the next four years. In 1971, when the Soviet Union ceased their FOBS testing program after eighteen launches, somewhat easing global tension, the Air Force decided to inactivate the 10th ADG while simultaneously reactivating the 10th ADS in its place.[122] Instead of keeping a launch crew on 24-hour alert, the 10th ADS kept only a small detachment on Johnston Island.[123] Relying on sophisticated intelligence methods (particularly reconnaissance satellites) to give ample warning of any

[121] *Space and Missile Systems Organization*, 11-12.
[122] Eric Lemmon, phone interview by Patrick Nowlan, 28 February 1995; Peebles, 76. All assets of the 10th ADG were transferred to the newly reactivated 10th ADS in January 1971.
[123] The detachment on Johnston Island consisted of administrative, laboratory, communications, security, safety, corrosion control, and supply personnel who were assigned for one-year tours of duty.

dangerous developments in the Soviet Union, the 10th ADS maintained only one Program 437 combat launch crew on 30-day call-up status. Once every six months or so, this crew traveled to Johnston Island to conduct training exercises[124] (Figure 14).

Figure 14: Thor at Johnston Island

Disaster struck Program 437 in August 1972 when Hurricane Celeste passed near Johnston Island and caused severe damage to the facilities there. Maintenance personnel had been evacuated from the island before the storm hit. Air reconnaissance conducted after the storm passed revealed that the roofs of several of the facilities at Johnston Island had been torn away exposing computers and other equipment to salt water. A monstrous recovery effort soon began, and in several weeks the two pads were fully operational again.

After Hurricane Celeste, however, Program 437 continued to exist in name only. While the storm had demonstrated the vulnerability of the Johnston Island complex to the elements, there were also serious concerns about the facility's vulnerability to an enemy commando strike launched from a submarine or a surface ship. The island was hundreds of miles from the nearest support facility in Hawaii. The fact that during several of the Program 437 tests Soviet subs were lurking only 10 miles off shore served only to heighten these fears.[125] In addition, there were continuing concerns with the dwindling numbers of available Thor boosters and fears that using a nuclear warhead to destroy enemy satellites could inadvertently trigger a full-scale nuclear war.[126]

Program 437 was officially terminated on 1 April 1975 after US and Soviet officials agreed to ban the orbiting of any nuclear weapons. Two more Thor launches at Johnston Island followed the official termination, however. These launches, in September and November 1975, utilized

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[124] The last Program 437 CTL launch took place on March 28, 1970. The next launch attempt at Johnston Island, on 25 April 1970, was actually in support of the anti-ballistic missile Special Defense Program (SDP). The SDP was cancelled after this unsuccessful launch attempt. A High Altitude Program (HAP) launch took place on 24 September 1970 to demonstrate the capability to resume atmospheric nuclear testing. The payload was not a nuclear device (Peebles, 93-94; Eric Lemmon, correspondence with Patrick Nowlan, 22 March 1995).
[125] Chun, 21.
[126] Ibid., 31.

two Program 437 Thor missiles to support the Army's Ballistic Missile Defense Test Target Program.[127]

Activities at SLC-10E ceased when the cancellation of Program 437 eliminated the need for the facility. However, military launches continued at SLC-10W until 15 July 1980 when the last Thor boosters lifted off the pad. This operation, Operation 7383, was the fifth and final launch in the series of Block 5D-1 payloads used in support of the DMSP.[128]

Deciding to use the Atlas booster for the DMSP, the Air Force terminated the Thor space program in July 1981 and disbanded its launch crews. Both pads at SLC-10 remained virtually abandoned over the next five years. In 1986, SLC-10 became a National Historic Landmark (NHL) under the National Park Service's "Man in Space" program. At the time of SLC-10's nomination as an NHL, the Air Force turned the complex over to the 4315th Combat Crew Training Squadron for restoration and conversion into the Vandenberg Air Force Base Space and Missile Heritage Center.

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[127] Details of these last two launches can be found in McDonnell Douglas, "Ballistic Missile Defense Test Target Program (BMDTTP): Systems Integration Plan" (March 1975). A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.
[128] There have been 31 Thor launches from SLC-10W since it was commissioned on 1 Oct 1958. The first launch occurred on 14 August 1959 when a Thor SM-75 IRBM was fired by an IRBM crew. Six Burner I and 2 Burner II payloads were launched between 18 January 1965 and 8 February 1967 by the 4300th Support Squadron. Between 29 June 1967 and 6 June 1979 10 Burner II, 8 Burner IIA and four block 5D-1 payloads were launched by the 10th AERODS. See "Launch Vehicle Flight Report: Operation 7383 Block 5D-1/S-4, 15 July 1980", Space Systems Engineering Section, Maintenance Engineering Branch, 394th ICBM Test Maintenance Squadron, Vandenberg, AFB, CA. A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.

CONCLUSION

The research and development of new space and missile systems in many ways defined the confrontation between the Soviet Union and the United States known as the Cold War. The Thor contributed to an impressive number of early research programs, serving as both an operational IRBM, a test vehicle for the ICBM reentry vehicles, and as a booster for an array of space launches that represent the formative stages of satellite, and anti-satellite, technology. Activities at Space Launch Complex 10 contributed to the intermediate-range ballistic missile training program, the Defense Meteorological Satellite Program, and to the anti-satellite efforts of Program 437. The history of Space Launch Complex 10 provides an excellent representative sampling of the Thor's importance, durability, and versatility.[129]

[129] An indication of the durability and versatility of the Thor booster can be found in the history of the booster used in the 1980 launch from SLC-10W. Booster 59-2425 was built in the summer of 1959 and stationed at Lincolnshire in the UK, remaining there from August 1960 to May 1963. In June 1963, the booster arrived at Norton AFB where it was stored until December 1970. At this time, the Booster was sent to Santa Monica for conversion from the SM-75 (DM-18A) configuration to the LV-2f configuration (DSV-2U). The Booster was then returned to Norton AFB and stored until October of 1974, at which time it was sent to VAFB. The booster was again modified in 1978 and finally launched on 15 July 1980. See "Launch Vehicle Flight Report: Operation 7383 Block 5D-1/S-4, 15 July 1980", Space Systems Engineering Section, Maintenance Engineering Branch, 394th ICBM Test Maintenance Squadron, Vandenberg, AFB", 1. A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.

ARCHITECTURAL DESCRIPTION OF SPACE LAUNCH COMPLEX 10[130]

SLC-10 was comprised of three launch pads (Pad 10-East, Pad 10-West, and the LE-8 Facility, also known as Pad 10-North) with a centrally located Blockhouse, technical support buildings, and shared facilities. The entire complex, constructed to support the launching of the Thor missiles, encompasses 138 acres (Figures 15 and 16). Each of the three virtually identical pads was self-contained within its own perimeter fence and oriented in an east-west direction. The shelter at SLC-10W received an extension to the west end in the mid 1970s to support additional missile configurations. The West Pad retains the greatest integrity of the three pads. The East Pad Missile Shelter is used for missile component storage. The LE-8 facility was decommissioned and dismantled in the early 1970s.

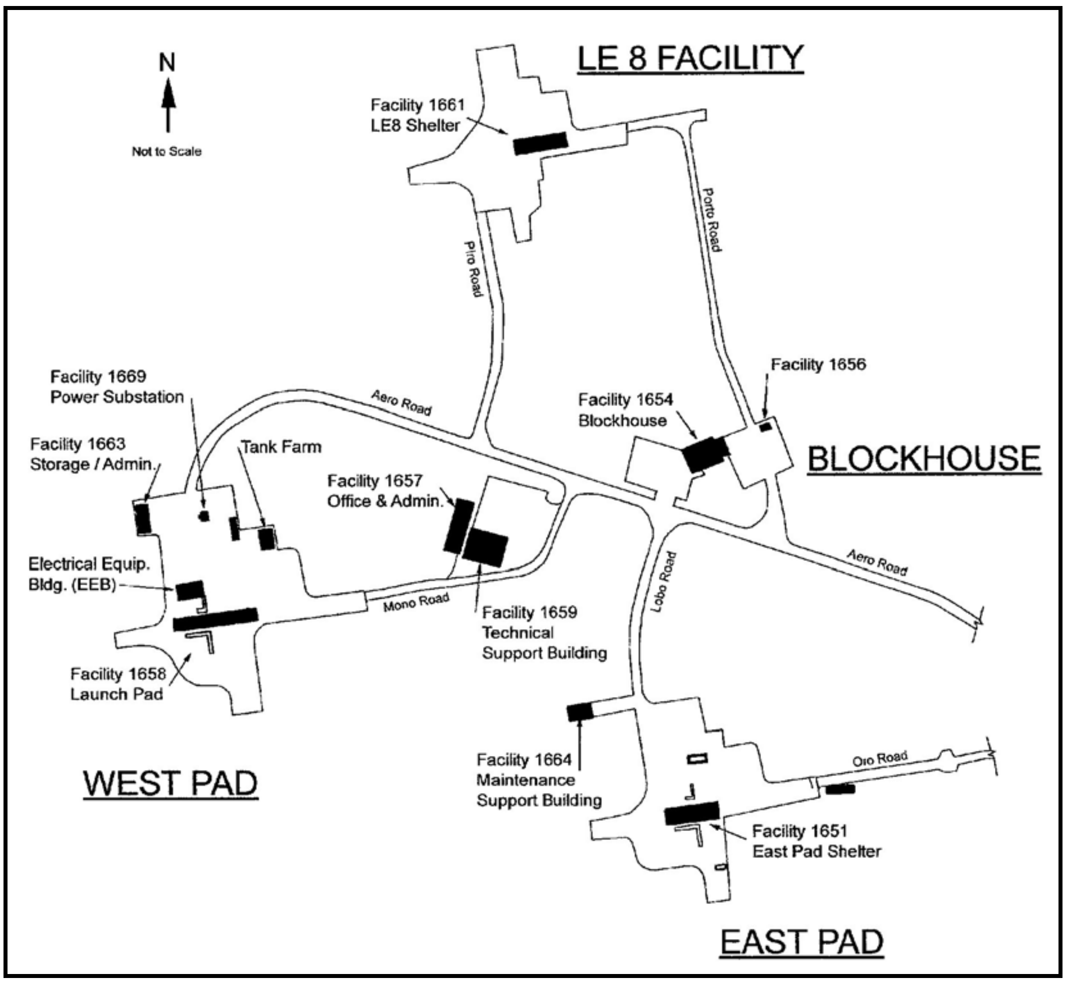

Figure 15: SLC-10 Layout

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130 Much of the information was obtained in numerous conversations with Mr. Donald J. Prichard since 1995.

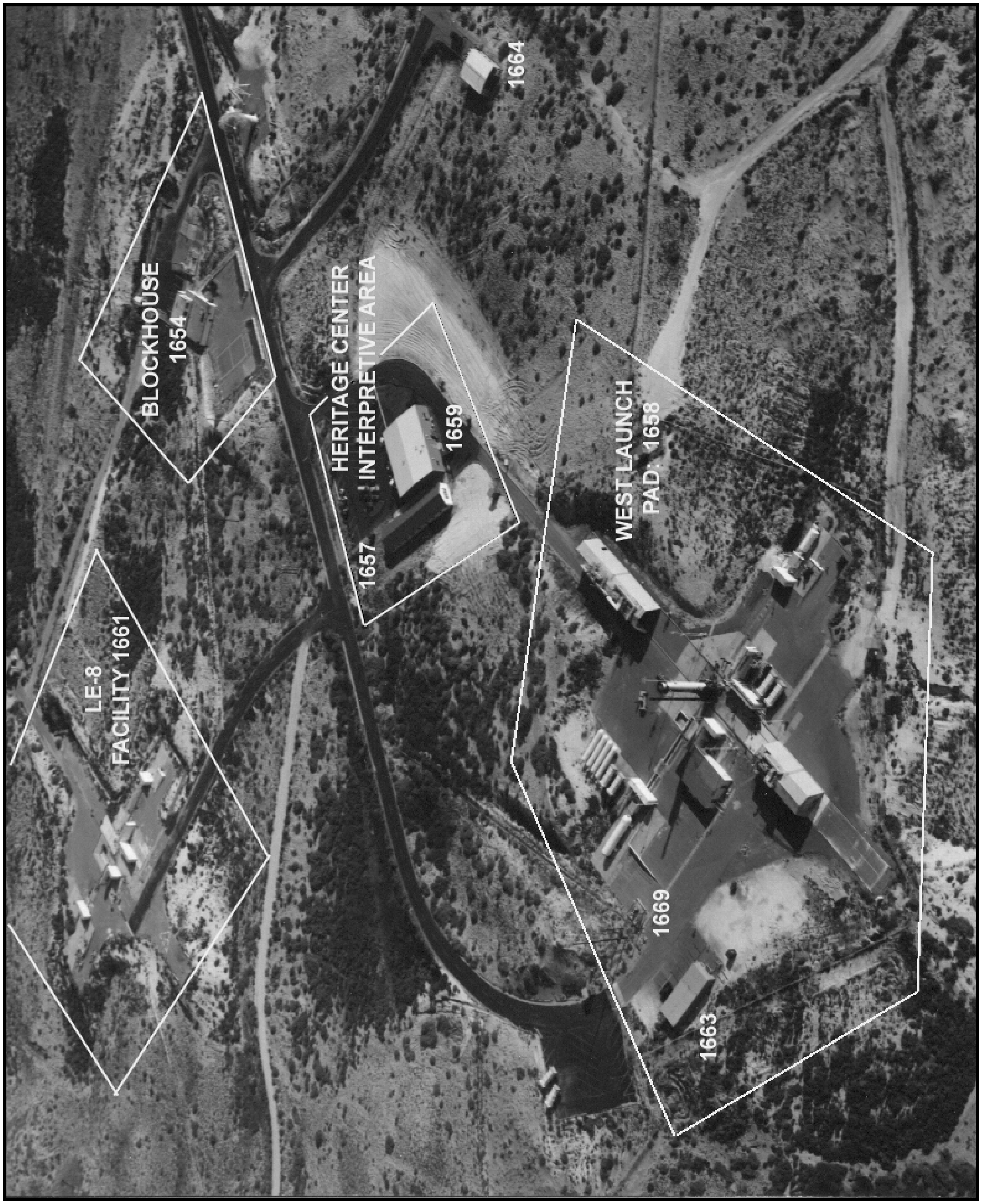

Figure 16: Aerial Photograph of SLC-10 Taken Mid-1970s

BLOCKHOUSE AREA AND SHARED FACILITIES

Facility 1654: Blockhouse (HAER No. CA-296-A)

The Blockhouse, also known as the Launch Control Center or the Launch Operations Building, served as the main control station for SLC-10. Originally, the Blockhouse was a single operations building controlling launch operations on the East Pad. In time, a second Blockhouse was constructed adjacent to and west of the original, or East Blockhouse. This Blockhouse controlled launch operations on the West Pad. (See photographs CA-296-A-1 through CA-296-A-12.)

East Blockhouse

The East Blockhouse, completed in 1959, is a one-story building containing approximately 1,600 square feet. The building was operated by the 392nd Missile Training Squadron as the operations and communications control center for launch activities on the East Pad. The building is T-shaped in plan measuring 52' wide by 43' in length (Figure 17).

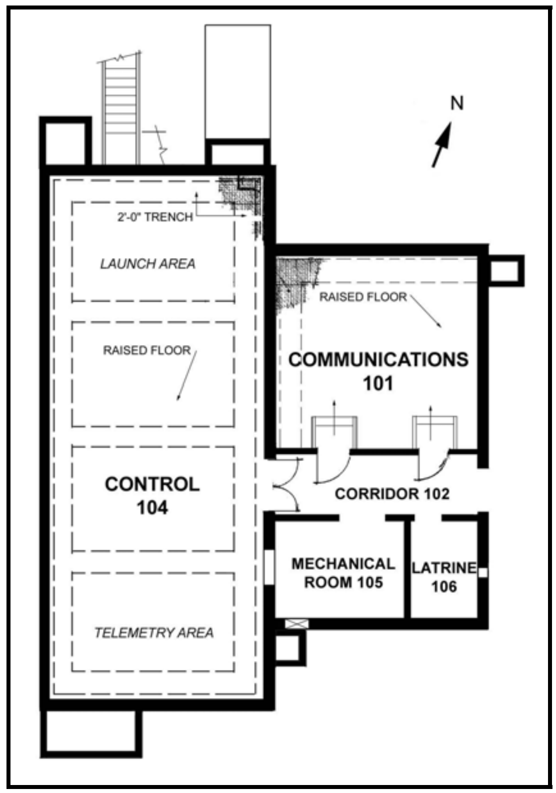

Figure 17: East Blockhouse Floorplan

The Blockhouse is of "hardened" construction designed to protect technicians, instrumentation, and sensitive equipment from the launch blast and toxic gases. The building must also withstand the shock of a misfired or exploding rocket. The foundation, floor, exterior walls and center wall are constructed of heavily reinforced concrete. The flat roof is constructed with layers of reinforcing steel embedded in high strength concrete.

Access into the East Blockhouse is possible from the northeast side through a 5-6" wide single-panel steel blast door. The blast door, which was closed during launches, protected the two sets of doors accessing the interior of the building. The interior of the building was divided into four rooms and a central corridor. Flanking the central corridor was the Communications room on the north side and a latrine and mechanical room on the south. The Control Room, measuring approximately 20' wide by 50' in length, formed the "T" at the west end of the corridor. The Control Room was further "divided" into the launch area on the north end and the telemetry area on the south end. Each area contained consoles, controls, equipment, monitors and TV stands specific to their designated missions. The Communications Room served as the communications hub for the entire complex.

Interior finishes included 2"x4" wood stud and ½" gypsum board partitions, asbestos resilient flooring, and acoustical tile and gypsum board ceilings. Two-foot wide concrete cable trays were imbedded within the concrete slab around the perimeter of the Control Room and through the dividing wall into the Communications room. Raised access floors were installed in both rooms to both cover and manage the hundreds of feet of cabling spanning between the launch support equipment within the Blockhouse and extending out to the launch pad.

Figure 18: Access ladder

Located in the northwest corner of the Control Room is a roof scuttle that provided emergency egress from the building. The scuttle measures 2'-0" by 2'-6" with a #14 gauge steel cover and steel ladder rungs (Figure 18).

As missions changed in response to advances in technology, the Blockhouse was modified and enlarged. By 1962, a wood-frame penthouse had been constructed and bolted to the flat roof of the Blockhouse. The two-room penthouse was a "self-help" project completed by students of the 392nd to provide extra study space. The penthouse measured 37'-6 ½" by 22'-3" and contains approximately 814 square feet divided into two rooms. The penthouse was constructed as a "wooden box" bolted to the top of the Blockhouse. The penthouse was constructed with 2"x6" wood joists and rafters, and 2"x4" wood studs sheathed with cementitious wall panels on the exterior and gypsum board on the interior. The ceiling was covered with acoustic tiles and the floors with 12" square tan vinyl tiles. Access to the penthouse was gained via an exterior steel staircase located on the north side of the building. Three of the four sides of the penthouse contained numerous sliding wood frame windows varying in size from 6'-4" wide by 3'-2" tall to 10'-1" wide by 3'-7" tall. The two doors measured 3' wide by 6'-8" tall. All window and door frames were painted blue.

West Blockhouse[131]

Along with the addition of the penthouse to the original Blockhouse, a second Blockhouse was constructed in 1964 and became known as the SLC-10 West Blockhouse. This Blockhouse was constructed along the southwest side of the original Blockhouse to house the 4300th Support Squadron. To maintain separation and autonomy between the two Squadrons, the SLC-10 West

[131] "Const Addn to Bldg 1654: Floor Plan, Sections & Schedules", Strategic Air Command, Vandenberg Air Force Base, California, Drawing Number 136-4, Sheet 3 of 10, Filed under 1654-4-3, (Strategic Air Command, Vandenberg Air Force Base, California, January 16, 1964); "Const Addn to Bldg 1654: Foundation & Roof Plans & Sections", Drawing Number 136-4, Sheet 4 of 10, Filed under 1654-4-4 (Strategic Air Command, Vandenberg Air Force Base, California, January 16, 1964); "Const Addn to Bldg 1654: Details", Drawing Number 136-4, Sheet 5 of 10, Filed under 1654-4-5, (Strategic Air Command, Vandenberg Air Force Base, California, January 16, 1964).

Blockhouse was constructed as a “free-standing” structure adjacent to the southwest wall of the original SLC-10 East Blockhouse (Figure 19). The shared center wall between the two Blockhouses was actually two separate reinforced concrete walls, one for each Blockhouse. The two Blockhouses continued to operate independently of one another with each squadron responsible for their own training and operations until 1968 when they merged to form the 10th Aerospace Defense Squadron. At that time, a doorway was cut in the shared center with the SLC-10 West Blockhouse becoming the single control center for the complex.

The building was used as the operations and communications control center for launch activities on the West Pad. The one-story, rectangular in plan building encompasses approximately 1,215 square feet, and measures 42’-4” wide by 52’-4” in length. Like the East Blockhouse, the West Blockhouse is also of “hardened” construction. The floor was constructed with a reinforced concrete foundation and a 4” reinforced concrete floor poured over undisturbed or compacted earth fill. Concrete tie beams span between the exterior and center interior footings. The center wall’s continuous footing measures 7’-6” wide by 1’-6” deep. Both the exterior walls and interior center wall measure 1’-2” thick with an interior room height of 9’. The flat roof is also 1’-2” thick constructed of layers of reinforcing steel embedded in high strength concrete covered with 5-ply built up roofing material.[132] For added protection, a shale berm was constructed around approximately two-thirds of the structure. The berm also served as a barrier against the wind coming off the Pacific Ocean.

Access into the West Blockhouse is possible from the southeast side through a single-panel steel blast door. The interior of the building is divided into five rooms and a central corridor. The rooms included the Launch Control Room, Telemetry Area, Mechanical Room, Latrine, and storage. The Launch Control Room and Telemetry Area contained launch operations and timing sequence equipment, consoles, monitors and TV stands. The Launch Control Room was further divided with an observation room at the north end. The walls were constructed of either 2” x 4” studs with ½” gypsum board or concrete masonry units. Twelve-inch acoustical tile was applied to the walls from floor to 6’ above the floor in the central hall, and rooms 1 and 2 for soundproofing. Acoustical tile was also applied to the ceilings. Both Control Rooms and the observation room were equipped with a raised access floor.

[132] “Const Addn to Bldg 1654: Foundation & Roof Plans & Sections, Filed under 1654-4-4.”

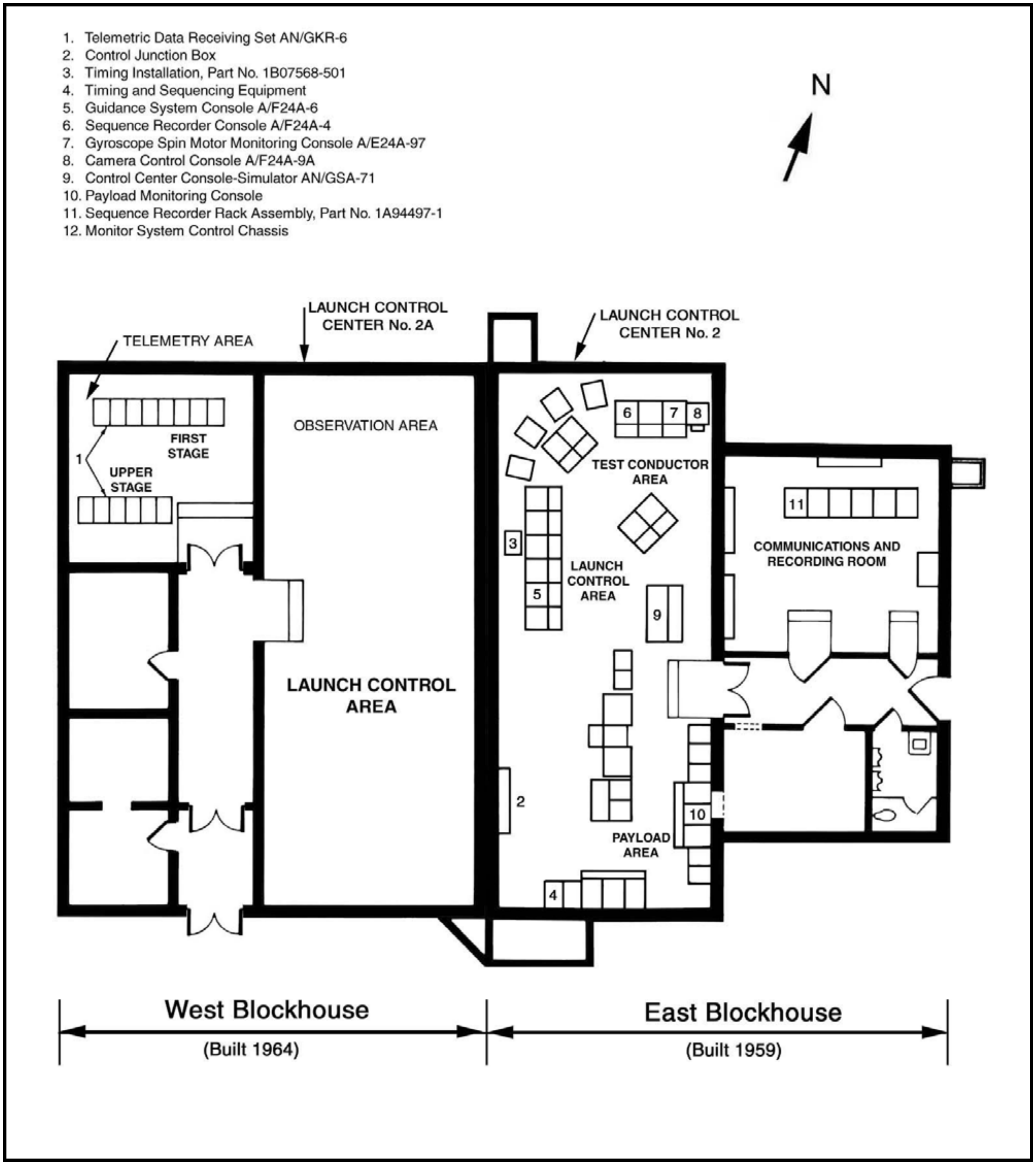

Figure 19: Combined Blockhouse

Figure 20: Technicians at Blockhouse Consoles

The Launch Control Areas contained numerous control panels, communications equipment and monitoring consoles used by technicians to monitor, test, and conduct pre-flight check-out of the space vehicle prior to and during launch proceedings[133] (Figure 20). Consoles included: Launch Conductor/Range Status, Space Launch Coordinator, Component Tester, Guidance System Phase 1, Fuel Monitor and Control, Safety and Targeting, Launch Monitor and Control, and the Launching Countdown and Checkout Set. The Launching Countdown and Checkout Set was a five-bay console designed to monitor and check the operation of the missile prior to launching. The left-hand bay contained a single monitor panel that metered the gyro circuits and a gimbal control panel to function and monitor the gimbal circuits. The other four bays contained propellant checkout systems, a recorder, relay control panels and various other indicators and controls to check the various missile functions.[134]

The Launch Control Area of the West Blockhouse still contains original launch support equipment. (See photographs CA-296-A-10 through CA-296-A-12.) A raised floor was installed in both the Launch Control Area and the Telemetry Area to house, manage, and organize the hundreds of feet of cabling needed to support and monitor launch operations at the launch pads from within the Blockhouse.

Launch personnel did not have a direct line of sight to any of the launch pads from the Blockhouse. Therefore, to provide a "line of sight" TV monitors were installed in the Control Rooms in both Blockhouses with camera stands strategically located throughout the SLC-10 complex.

Instrumentation Trench

A reinforced concrete instrumentation trench extends out to the launch pads from the east side of the original Blockhouse. A second trench is located on the north side of the East Blockhouse. The U-shaped instrumentation trenches, recessed several feet below grade, were designed to

[133] Some of the equipment in the Control Room remains operational. One console, for example, continued to function in the test position, unattended, from 1981 to 1991 (Mr. Donald J. Prichard, interview with author 11 January 1994).

[134] "CPC Launching Countdown and Checkout Set, DAC Model DSV-25-100", 18355, A, 1A04191, 1969.

protect the hundreds of yards of communication and electrical cabling from both the environment and the launch blast. The trenches were covered with removable treated 8" wooded slats to allow easy access by the technicians to the cables below.

When the West Blockhouse was constructed, the instrumentation trenches were modified to allow the cabling from the Blockhouse to use the existing trenches. The instrumentation trenches extend from the Blockhouse, follow the access road and terminate at the skid-mounted transformer units.

Antennae

Five antennae, two Teltrac, two Command, and one S-Band telemetry, were constructed to assist the Blockhouse with the checkout and launch of the rocket. The two Teltrac antenna towers were constructed of 4" diameter pipe columns supporting a 12'-0" square platform with 2"x10" wood framing sheathed with exterior grade plywood. The top of the north tower platform was at 24' above grade while the south tower platform was at 6' above grade. Four 4' square by 2' deep reinforced concrete piers supported the corners of the tower. The plywood platform was enclosed with 3'-6" high 1 ½" diameter pipe posts with 5/8" diameter nylon rope spanning between the posts. The antenna support was 48" outside diameter steel plate flush with the plywood platform and supported by an 8" wide flange beam from below. Both the north and south towers were equipped with 28" wide steel open rung ladders accessing the platform. The north tower ladder was enclosed with a safety cage.[135]

The two square command antenna towers were constructed of 4" diameter pipe columns supporting a 9'-6" x 8' plywood platform. The top of the north tower platform was at 19' above grade while the south tower platform was at 18' above grade. Four 3' square by 1'-6" deep reinforced concrete piers supported the corners of the tower. The plywood platform was enclosed with 3'-6" high 1 ½" diameter pipe posts with 5/8" diameter nylon rope spanning between the posts. The antenna support was 26" outside diameter steel plate flush with the plywood platform and supported by an 8" wide flange beam from below. A 2' wide ladder provided access to the platform.[136] The command towers were located adjacent to the east and west sides of the Blockhouse. With the decommissioning of the Thor program at SLC-10, all of the antennae were dismantled and removed.[137] The foundations of the command antenna towers are still visible adjacent to the Blockhouse.

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[135] "Launch Complex 75-2 Modifications, Launch Operations Bldg.: Teltrac Antenna Towers, Plan, Sections & Details", Specification No. OC1-ASI-63-42 (Rev), Drawing Number: S-8, Filed under 1654-3-6, Department of the Air Force, Space Systems Division (AFSC), Inglewood, California, (Koebig & Koebig, Inc., Engineering / Architecture, Los Angeles, CA, August 1963). The exact location of the Teltrac antennae could not be determined.

[136] "Launch Complex 75-2 Modifications, Launch Operations Bldg.: Command Antenna Towers, Plan, Sections & Details", Specification No. OC1-ASI-63-42 (Rev), Drawing Number: S-9, Filed under 1654-3-7, Department of the Air Force, Space Systems Division (AFSC), Inglewood, California, (Koebig & Koebig, Inc., Engineering / Architecture, Los Angeles, CA, August 1963).

[137] The exact date of the decommissioning and dismantlement of the antennae is unclear as many of the Real Property records of the complex from that period cannot be located.

The S-Band Telemetry Antenna was installed in 1969 on a berm across the road and to the south of the Blockhouse (Figure 21). The pedestal-mounted antenna was located within a fenced area 36' square. The actual antenna foundation 10' square. Communication, control and power lines were located in an existing cable trough that connected to the Blockhouse.[138]

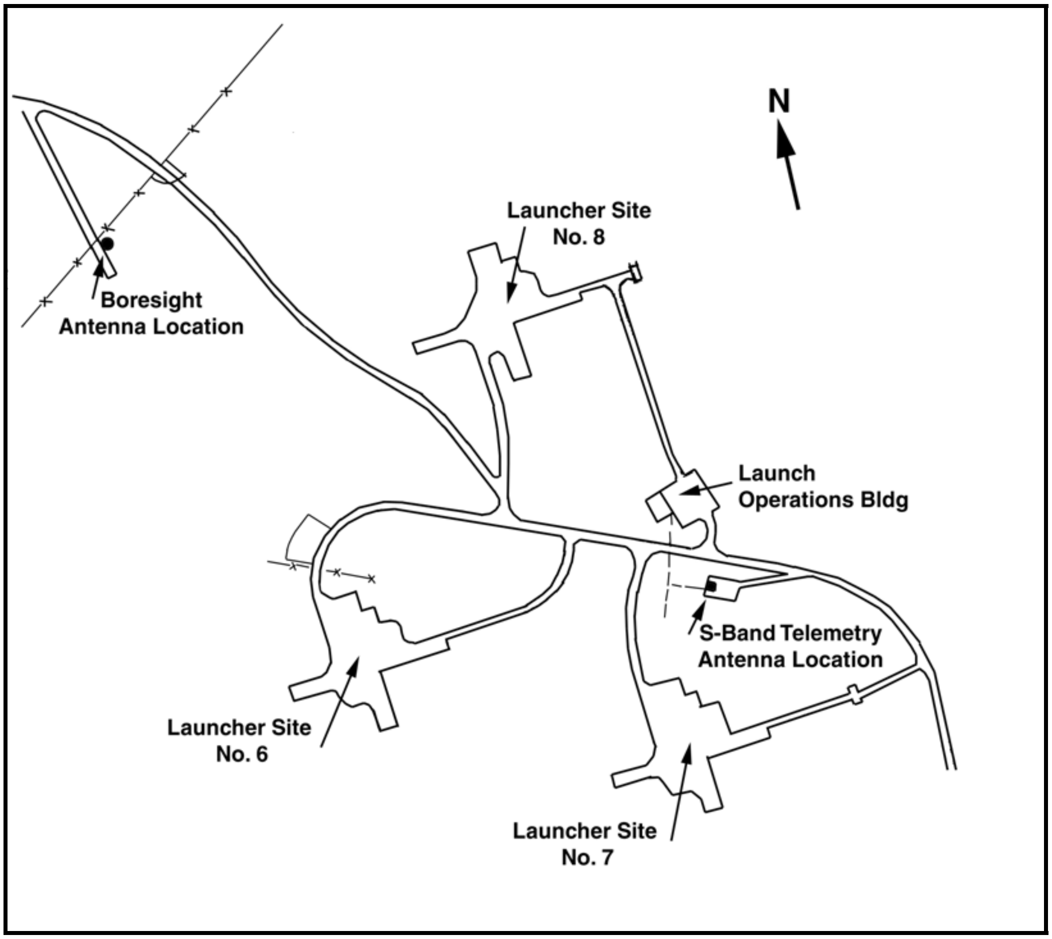

Figure 21: Vicinity Map of S-Band Antenna and Boresight

The Telemetric Data Receiving Set AN/GKR-6, a complete telemetry ground station (TMGS), consisted of two sections. One section was designated "First Stage TMGS." The second system was designated the "Upper Stage TMGS." The complete TMGS would monitor input signals from either a first stage launch vehicle or a combined first and upper stage launch vehicle. The TMGS was a passive electronic system that gathered information from a remote location. The information was transmitted to the TMGS by radio, via a remote antenna system or through a

[138] "Paving and Miscellaneous, SLC-10 East, Antenna Area", Filed under Drawing NO. 1655-1-1, (Department of the Air Force, Space and Missile Test Center, June 1970). No information on the actual construction of the S-Band antenna itself was located.

closed loop coax land line to receivers within the ground station where it was recorded. The TMGS contained the electrical equipment necessary for signal condition, demodulation, discrimination and reproduction of data signals, decommutation of sampled data, recording of data, and quick-look display of analog signals.[139]

The boresight antenna pad, located at the far northwest side of the SLC-10 was used to align the S-Band telemetry antenna.[140] The boresight consisted of a concrete pad, wood pole, and a bronze point. The 8’ x 8’ x 1’ poured concrete pad supported not only the boresight pole but the 480v to 120/240v transformer, breaker panel telemetry power supply and grounding equipment as well. The 85' tall pole supporting the sighting instrument was of treated Class I Douglas Fir. Plastic moulding covered the bottom 10’ of the pole thereby discouraging animals from climbing the pole and disrupting service. Atop the wood pole was a government furnished 12” solid bronze full nickel plated point that served as the actual sighting mechanism. A 3/8” 7 strand guy wire stabilized the boresight pole from excessive movement.[141]

Facility 1656: Metal Building (HAER No. CA-296-B)

Facility 1656 (no official building name and is referred to as the Metal Building) is a World War II temporary cantonment-type structure originally built in the main cantonment area at former Camp Cooke in 1942. The building was relocated to its present location to support activities at SLC-10 in 1972. Equipment housed in the facility allowed technicians to monitor power generation.

The building is a small rectangular facility encompassing 166 square feet. The wood-frame building was constructed on the existing concrete slab with a 4” x 6” redwood base foundation. The walls are sheathed with corrugated metal siding as is the low-pitched gable roof. The building contains four multi-lite double-hung wood windows, one per facade. A single personnel door is located on the east side of the building. (See photograph CA-296-B-1.)

Facility 1657: Office and Administration Building (HAER No. CA-296-C)

The Office and Administration Facility, also known as the Technical Orders (TO) facility, is a 1942 World War II temporary cantonment-type structure originally located in the main cantonment area at former Camp Cooke. Originally used for storage and designated as Building T-6401, the structure was moved to its present location in 1964 to support activities at SLC-10. The facility, now classified as a semi-permanent structure, has undergone modifications over the

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[139] Technical Manual Operation and Maintenance Instruction T.O. 31s7-2GKR6-1, “S-Band Only, Telemetric Data Receiving Set AN/GKR-6”, prepared under contract AF04(695)-309, F04701-69-C-0007, (McDonnell Douglas, Santa Monica, CA, July 1969, changed September 1969), 1-1 thru 1-2.
[140] “Guide to Terminology for Space Launch Systems”, American Institute of Aeronautics and Astronautics, ANSI/AIAA G-057-1994, (Washington DC, 1994).
[141] “S-Band Telemetry Antenna Installation, Antenna Enlargements & Details”, Filed under Drawing No. 1666-1-8, Vandenberg AFB, DACA09-69-B-0108, (Quinton Engineers, Ltd. Los Angeles, CA, April 1969).

years to support the changing needs of the complex. The TO Facility served at various times as a storage shed, a snack bar, a break area, and as administrative space for the pad chief and staff. Records of the complex's mission can be found in this facility in the form of an entire interior wall covered with Thor technical orders. In 1987, this facility was transferred to the Vandenberg Air Force Base Space and Missile Heritage Center and placed under caretaker status. (See photographs CA-296-C-1 through CA-296-C-5.)

When the building was moved in 1964, it underwent alterations to support the pad's activities (Figure 22). The one-story wood-frame building, containing 2,740 square feet, is constructed on a 4" reinforced concrete foundation, sheathed with horizontal wood siding, and a gable roof with asphalt shingles. The multi-lite double-hung wood windows were repaired and reused throughout the building. Two existing sliding doors, trim and hardware were removed and new wooden doors installed. The existing exterior sliding door in Room 3 remained. A new wood frame wall was constructed approximately 35' from the north end of the building thus dividing the interior into three rooms. Room 1 was located at the north end. Gypsum board was installed on all interior walls and the ceiling of Rooms 1 and 2. The third room was left unfinished.

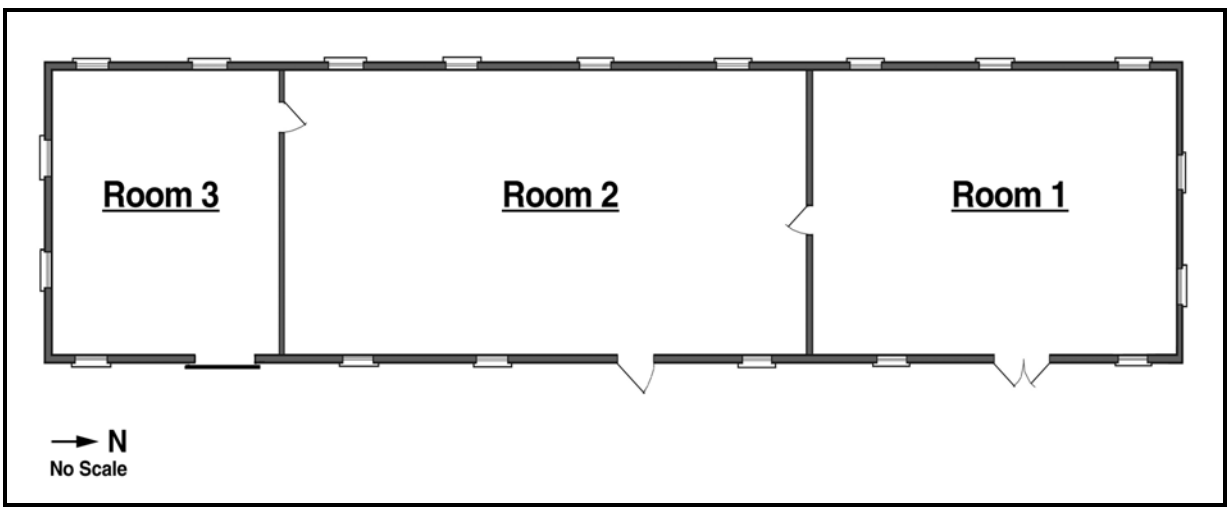


Figure 22: Floor Plan of Building 1657 in 1964

After the Vandenberg Air Force Base Space and Missile Heritage Center became caretaker of the launch pad and related facilities in 1987, the building again underwent alterations. Alterations included subdividing the interior of the building into five areas (Figure 23). The 1964 wall between Areas 1 and 2 was removed and two new 2"x4" wood frame walls were constructed thus creating Areas 1, 2 and 3. Area 1 now contains the entry vestibule, mechanical room, unisex bathroom, and caretaker's office. Areas 2 and 3 now contain museum displays. Area 4 is currently used for model construction and storage. The word "Thor" was originally inlaid in the floor of Area 4 with red asbestos tiles. The original layout was removed when the asbestos was abated from the building and was authentically replicated using composition tiles.

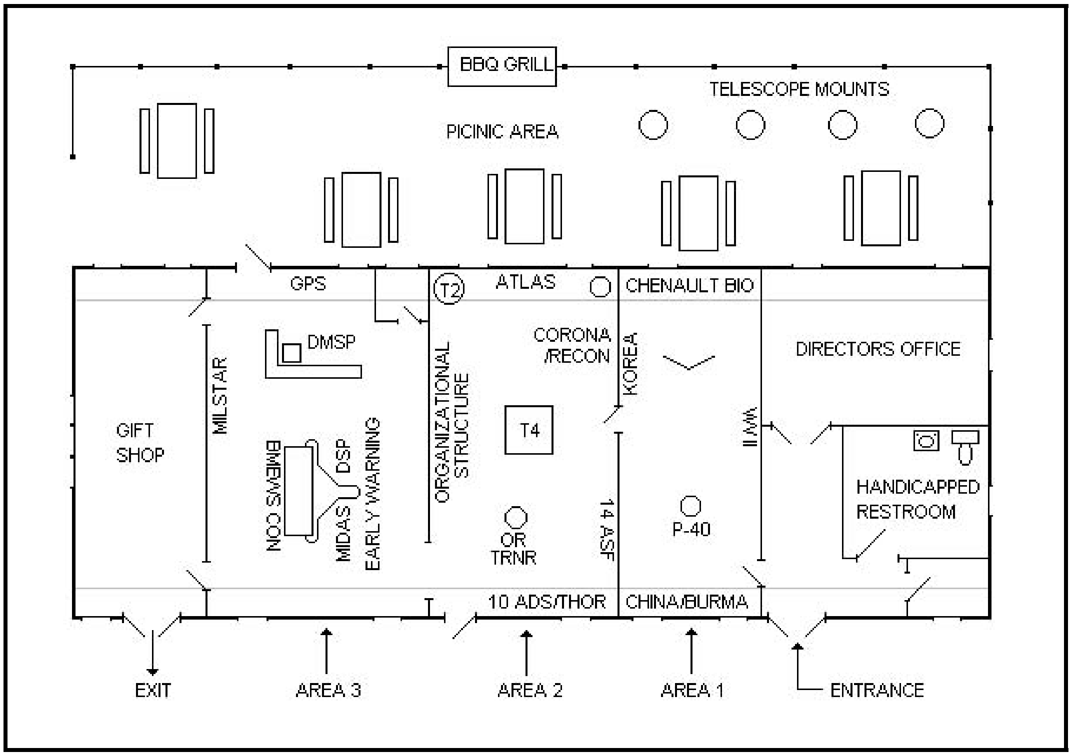


Figure 23: Proposed 14th Air Force Exhibit Layout

Facility 1659: Technical Support Building[142] (HAER No. CA-296-D)

The Technical Support Building (TSB) was constructed in 1977 to provide support space for on-site contractors. The one-story rectangular building, encompassing 4,810 square feet, measures 60'-0" x 80'-2" and is oriented in the east-west direction. (See photographs CA-296-D-1 through CA-X-296-6.)

The building foundation is constructed on a 6" poured reinforced concrete slab with 6"x6" 1.4/1.4 wire mesh and the finished floor at a minimum of 6" above grade. The building is a pre-engineered building with the north, east and south walls constructed of metal panel siding

[142] "SLC-10 W Alteration, TSB Structural Plans & Details", Drawing Number S-8, D.O. File No. 1801/174 (1658-11-14), Spec. No. DACA09-76-B-0016, Vandenberg Air Force Base, CA, Department of the Air Force, Space and Missile Systems Organization, Los Angeles, CA, (S&T Western, Inc., Consulting Engineers, a Unit of STV, Inc., Long Beach, CA, February 1976); "SLC-10 W Alteration, Technical Support Building Plan, Elevations & Section", Drawing Number A-4, D.O. File No. 1801/179 (1658-11-19), Spec. No. DACA09-76-B-0016, Vandenberg Air Force Base, CA, Department of the Air Force, Space and Missile Systems Organization, Los Angeles, CA, (S&T Western, In., Consulting Engineers, a Unit of STV, Inc., Long Beach, CA, February 1976); "SLC-10 W Alteration, TSB Schedules & Details", Drawing Number A-5, D.O. File No. 1801/180 (1658-11-20), Spec. No. DACA09-76-B-0016, Vandenberg Air Force Base, CA, Department of the Air Force, Space and Missile Systems Organization, Los Angeles, CA, (S&T Western, In., Consulting Engineers, a Unit of STV, Inc., Long Beach, CA, February 1976).

(corrugated) bolted to a steel I-beam structure. The west wall is constructed with 8” x 8” x 16” concrete masonry units with all cells filled solid with grout. The west wall was constructed of concrete masonry units to assist in protecting the building from any residual effects of the launch blast from the West Pad. The slightly pitched gable roof is also constructed with metal panels. The doors leading into the building were originally hollow core metal. Several of the original doors have been replaced with fiberglass doors. The windows are sliding anodized natural aluminum with ¼” clear tempered plate glass.

The interior of the building was constructed with three shop areas separated by a support core. (Figure 24). The west end of the building originally contained the electrical shop and was accessed by a pair of steel doors. The east end of the building, and the largest of the spaces, contained both the Machine Shop Equipment Area and the Mechanical and Maintenance Shop. A steel roll-up door, centered on the east wall, provided access into this area. A two-ton hoist set on a monorail beam bisected the two areas in an east-west direction. Two additional steel personnel doors were located in the southeast and northwest corners of the space. The floors, walls, and ceiling structure were left exposed with batt insulation placed in the walls and ceiling.

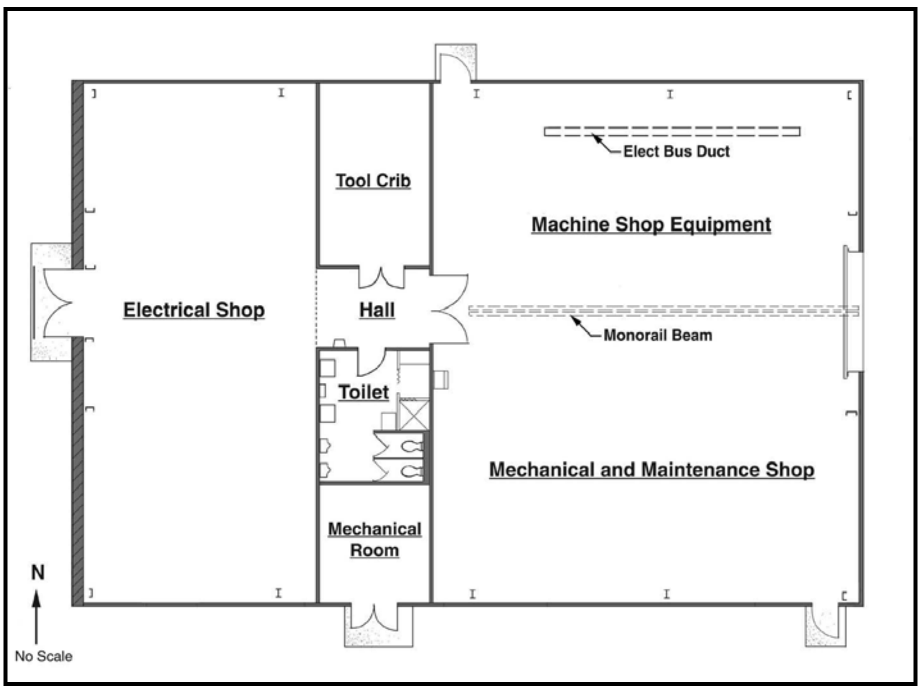


Figure 24: Building 1659 Original Floorplan

The 12’-0” wide central support core consisted of a tool crib, toilet room, and mechanical room. An 8’ hall separated the tool crib on the north from the toilet room and mechanical room to the south. The mechanical room was accessed from the outside of the building. The support core was framed with 2” x 6” wood studs at 16” on center and ½” gypsum board. Ceramic tile was installed in the toilet room for moisture control. The toilet room contained two stools, two urinals, two lavatories, one service sink and a shower/drying area.

The facility was supplied with 480v power to support a complete machine shop and fabrication workshop for the west launch pad. Technicians performed maintenance on Aerospace Ground Equipment (AGE) such as air conditioning trailers and hydraulic power units in this facility. The facility also served as a tool crib.

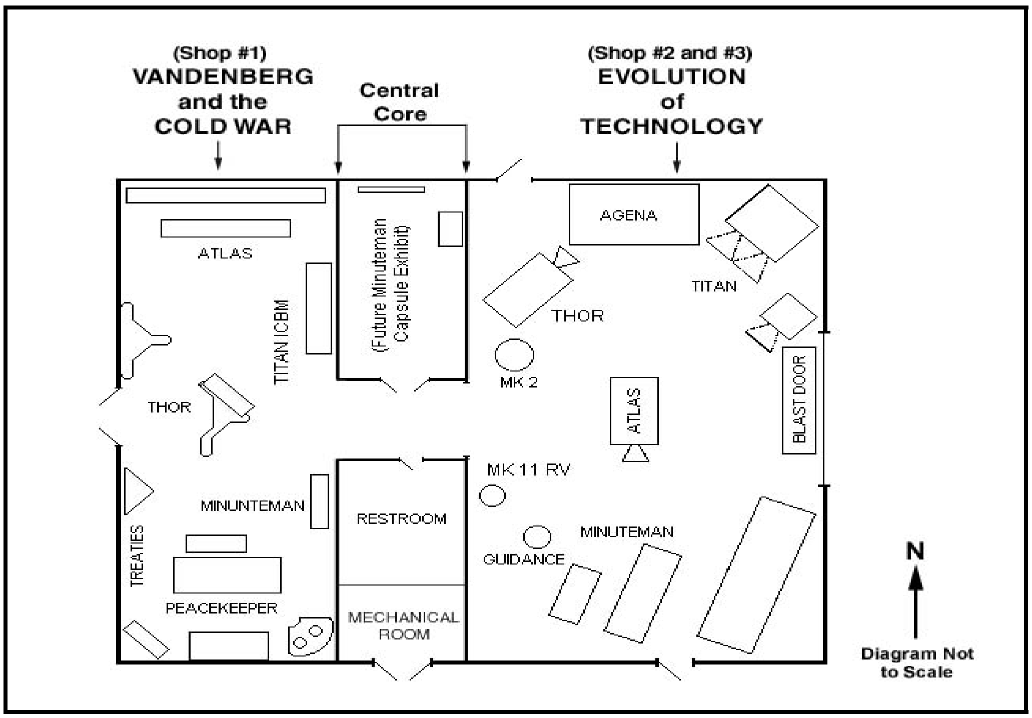


Figure 25: Facility 1659 Exhibit Layout

When the building was put under the control of the Vandenberg Air Force Base Space and Missile Heritage Center, it use was changed from support and maintenance for the west launch pad to a museum/exhibit space for the entire complex. The interior structure of the building was not modified, however, fabric was draped over the walls and new exhibit lighting was installed (Figure 25).

Facility 1665: Hydrogen Peroxide Pumping Station (HAER No. CA-296-E)

The Hydrogen Peroxide Pumping Station is located behind the dismantled LE-8 Pad. Hydrogen peroxide was brought to the station in tank carts and then pumped out to each pad. The Hydrogen peroxide was used by the rocket's payload. Hydrogen peroxide is highly explosive under certain conditions. For this reason, the Pumping Station was located approximately 100 yards northeast of the inactive LE-8 Pad and was therefore, physically separated from the active Pads, 10-W and

10-E. As a further measure, launch technicians were required to wear protective suits at all times when handling the hydrogen peroxide.

The storage and pumping equipment were located in a rectangular steel frame structure that is two bays long and one bay in width. The structure does not have side walls and is covered with a slightly pitched corrugated metal gable roof. (See photograph CA-296-E-1.)

SLC-10 EAST PAD

Launch Area

SLC-10 East Pad was originally constructed to support Royal Air Force (RAF) training Thor IRBM launches in 1959. In 1962, the Air Force dismantled both the East and West pads and transported the equipment to Johnston Island in support of the Program 437. To support Program 437 Douglas Aircraft was contracted to rebuild both the East and West Pads at SLC-10. The East Pad, rebuilt maintaining the original THOR IRBM complex configuration using equipment from dismantled Thor IRBM sites located in England, supported Program 437 crew training exercises (Figures 27 and 28).

The East Pad is located approximately 400' southeast of the Blockhouse. Access to the pad is possible via Lobo Road and Oro Road off of Aero Road. The primary facility on the East Pad was the Launch Shelter (Facility 1651). The pad consists of the Missile Shelter, propellant facilities, and support facilities. Launch equipment surrounding the shelter and supporting the missile during launch included the Maintenance Support Building (Facility 1664), liquid oxygen (LOX) storage facility, Rocket Propellant (RP-1) fuel storage facility, propellant transfer equipment, gaseous nitrogen (GN_2) facility, numerous power, hydro-pneumatic, electrical equipment, and air conditioning trailers, theodolite station, camera stands, and cabling networks which electrically connect the launch emplacement to the Blockhouse. All of these facilities, except for the Maintenance Support Facility, have been collectively designated as Facility 1651. (See photographs CA-296-I-1 through CA-296-I-4.)

Facility 1651: East Pad (HAER No. CA-296-F)

Missile Shelter and Supporting Facilities

The Missile Shelter, the primary facility on the east launch pad, is centrally located on the pad and oriented in an east-west direction. The western end of the pad, towards the Pacific Ocean, was considered down range (See photograph CA-296-F-1 and CA-296-F-2). The Missile Shelter was flanked on the north and south sides by aerospace ground equipment, fueling systems, and communications and camera equipment.

To the north of the Missile Shelter was an L-shaped reinforced concrete blast wall (measuring 5' thick by 15' tall) originally constructed to protect the trailer-mounted missile launching countdown group, hydraulic pumping unit, trailer-mounted air conditioner, the check-out trailer, power pack trailer, electrical sub-station trailer and communication poles. The concrete overflow basin was also adjacent to the Missile Shelter and collected any fuels or liquids dumped from the rocket. Farther to the north was a second blast wall protecting the LOX storage tank, LOX pipeline outfit, GN_2 tanks, and trailer-mounted vacuum. Located in front of the blast wall was the skid-mounted power transformer unit which "stepped down" the incoming power source to a usable 480v AC. The skid-mounted design provided for quick and easy transport of equipment. This unit is functioning and powers the remaining equipment at the pad. Concrete instrumentation trenches spanned between support trailers, propellant farms and the Missile Shelter. To the south of the Missile Shelter was a second L-shaped blast wall protecting nitrogen tube trailers, the helium trailer, and hydro-pneumatic pump trailer. Farther to the south, approximately 100’ from the Missile Shelter, was a second blast wall protecting the RP-1 fuel storage facility, fuel pipeline outfit, and the trailer-mounted fuel filter unit. The majority of the equipment and fueling systems have been removed.

The Missile Shelter provided an environmentally protective enclosure for the launch vehicle, erecting-transporting boom, and erecting-launching mount during build-up and check-out. The panelized pre-fabricated shelter was constructed of ten bent-column ribs sheathed with steel, paper-honeycomb-filled panels. Prior to modification, the shelter measured 108’ long, 28’-10” wide and 20’ tall. The two different sizes of wall panels used were 8’ and 3’-11” in width by 15’-7” tall and 2 ½” thick (Figure 29). (See photographs CA-296-F-3 through CA-296-F-7.)

During assembly, check-out and pre-launch proceedings, the shelter was closed protecting the missile in a horizontal position. The interior of the shelter was equipped with hoses, valves, electrical and communication lines, convenience outlets, interior lights, hoists, auxiliary switchboard, warning horn, override, limit and manual control switches. The shelter was also equipped with retractable access platforms and two hook block hoists suspended from I-beams each with a ½ ton capacity.

The retractable access platforms, located on both sides of the shelter, were hinged thus allowing the platforms to be raised and lowered. This allowed technicians to work on all aspects of the missile during mating and pre-launch procedures (Figure 26). (See photograph CA-296-F-16.)

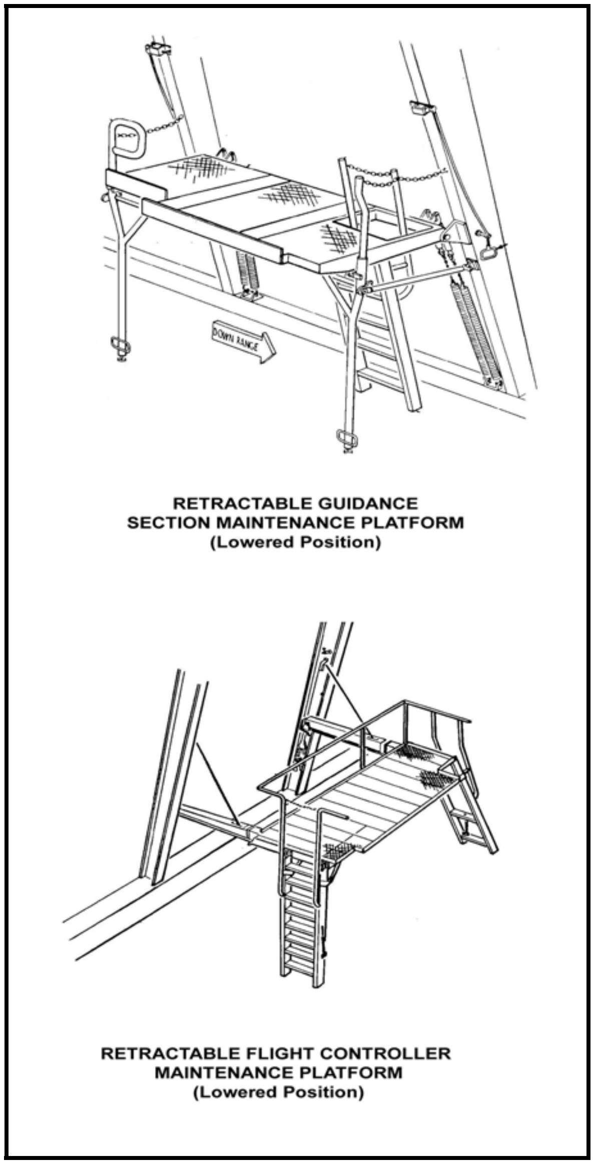
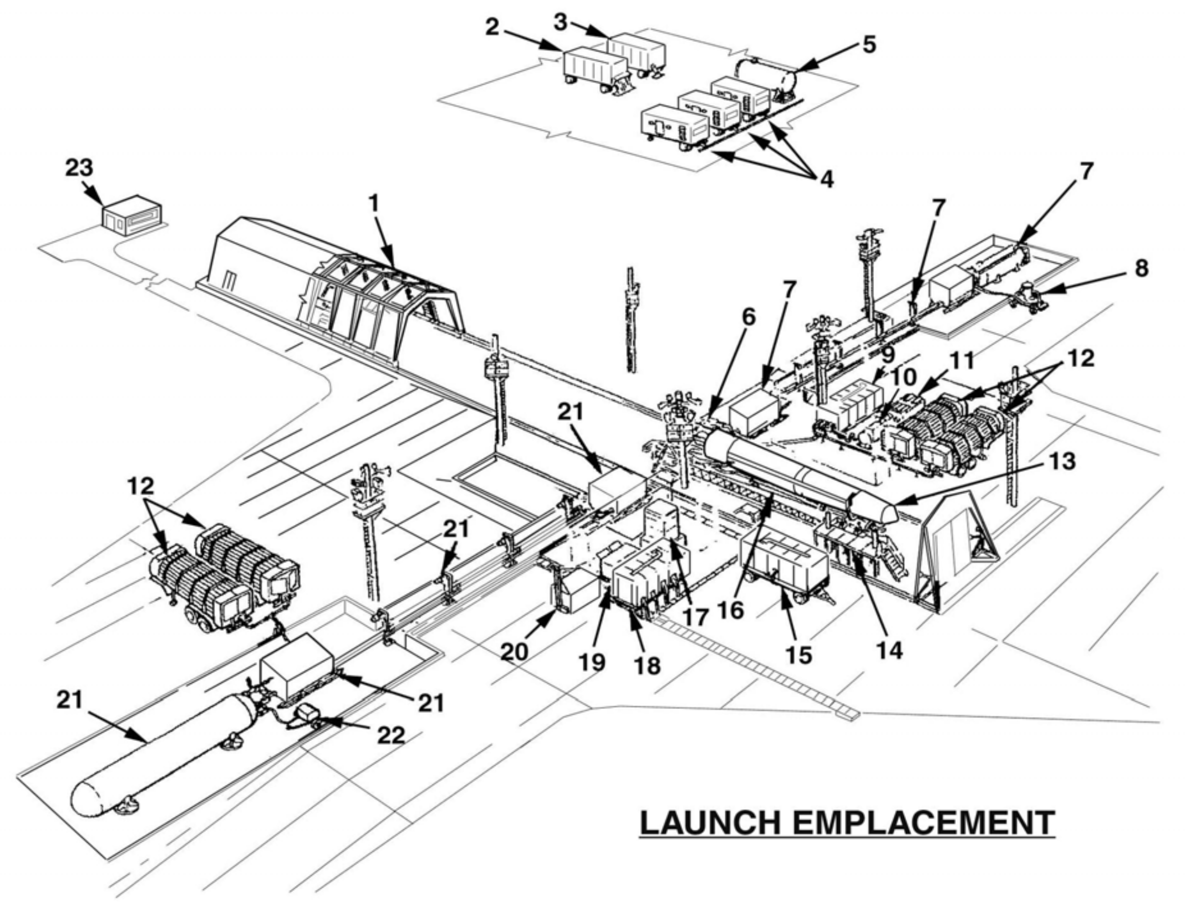


Figure 26: Work Platforms



Key

1. Panelized Prefabricated Building SHU-2/E
2. Trailer-Mounted Power Switchboard JEU-2/M
3. Trailer-Mounted Launching Control Group A/M24A-2
4. Trailer-Mounted Diesel Engine Generator Set AF/M32A-12*
5. Diesel Fuel Storage Tank TMU-5/E*
6. Ballistic Missile Erecting-Launching Mount MTU-1A/E
7. Fuel Pipeline Outfit GSU-6/E and Fuel Storage Tank TMU-4/E
8. Trailer-Mounted Fuel Filter Unit GSU-7M
9. Trailer-Mounted Hydro-Pneumatic Systems Controller AF/M46A-1
10. High Pressure Gas Storage Tank TMU-6/E*
11. Power-Driven Reciprocating Compressor A/M32A-27*
12. Compressed Gas Cylinder Semitrailer AF/M32A-17 Typical (2 Places)*
13. SM-75 Missile*
14. Short Range Azimuth Alignment Electrotheodolite AN/GVQ-3
15. Trailer-Mounted Ballistic Missile System Checkout STation TTU-92/M*
16. Ballistic Missile Erecting-Transporting Boom GSU-33/E, And Rear Dolly GSU-32/M
17. Trailer-Mounted Air Conditioner AF/M32C-1*
18. Trailer-Mounted Missile Launching Countdown Group A/M24A-1A
19. Hydraulic Pumping Unit PMU-14/E
20. Skid-Mounted Power Switchboard JEU-1/E
21. Liquid Oxygen Pipeline Outfit GSU-5/E
22. Trailer-Mounted Vacuum Pump PMU-1/M
23. Long Range Azimuth Alignment Electrotheodolite AN/GVQ-4

*This Equipment Located at the Launch Emplacement and Rim Building

Figure 27: Standard Launch Emplacement for Thor IRBM Launch Vehicles

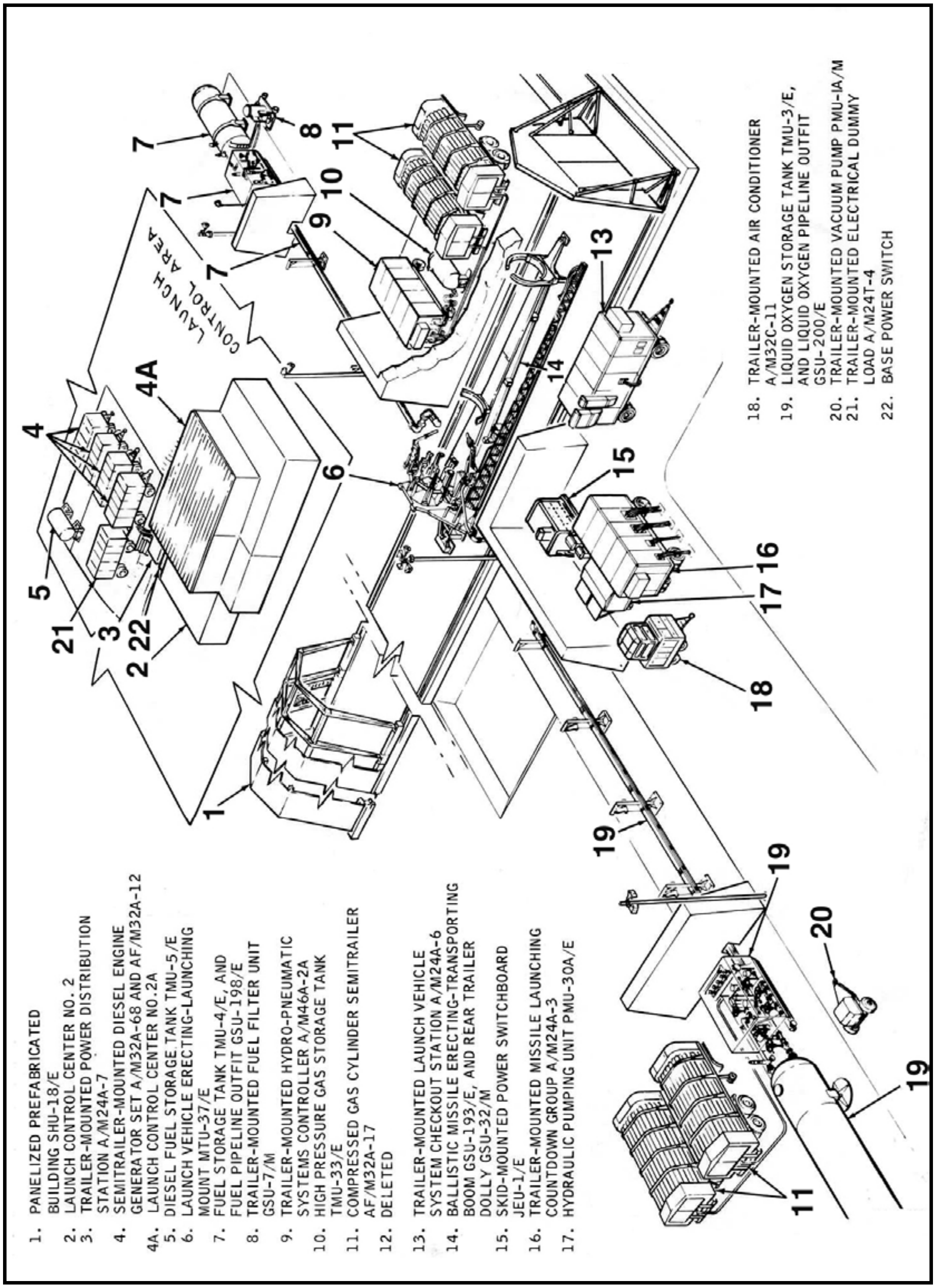


Figure 28: Standard Launch Emplacement for Thor IRBM Program 437

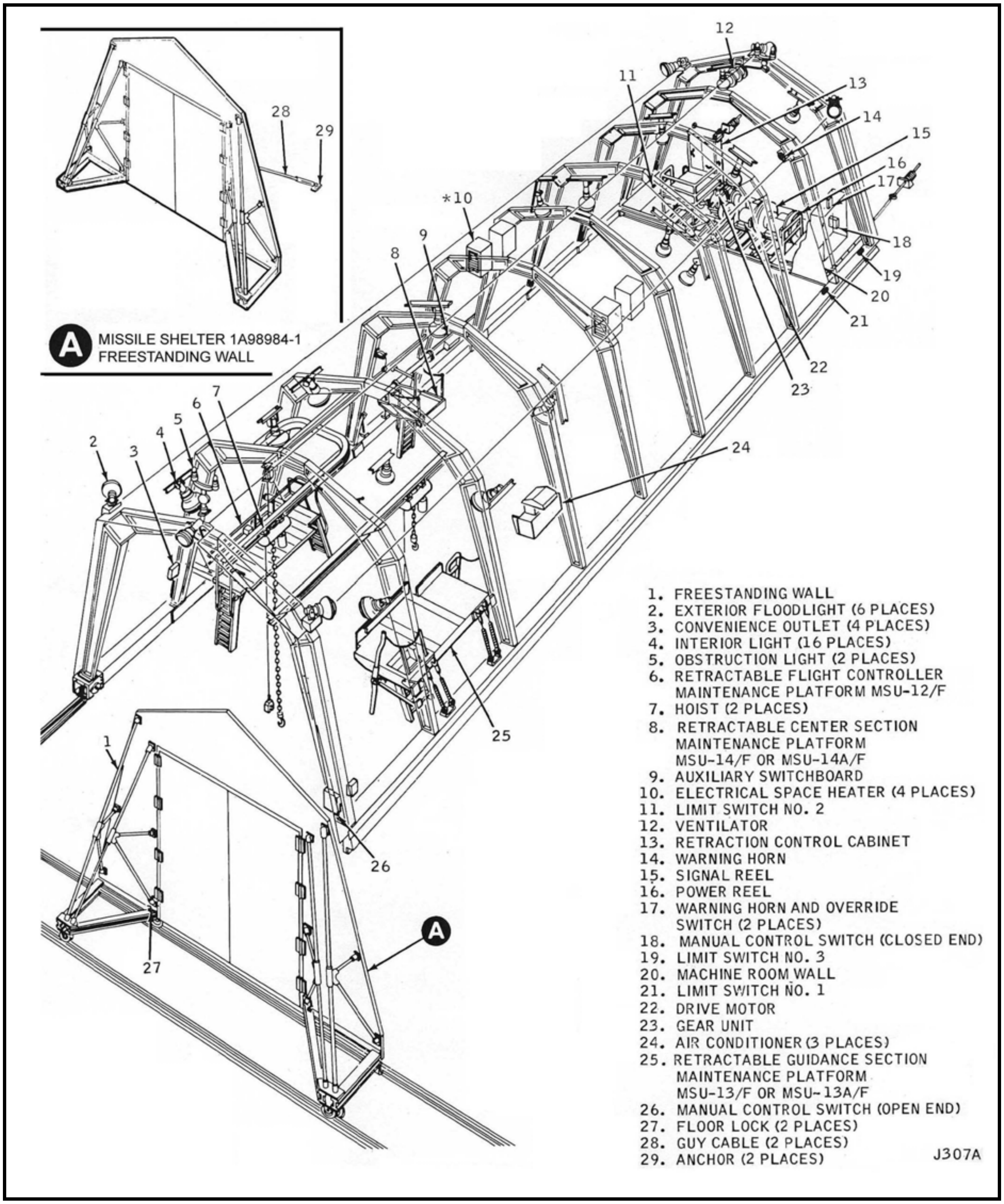


Figure 29: Standard Missile Shelter Components

Transportation and mating of launch vehicle consisted of three basic components: the Erecting-Transporting Boom; the Hydraulic Pumping Unit; and the Missile and the Launch Vehicle Erecting-Launching Mount.[143]

Build-up of the missile began with the delivery of missile components to the launch complex by means of the erecting-transporting boom, a truck-pulled trailer. The free-standing wall doors, at the west end of the Missile Shelter, were opened to allow the erecting-transporting boom to be maneuvered into the shelter and mated to the erecting-launching mount, where missile assembly began. The first stage of the missile was attached to the upper launch mount with threaded pins. Additional stages were then added in sequence until complete. The trailer remained in position, supporting the missile, until the missile was raised to a vertical position.

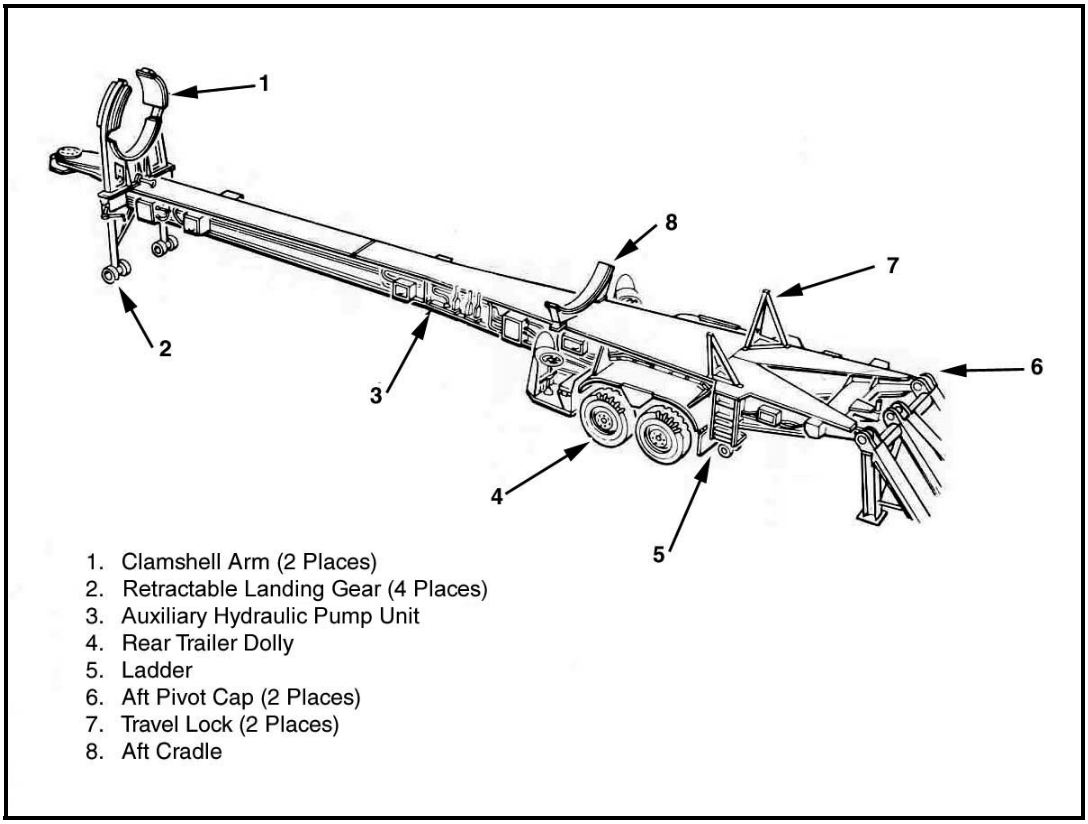


Figure 30: Erecting-Transporting Boom

The erecting-transporting boom functioned as a transporting unit for the launch vehicle with the addition of a steerable Rear Trailer Dolly and a prime mover, an M-52 truck-tractor. The

143 Technical Manual Maintenance Instructions - T.O. 21M-437-2-8 "Launch Vehicle Erecting – Launching Mount System", (Published under authority of the Secretary of the Air Force, 15 May 1964, change 17-15 June 1973), 1-1 thru 1-3.

erecting-transporting boom had a forward cradle with hydraulically operated clamshell arms, an aft cradle, and travel locks for holding the launch vehicle in place during transport and erection (Figure 30). The boom also contained an auxiliary hydraulic pump unit and attaching devices for connecting the boom to the erecting-launching mount and aligning the vehicle during mating procedures. Attaching devices were used to secure the connection of the erector lever to the launch mount and as pivot points for the erecting-transporting boom during launch vehicle erection. Four retractable landing gears, two forward and two aft, assisted with the alignment procedures and also supported the erecting-transporting boom in the horizontal position.

The erecting-launching mount, in conjunction with the erecting-transporting boom, erected and supported the launch vehicle using electrical power and hydraulic pressure from the hydraulic pumping unit (Figure 31). The erector cylinder raised and lowered the launch vehicle and boom. Attached to the erecting-launching mount were fuel, liquid oxygen, and electrical power services. Actuators associated with each of the service masts and with the launch vehicle support legs retracted these components at lift-off.

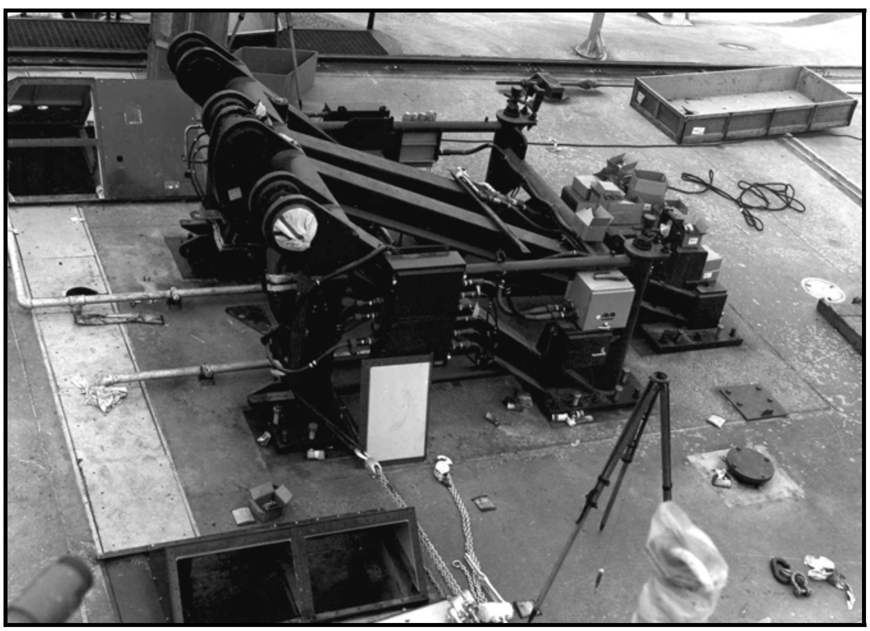


Figure 31: Lower Launch Mount

The erecting-launching mount was composed of two sections: a lower launch mount (containing assemblies, an erector cylinder, an erector lever and link, leveling jacks, a hydraulic manifold, and an electrical junction box), and an upper launch mount containing a flame deflector, pylons and retractable launching legs, and fuel, liquid oxygen, and umbilical masts with actuators and with related equipment) (Figure 32).

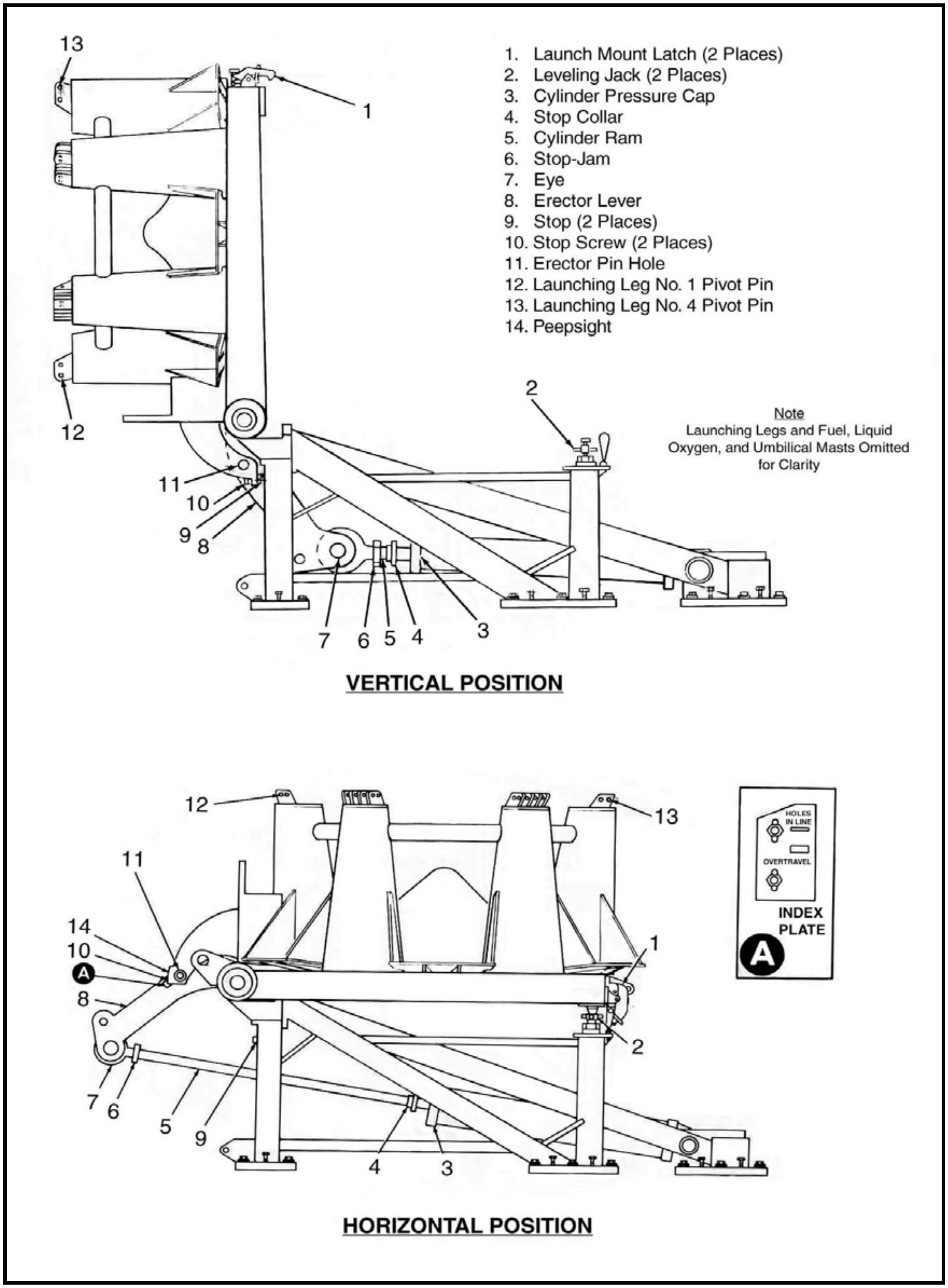


Figure 32: Upper Launch Mount - Alignment

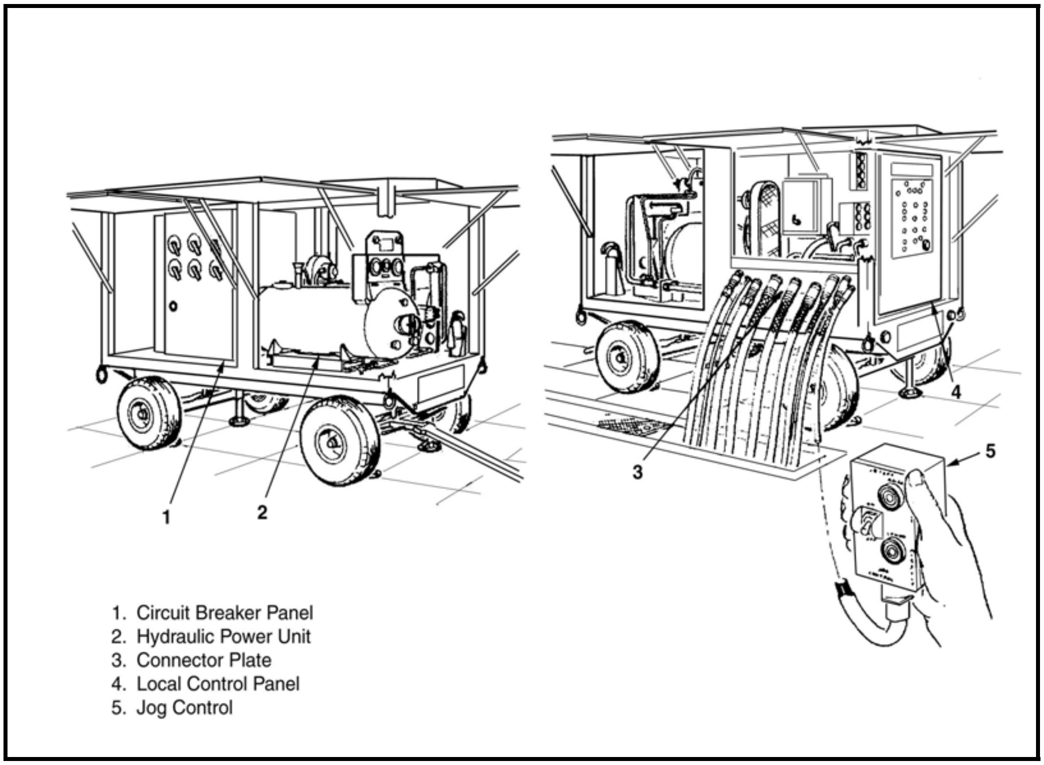


Figure 33: Hydraulic Pumping Unit

The Hydraulic Pumping Unit was part of the AGE which was comprised of components that affected the launch. The AGE was divided into five areas: Control Center, Launch Emplacement launching equipment, Checkout equipment, Power generation equipment, and Direction Center.

The Hydraulic Pumping Unit supplied hydraulic pressure to the erecting-launching mount and all electrical control signals for operating hydraulic controls, the shelter operation, and launch pin operation. The hydraulic pumping unit operated a 60-horsepower motor that powered two hydraulic power unit pumps (Figure 33). The hydraulic pumping unit contained a hydraulic power unit; electrical control units; and electrical, pneumatic, and hydraulic connectors. The hydraulic power units supplied hydraulic pressure to various components of the erecting-launching mount system during countdown. Electrical power, converted to 120v DC, operated the launch pin actuators on the erecting-launching mount. Electrical power for the erecting-launching mount interlock switches and electrically operated hydraulic components was supplied through cables from the hydraulic pumping unit connector plate.[144]

[144] Ibid., 1-3.

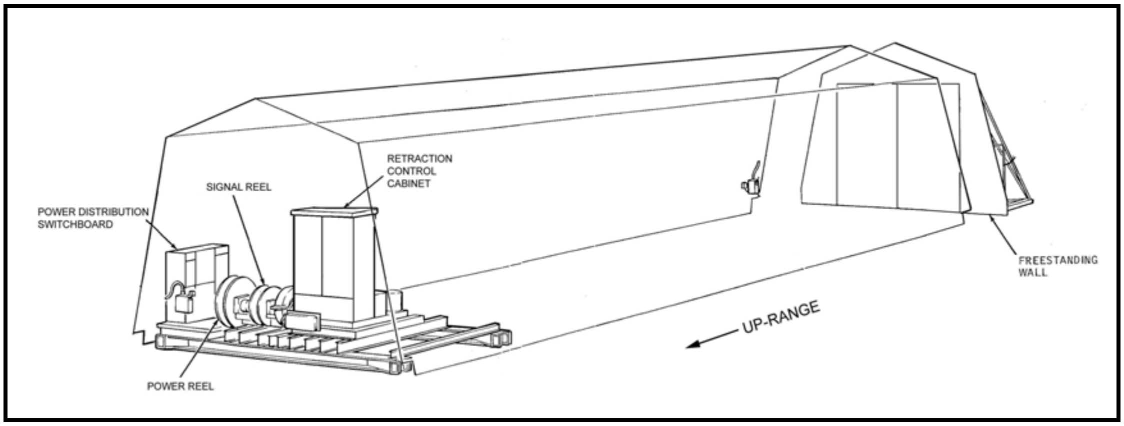


Figure 34: Retraction Mechanism

Before the missile was raised to a vertical position, the main shelter was rolled back from the launch pad to a "stowed" position on the east side of the pad leaving the "free-standing" wall at the west end of the pad. Two parallel rows of railroad-type rails, extending the length of the launch pad, were bolted to the concrete apron. The east side of the shelter contained a 60 horsepower electric motor that powered a gear drive and chain system (Figure 34). The drive was attached to a pipe on the shelter carriage and the cables were anchored to the east end of the rails. The wire rope shelter cables measured 275' long and ¾" in diameter. When the drive was engaged the cable was spooled onto a drum located inside the shelter. Two additional drums spooled the 480v power line and the communication lines that ran into the shelter. The communication lines extended back to the Communications Facility. Once the shelter cleared the launch mount a microswitch was triggered that moved the process into "high gear" until the shelter reached the stowed position. (See photographs CA-296-F-10, CA-296-F-11, CA-296-F-17, and CA-296-F-18.)

Once the shelter was stowed, the hydraulic actuator was triggered. A rod, powered by the hydraulic actuator, pushed the entire trailer/missile assembly into a vertical position. A vertical alignment check provided a means of precisely aligning the launch vehicle in two planes to minimize the effects of any system errors due to axis misalignmnent.[145] Once the missile was raised into position and aligned, the trailer was removed. The erecting-launching mount remained to supply the missile with electrical, communication, and propellant connections. (Figure 35). The launch mount pins would then automatically unthread while the missile remained in position, resting on the launch mount, held in place by its weight alone. When fully fueled the missile weighed approximately 100,000 pounds.

[145] Technical Manual Operation – T.O. 21M-437-1-1-1, "Program 437 Weapon System", (Published under the Authority of the Secretary of the Air Force, 15 June 1971, change 3-30 November 1975), 2-5.

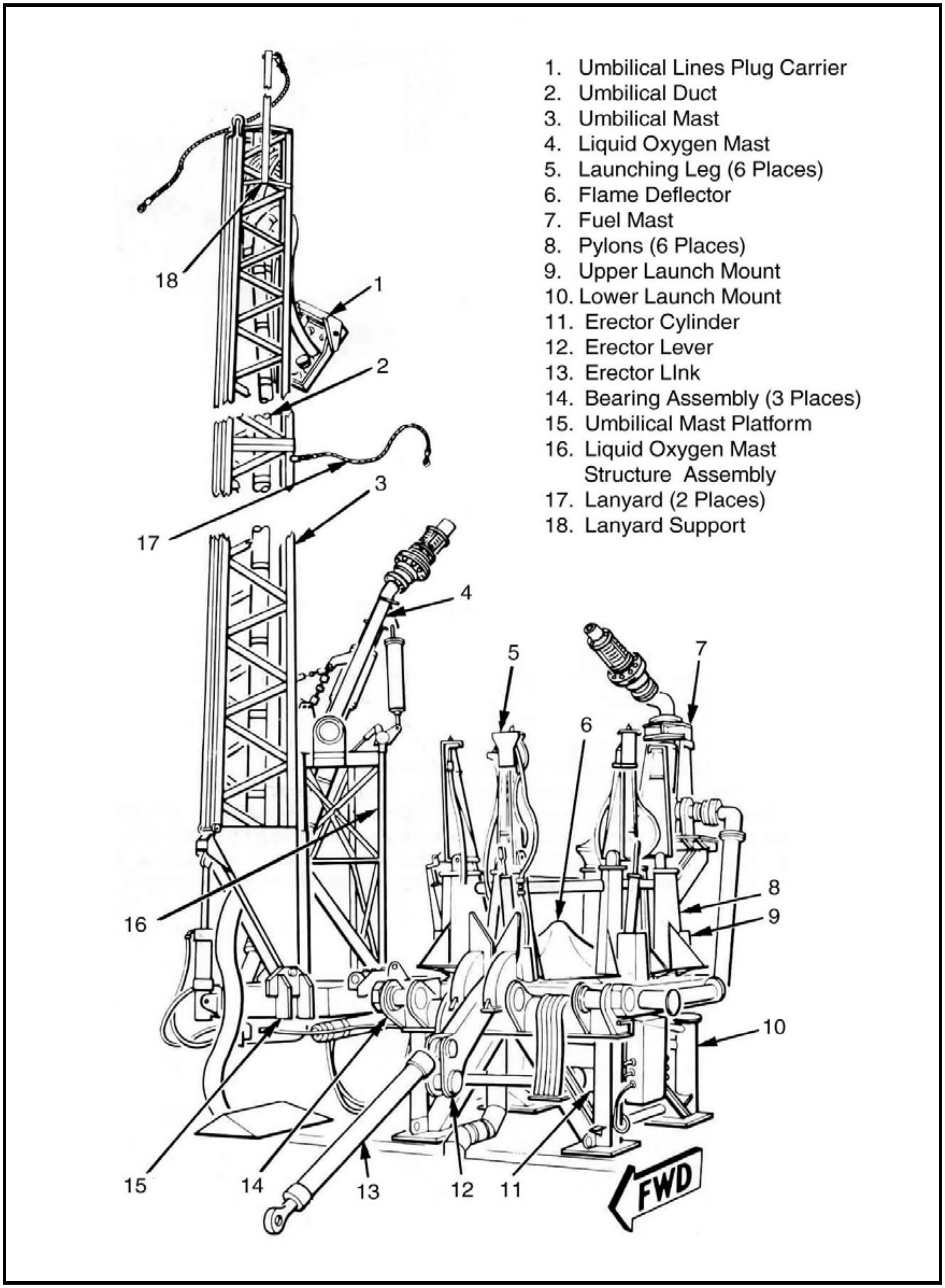


Figure 35: Erecting-Launching Mount

The launch mount at SLC-10 was considered a dry mount. An integral part of the steel launch mount was the blast deflector. The cone-shaped deflector directed the launch blast down and away from the missile preventing possible blast damage. (See photographs CA-296-F-33 and CA-296-F-34.)

Various cables and connections supporting the launch process were laid within below grade trenches located on both sides of the shelter. The sensitive cabling and equipment attached to and surrounding the missile during the launch were coated with an ablative material, nicknamed "pucky", a urethane-based compound intended to protect the cables long enough for the missile to be launched. The majority of this cabling was incinerated by the blast, necessitating its replacement after every launch.

The erecting-launch mount and most of the supporting equipment has been removed from the Missile Shelter. Currently, the shelter serves as a museum storage facility for the complex with several types of missile components on display.

Fueling System[146]

A two-part propellant system was used to launch the Thor missile: oxidizer and fuel. The propellant transfer system consisted of LOX storage tank, LOX pipeline outfit, fuel storage tank, fuel pipeline outfit and associated checkout and maintenance equipment installed at the launch emplacement. The propellant transfer system performed three major functions: the storage of propellants, their loading into and unloading from the launch vehicle tanks. The oxidizer, LOX, was a highly explosive light blue transparent liquid, much more flammable than gaseous oxygen.[147] The fuel was RP-1, a light cut kerosene with a high burn factor. Because of their volatility, both the LOX and RP-1 required careful handling and storage in steel and aluminum tanks and distribution lines. To minimize the chance of the LOX and the RP-1 coming in contact with each other prior to launching, the two systems were located on opposite sides of the launch pad, approximately 275' apart.

Liquid Oxygen Storage and Pumping Facility

The Liquid Oxygen (LOX) facility was located approximately 135' north of the Missile Shelter. The facility consisted of a 13,500-gallon steel vacuum tank, valve transfer unit, transfer piping, valves, gauges regulators, filters, check valves, and relief valves that controlled the transfer of the liquid oxygen to the launch vehicle (Figure 36). These components were located behind a reinforced concrete blast wall in an open-ended rectangular concrete pit approximately 3' deep. The recessed location and concrete wall protected the tank and supporting equipment from the

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[146] Much of the information discussed in the Fueling System section was obtained from Technical Manual Maintenance Instructions – T.O. 21M-437-2-5, "Propellant Transfer System", (Published under the Authority of the Secretary of the Air Force, 1 February 1969, change 6-30 August 1975), 1-1 thru 1-4. Refer to Figure 27 for location of propellant equipment at the launch pad.

[147] R.E. James, ed., Handbook of Liquid Propellants, (Martin Company Cocoa Division, 1961), 10.

launch blast. The Trailer-Mounted Vacuum Pump, also located adjacent to the LOX facility, maintained air-free conditions within the liquid oxygen storage tank annular space.

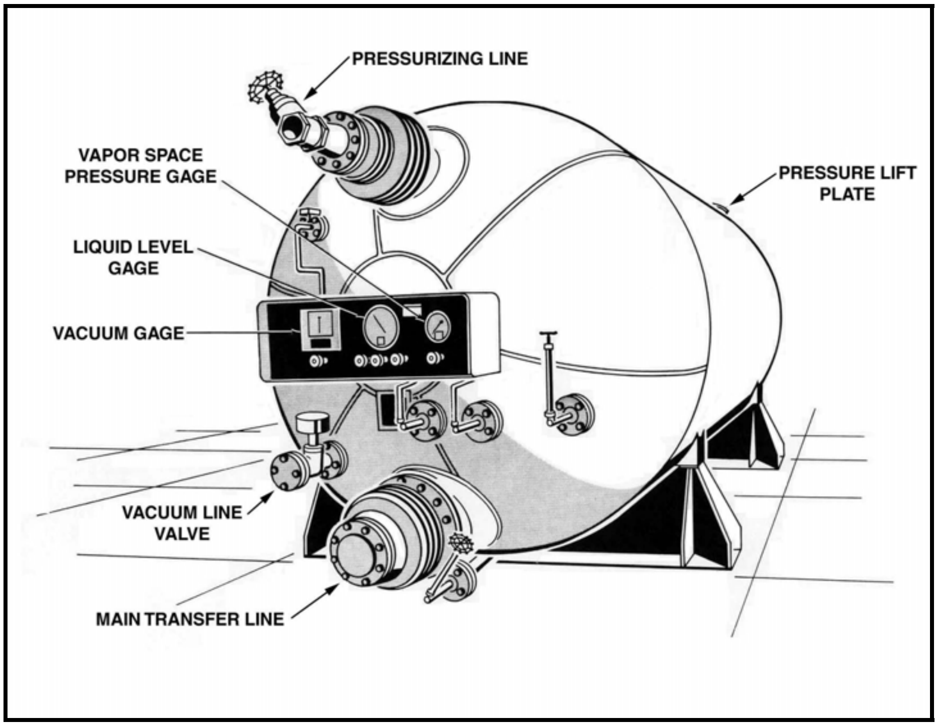

Figure 36: Liquid Oxygen Storage Tank – End View

The skid-mounted valve transfer unit calibrated, monitored, and pumped the LOX through a series of pipes to the Missile Shelter. To prevent the LOX from turning to gas it was stored at extremely low temperatures and, as a result, all receiving containers were gradually cooled to prevent thermal shock.[148] Extreme care was required to ensure that the liquid was stored properly, was free of contaminants, and the tank was equipped with relief vents to prevent pressure build-up. The steel piping extended through the blast wall and was suspended in U-shaped concrete trenches with spring-loaded canisters and turnbuckles allowing for flexing of the pipes that might occur during LOX transfer. In some areas, the trenches were covered with steel access grates for both environmental and blast protection. Electrical and communication cables, extending between the LOX facility and the Missile Shelter, were housed in a separate instrumentation trench. A sunken effluent area lies adjacent to the trench. A second L-shaped blast wall is located on the opposite side of the trench. (See photograph CA-296-F-12 and CA-296-F-24.)

The Compressed Gas Cylinder Semi-Trailer, located adjacent to the LOX storage facility, stored compressed nitrogen gas that pressurized the liquid oxygen storage tank and pre-pressurized the

[148] Ibid.,_ 12.

vehicle liquid oxygen tank. The compressed nitrogen gas also supplied purge pressure to the LOX transfer equipment when the transfer operations were not being performed. The gaseous nitrogen pipeline outfit connected the compressed gas cylinder semi-trailers to the liquid oxygen pipeline outfit.

Fuel Storage and Pumping Facility
The fuel transfer facility, RP-1, was located approximately 110' south of the Missile Shelter. Similar to the LOX facility, the RP-1 facility consisted of a 6,500 gallon steel vacuum tank, fuel transfer unit, transfer piping, valves, gauges, regulators and filters used for the controlled fuel loading into and out of the vehicle fuel tank. These components were located behind a reinforced concrete blast wall in an open-ended rectangular concrete pit approximately 3' deep. The recessed location and concrete wall protected the tank and supporting equipment from the launch blast.

RP-1 was delivered to the launch complex in tanker trailers. Technicians backed the tankers up to the RP-1 pumping car that then transferred the fuel to the steel storage tank. The skid-mounted valve transfer complex calibrated, monitored and pumped the fuel, with the aid of pressurized gaseous nitrogen, to the Missile Shelter through a series of pipes set within U-shaped concrete trenches. The pipes were suspended with spring canisters and turnbuckles allowing for any flexing of the pipes that might have occurred during the RP-1 transfer. The trenches were covered with steel and concrete access grates for both environmental and blast protection. Electrical and communication cables, extending between the RP-1 facility and the missile, were housed in a separate concrete instrumentation trench. (See photographs CA-296-F-22 and CA-296-F-23.) A necessary safety measurement required that all equipment be electrically grounded to prevent the buildup of any static charge that was generated by the flow of RP-1 through the lines and in passing from one storage container to another. A resultant spark discharge could have ignited any air / vapor mixture present.[149]

The Compressed Gas Cylinder Semi-Trailer, located behind the L-shaped blast wall just to the south of the Missile Shelter, stored compressed nitrogen gas used to pressurize the fuel storage tank, pre-pressurize the launch vehicle fuel tank, operating the pneumatic valves throughout the system, and for checkout and maintenance requirements. The High-Pressure Gas Storage Tank, also located behind the south side L-shaped blast wall, stored high-pressure nitrogen gas for pressurizing missile bottles.

Camera Stands[150]
The Blockhouse was not equipped with a direct line of sight to each of the three launch pads. To allow Blockhouse technicians to view proceedings, cameras were strategically located

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[149] Ibid., 39.
[150] "Install Camera System Cmpl. 75 Pad 6 – Structural", Drawing Number: 166-4, Sheet 1 of 2, Filed under 1658-5-1, (Strategic Air Command, Vandenberg Air Force Base, CA, August 1964).

throughout the complex. Several different types of cameras and mountings or stanchions were located throughout the launch complex.

Cameras were mounted atop open square platforms, supported on a 12' tall single steel column, and surrounded by a steel railing. A steel-rung ladder provided access to the camera platform. A second type of camera stand was either a 12' or 18' tall square tower with an interior stairway. Both the top and three sides of these towers were enclosed with 26 GA. corrugated aluminum. The open fourth side faced the launch area. A third type of camera mount measured 4' tall with a single pole supporting a rectangular camera base. Blast-proof cameras were also located atop blast walls and poles to provide for close-up viewing of launch proceedings.

Theodolite Shelter

The East Pad contained a theodolite shelter and azimuth alignment set. The long-range electrotheodolite shelter was located at the far east end of the launch complex and on a center line with the erecting-launching mount. The short-range electrotheodolite azimuth alignment set and target collimator were located inside the Missile Shelter on the west end.

The long-range electrotheodolite shelter was a small concrete and steel structure used for alignment and tracking of the rocket before and during flight. A reinforced concrete pedestal supported on an oversized concrete foundation prevented the theodolite from vibrating and thereby corrupting the alignment readings.

Facility 1664: Maintenance Support Facility[151] (HAER No. CA-296-G)

The Maintenance Support Facility is located approximately 150' northwest of the launch pad. Built in 1966, the building housed tools, spare parts, and other support items. The pre-manufactured rectangular building, measuring approximately 30' x 40' and oriented in the east-west direction, is constructed of insulated corrugated metal siding over a steel frame. The foundation is constructed with a 6" concrete slab with a turned-down footing and 6x6 10/10 wire mesh with a steel trowel finish. The top of slab is located at 6" above grade. A ¾" deep sawed construction joint bisects the building across its width.

The building contains a slightly pitched (1 to 12 pitch) insulated gable roof. The east (or main) façade of the building contains the only personnel door and maintenance door. The original insulated maintenance door measured 10'x10' and slid open to the north. The original sliding door has since been removed and replaced with a steel sectional overhead door.

The south, east and north façades contain operable 5' x 4' three-light steel awning windows. The interior of the building was divided into three areas. The largest area, containing the majority of

[151] "Maintenance Support Building, Plans, Elevations, Sections and Details", Drawing Number 153-4 (1664-1-2), Project No. VAB-153-4, Strategic Air Command, Vandenberg Air Force Base, (AETRON (A Division of Aerojet-General Corporation), Covina, CA, February 27, 1965).

the space on the east side, was the shop area. The southwest corner contained the tool crib and was separated from the shop area by a wire partition. The tool crib has since been enclosed with gypsum board over wood studs. The toilet room, measuring 12’-6” x 10’-4”, contained 2 stools, 2 urinals, 2 lavatories and a centered floor drain. Three types of lighting were used throughout the building: a commercial incandescent ceiling-type fixture with porcelain reflector; a commercial incandescent, wall-type fixture with asymmetric prismatic refractor and globe hinged to an aluminum weather-tight housing; and a two-tube industrial fluorescent fixture. (See photographs CA-296-G-1 through CA-296-G-3.)

SLC-10 WEST PAD[152]

Launch Area

The original launch equipment located at the West Pad was moved to Johnston Island to support the Program 437. In 1963, Douglas Aircraft rebuilt the SLC-10 West Pad maintaining the original Thor IRBM complex configuration using equipment from dismantled Thor IRBM sites located in England (Figure 37). Later modifications, supporting DMSP launches, made Pad 10-West the only launch pad of its kind.[153] These modifications are discussed later in this report.

The West Pad is located approximately 800' southwest of the Blockhouse. Access to the pad is possible via Mono Road and Aero Road. The primary facility on the West Pad was the Launch Shelter (Facility 1658). Launch equipment surrounding the shelter and supporting the missile during launch included the Storage / Administration Building (Facility 1663), Power Substation (Facility 1669), Electrical Equipment Building (EEB), a LOX storage facility, RP-1 fuel storage facility, propellant transfer equipment, gaseous nitrogen (GN_2) facility, numerous power, hydro-pneumatic, electrical equipment, and air conditioning trailers, theodolite station, camera stands, and cabling networks which electrically connect the launch emplacement to the Blockhouse. All of these facilities, except for the Storage / Administration Building and the Power Substation, have been collectively designated as Facility 1658 (Figure 38).

Facility 1658: West Pad[154] (HAER No. CA-296-H)

Missile Shelter and Supporting Facilities

The Missile Shelter, the primary facility on the west launch pad, is centrally located on the pad and oriented in an east-west direction. The western end of the pad, towards the Pacific Ocean, was considered down range. (See photograph CA-296-H-1.) The Missile Shelter, the primary facility on the launch pad, was flanked on the north and south sides by aerospace ground equipment, fueling systems, and communications and camera equipment.

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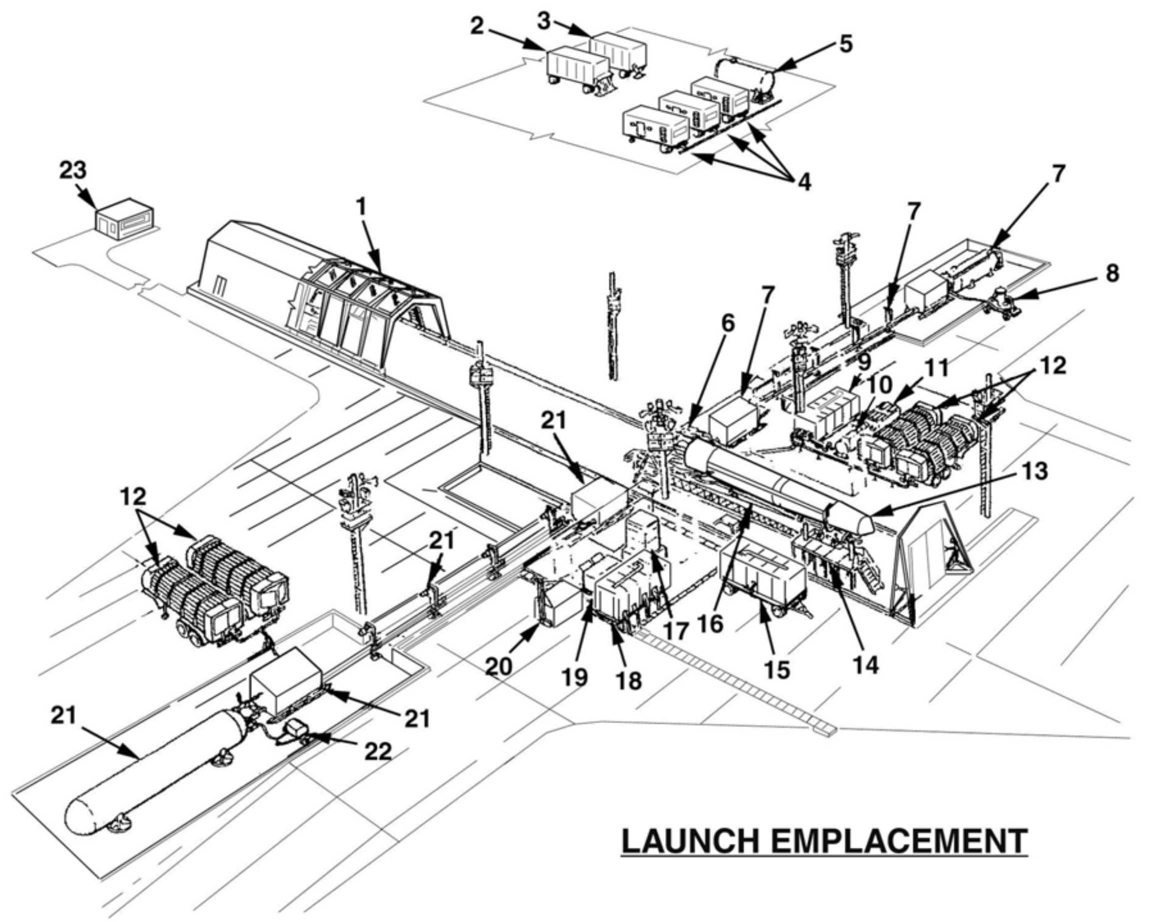
[152] Note: The architectural description for SLC-10 West launch area is nearly identical to the architectural description for SLC-10 East launch area as both pads were reconstructed in the Thor IRBM launch configuration in 1963. The authors decided to reproduce the descriptive text in the current section for ease of reference.

[153] Modifications included the addition of a retractable extension on the Missile Shelter, an electronic equipment building in lieu of similar trailer-mounted equipment, a water deluge and fire suppression system surrounding the launch mount, high-intensity floodlighting, closed-circuit television, payload air conditioning, gaseous nitrogen distribution, and high-capacity electrical distribution.

[154] "Technical Manual Operation 35E3-6-11, Service and Repair, Panelized Prefabricated Building, SHU-18/E, SHU-19/E, Part Numbers 1A24547-501, 1A98984-1", Douglas, AF04(695)-309, F09603-76-D-0419, (Published under Authority of the Secretary of the Air Force, 18 May 1964, Change 4 – 15 April 1977), 1-2.



Key

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3. Trailer-Mounted Launching Control Group A/M24A-2
4. Trailer-Mounted Diesel Engine Generator Set AF/M32A-12*
5. Diesel Fuel Storage Tank TMU-5/E*
6. Ballistic Missile Erecting-Launching Mount MTU-1A/E
7. Fuel Pipeline Outfit GSU-6/E and Fuel Storage Tank TMU-4/E
8. Trailer-Mounted Fuel Filter Unit GSU-7M
9. Trailer-Mounted Hydro-Pneumatic Systems Controller AF/M46A-1
10. High Pressure Gas Storage Tank TMU-6/E*
11. Power-Driven Reciprocating Compressor A/M32A-27*
12. Compressed Gas Cylinder Semitrailer AF/M32A-17 Typical (2 Places)*
13. SM-75 Missile*
14. Short Range Azimuth Alignment Electrotheodolite AN/GVQ-3
15. Trailer-Mounted Ballistic Missile System Checkout STation TTU-92/M*
16. Ballistic Missile Erecting-Transporting Boom GSU-33/E, And Rear Dolly GSU-32/M
17. Trailer-Mounted Air Conditioner AF/M32C-1*
18. Trailer-Mounted Missile Launching Countdown Group A/M24A-1A
19. Hydraulic Pumping Unit PMU-14/E
20. Skid-Mounted Power Switchboard JEU-1/E
21. Liquid Oxygen Pipeline Outfit GSU-5/E
22. Trailer-Mounted Vacuum Pump PMU-1/M
23. Long Range Azimuth Alignment Electrotheodolite AN/GVQ-4

*This Equipment Located at the Launch Emplacement and Rim Building

Figure 37: Standard Launch Emplacement for Thor IRBM Launch Vehicles

To the north of the Missile Shelter was an L-shaped reinforced concrete blast wall (measuring 5' thick by 15' tall) originally constructed to protect the trailer-mounted missile launching countdown group, hydraulic pumping unit, the check-out trailer, power pack trailer, electrical sub-station trailer, light and communication poles, and air conditioning trailer. The air conditioning trailer was a source of conditioned air that ventilated, heated, or cooled the launch vehicle during check-out procedures. The trailer contained three similar heating subsystems and two separate but similar refrigerated systems. Controls started, stopped, regulated, and monitored the air flow to the launch vehicle.[155] These trailers were later replaced with the Electrical Equipment Building.

The concrete overflow basin was also adjacent to the Missile Shelter and collected any fuels or liquids dumped from the rocket. Farther to the north was a second blast wall protecting the LOX storage tank, LOX pipeline outfit, GN_2 tanks, and trailer-mounted vacuum. Located in front of the blast wall was the skid-mounted power transformer unit which "stepped down" the incoming power source to a usable 480v AC. The skid-mounted design provided for quick and easy transport of equipment. This unit is functioning and powers the remaining equipment at the pad. Concrete instrumentation trenches spanned between support trailers, propellant farms and the Missile Shelter. To the south of the Missile Shelter was a second L-shaped blast wall protecting nitrogen tube trailers, the Helium trailer, and hydro-pneumatic pump trailer. Farther to the south, approximately 100' from the Missile Shelter, was a second blast wall protecting the RP-1 fuel storage facility, fuel pipeline outfit, and the trailer-mounted fuel filter unit. The majority of the equipment and fueling systems have been removed.

The Missile Shelter provided an environmentally protective enclosure for the launch vehicle, erecting-transporting boom, and erecting-launching mount during build-up and check-out. The panelized pre-fabricated shelter was constructed of ten bent-column ribs sheathed with steel, paper-honeycomb-filled panels. Prior to modification, the shelter measured 108' long, 28'-10" wide and 20' tall. The two different sizes of wall panels used were 8' and 3'-11" in width by 15'-7" tall and 2 ½" thick (Figure 38). (See photographs CA-296-H-2 through CA-296-H-8.)

During assembly, check-out and pre-launch proceedings, the shelter was closed protecting the missile in a horizontal position. The interior of the shelter was equipped with hoses, valves, electrical and communication lines, convenience outlets, interior lights, hoists, auxiliary switchboard, warning horn, override, limit and manual control switches. The shelter was also equipped with retractable access platforms and two hook block hoists suspended from I-beams each with a ½ ton capacity.

[155] "CPC Air Condition Trailer", 18355, A IA041196, (May 1972).

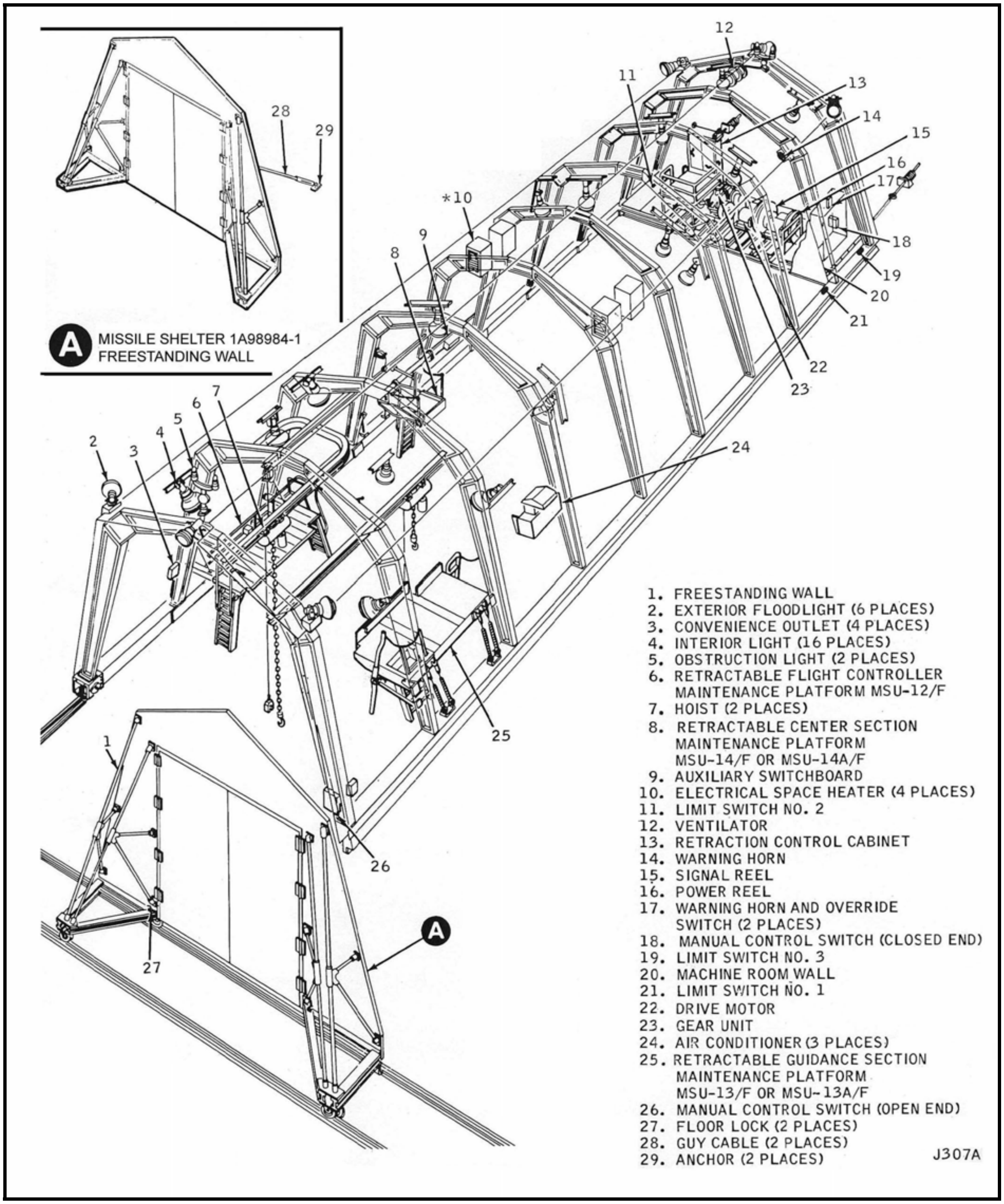

Figure 38: Standard Missile Shelter Components

The retractable access platforms, located on both sides of the shelter, were hinged thus allowing the platforms to be raised and lowered. This allowed technicians to work on all aspects of the missile during mating and pre-launch procedures (Figure 39). (See photographs CA-296-H-13 and CA-296-H-14.)

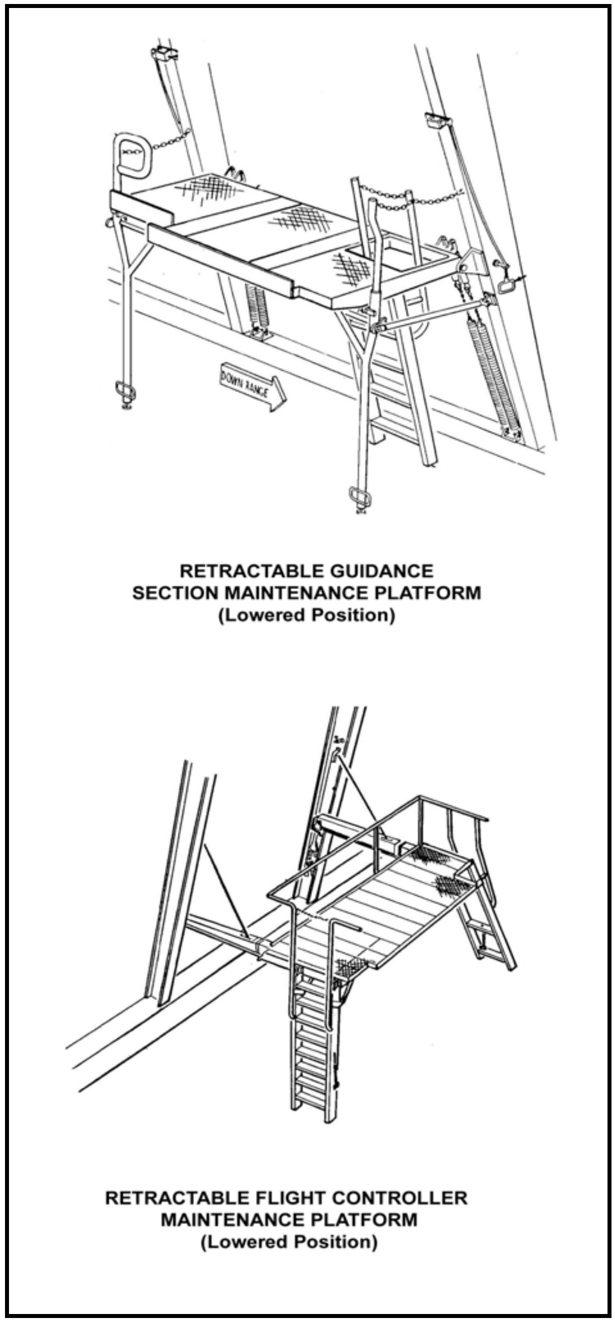

Figure 39: Work Platforms

Transportation and mating of launch vehicle consisted of three basic components: the Erecting-Transporting Boom; the Hydraulic Pumping Unit; and the Missile and the Launch Vehicle Erecting-Launching Mount.[156]

Build-up of the missile began with the delivery of missile components to the launch complex by means of the erecting-transporting boom, a truck-pulled trailer. The free-standing wall doors, at the west end of the Missile Shelter, were opened to allow the erecting-transporting boom to be maneuvered into the shelter and mated to the erecting-launching mount, where missile assembly began. The first stage of the missile was attached to the upper launch mount with threaded pins. Additional stages were then added in sequence until complete. The trailer remained in position, supporting the missile, until the missile was raised to a vertical position.

The erecting-transporting boom functioned as a transporting unit for the launch vehicle with the addition of a steerable Rear Trailer Dolly and a prime mover, an M-52 truck-tractor. The erecting-transporting boom had a forward cradle with hydraulically operated clamshell arms, an aft cradle, and travel locks for holding the launch vehicle in place during transport and

[156] Technical Manual - T.O. 21M-437-2-8 Maintenance Instructions "Launch Vehicle Erecting- Launching Mount System", (Published under authority of the Secretary of the Air Force, 15 May 1964, change 17-15 June 1973), 1-1 thru 1-3.

erection (Figure 40). The boom also contained an auxiliary hydraulic pump unit and attaching devices for connecting the boom to the erecting-launching mount and aligning the vehicle during mating procedures. Attaching devices were used to secure the connection of the erector lever to the launch mount and as pivot points for the erecting-transporting boom during launch vehicle erection. Four retractable landing gears, two forward and two aft, assisted with the alignment procedures and also supported the erecting-transporting boom in the horizontal position.

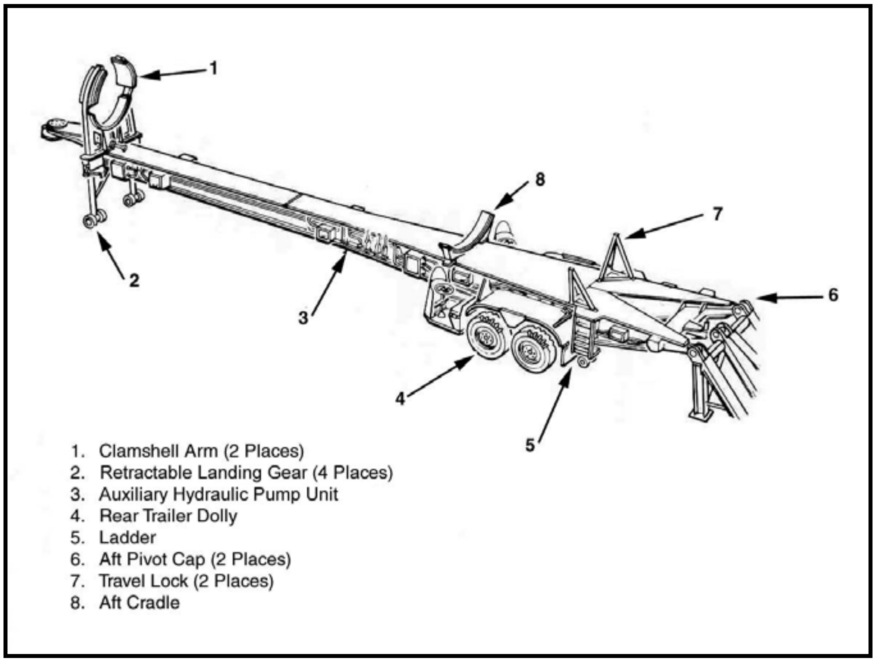

Figure 40: Erecting-Transporting Boom

The erecting-launching mount, in conjunction with the erecting-transporting boom, erected and supported the launch vehicle using electrical power and hydraulic pressure from the hydraulic pumping unit. The erector cylinder raised and lowered the launch vehicle and boom. Attached to the erecting-launching mount were fuel, liquid oxygen, and electrical power services. Actuators associated with each service mast and with the launch vehicle support legs retracted these components at lift-off.

The erecting-launching mount was composed of two sections: a lower launch mount, (containing bearing assemblies, an erector cylinder, an erector lever and link, leveling jacks, a hydraulic manifold, and an electrical junction box), and an upper launch mount (containing a flame deflector, pylons and retractable launching legs, fuel, liquid oxygen, and umbilical masts with actuators and related equipment) (Figure 41). (See photographs CA-296-H-8 through CA-296-H-10.)

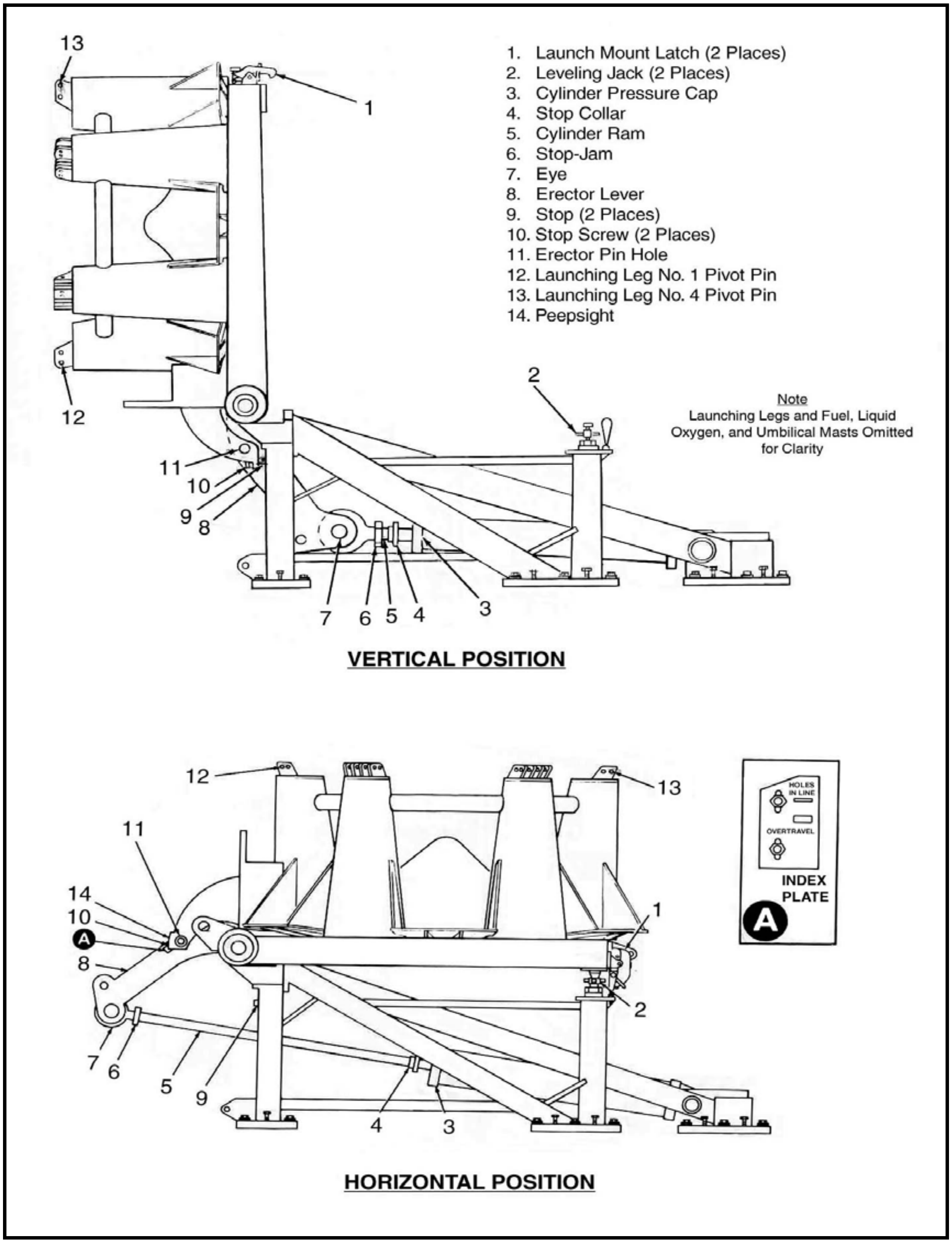

Figure 41: Upper Launch Mount - Alignment

The Hydraulic Pumping Unit was part of the AGE which was comprised of components that affected the launch. The AGE was divided into five areas: Control Center, Launch Emplacement launching equipment, Checkout equipment, Power generation equipment, and Direction Center.

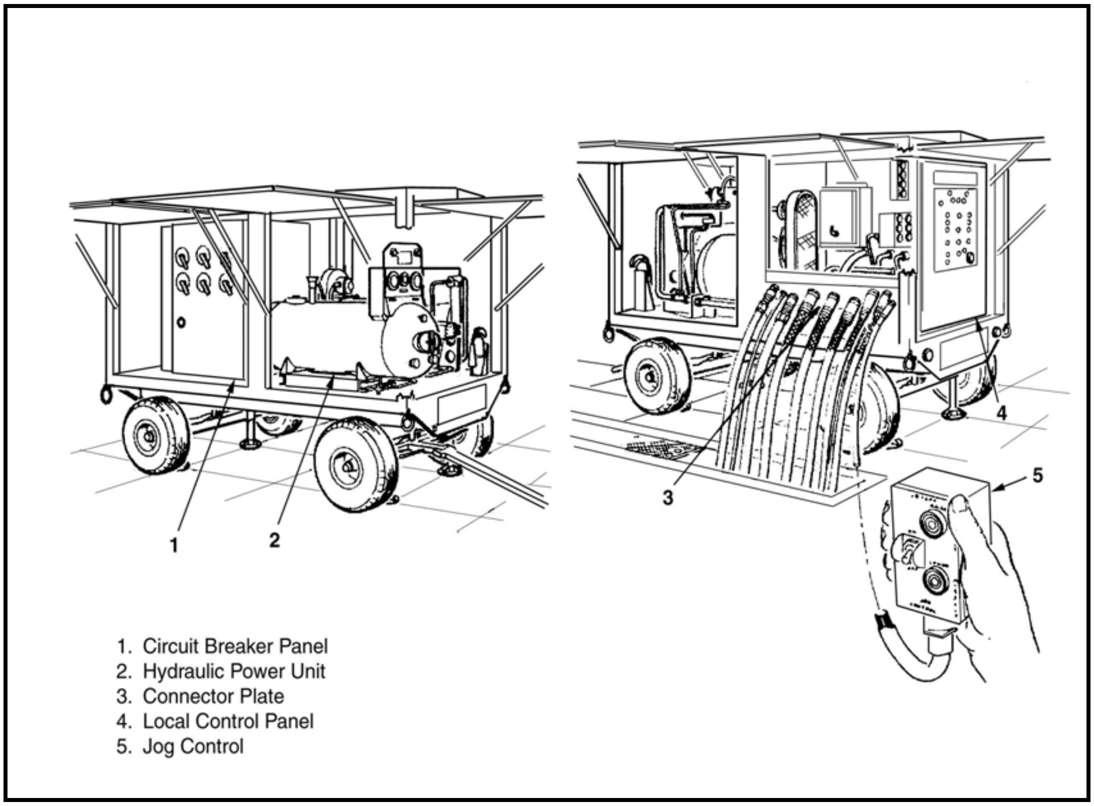

Figure 42: Hydraulic Pumping Unit

The Hydraulic Pumping Unit supplied hydraulic pressure to the erecting-launching mount and all electrical control signals for operating hydraulic controls, the shelter operation, and launch pin operation.[157] The hydraulic pumping unit operated a 60-horsepower motor that powered two hydraulic power unit pumps (Figure 42). The hydraulic pumping unit contained a hydraulic power unit; electrical control units; and electrical, pneumatic, and hydraulic connectors. The hydraulic power units supplied hydraulic pressure to various components of the erecting-launching mount system during countdown. Electrical power, converted to 120v DC, operated the launch pin actuators on the erecting-launching mount. Electrical power for the erecting-launching mount interlock switches and electrically operated hydraulic components was supplied through cables from the hydraulic pumping unit connector plate.

[157] Ibid., 1-2.

Before the missile was raised to a vertical position, the main shelter was rolled back from the launch pad to a "stowed" position on the east side of the pad leaving the "free-standing" wall at the west end of the pad. Two parallel rows of railroad-type rails, extending the length of the launch pad, were bolted to the concrete apron. The east side of the shelter contained a 60 horsepower electric motor that powered a gear drive and chain system (Figure 43). The drive was attached to a pipe on the shelter carriage and the cables were anchored to the east end of the rails. The wire rope shelter cables measured 275' long and ¾" in diameter. When the drive was engaged the cable was spooled onto a drum located inside the shelter. Two additional drums spooled the 480v power line and the communication lines that ran into the shelter. The communication lines extended back to the Communications Facility. Once the shelter cleared the launch mount a microswitch was triggered that moved the process into "high gear" until the shelter reached the stowed position. (See photograph CA-296-H-12.)

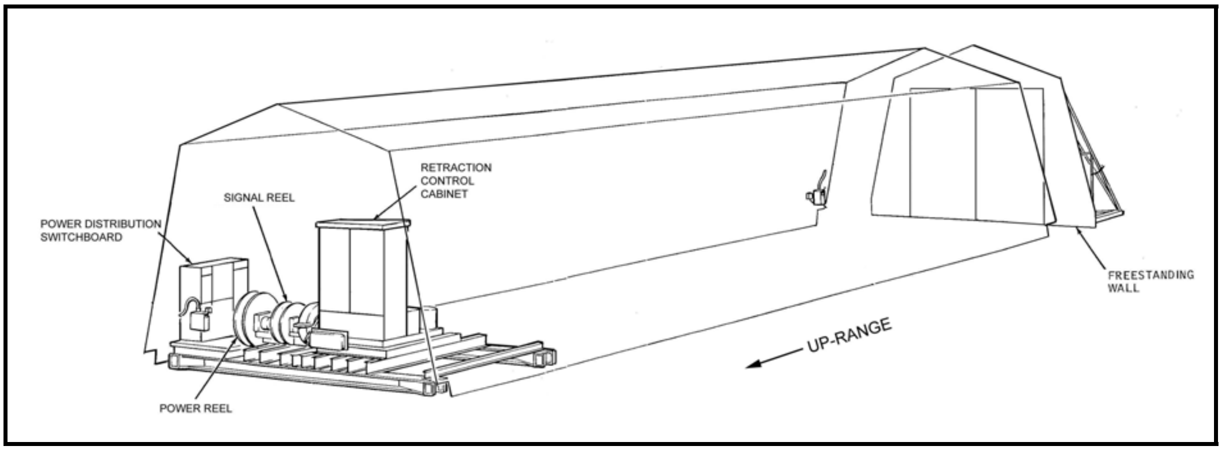

Figure 43: Retraction Mechanism

Once the shelter was stowed, the hydraulic actuator was triggered. A rod, powered by the hydraulic actuator, pushed the entire trailer/missile assembly into a vertical position. A vertical alignment check provided a means of precisely aligning the launch vehicle in two planes to minimize the effects of any system errors due to axis misalignmnent.[158] Once the missile was raised into position, the trailer was removed. The erecting-launching mount remained to supply the missile with electrical, communication, and propellant connections (Figure 44). The launch mount pins would then automatically unthread while the missile remained in position, resting on the launch mount, held in place by its weight alone. When fully fueled the missile weighed approximately 100,000 pounds.

[158] Technical Manual Operation – T.O. 21M-437-1-1-1, "Program 437 Weapon System", 2-5.

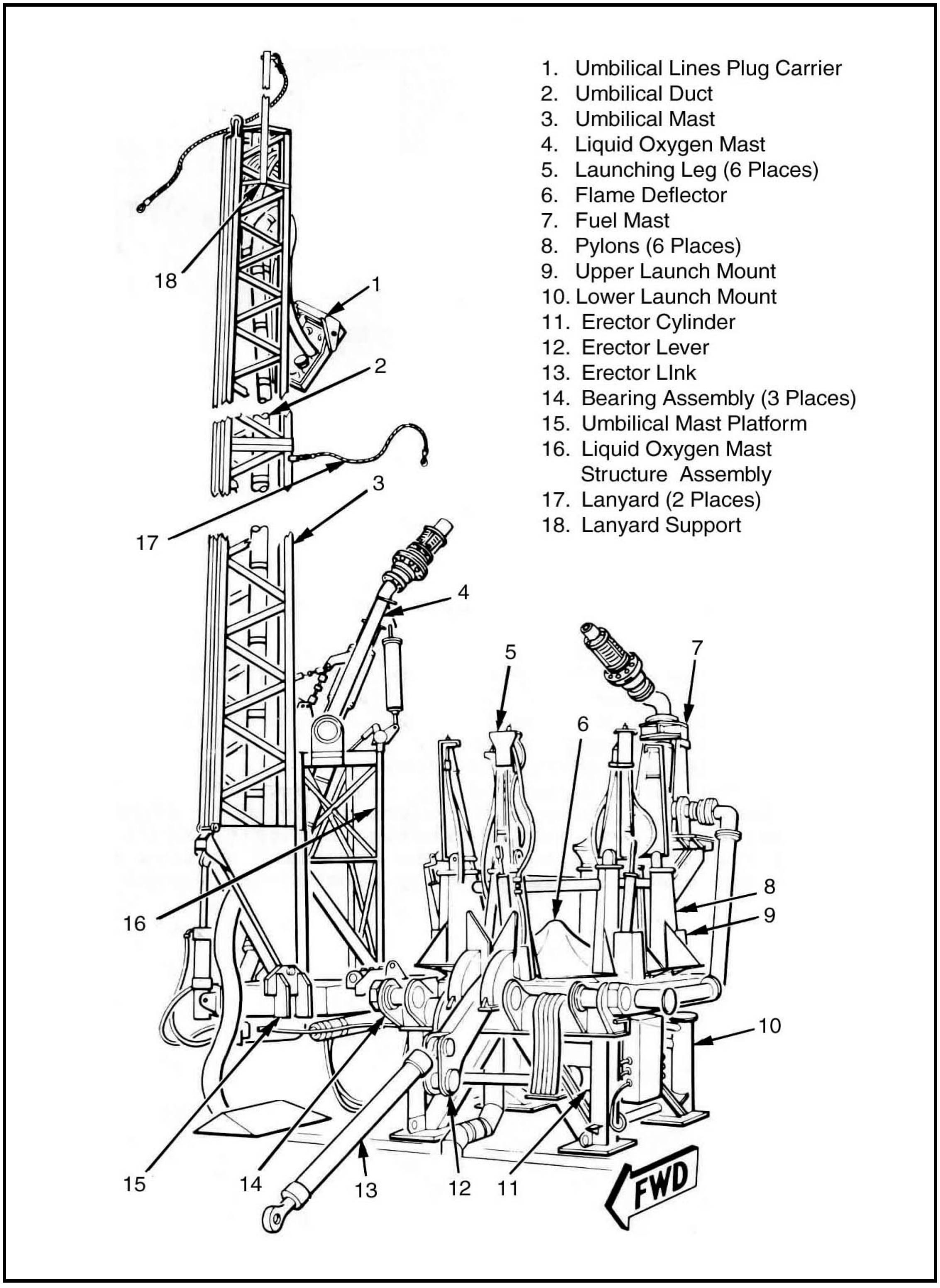

Figure 44: Erecting-Launching Mount

The launch mount at SLC-10 was considered a dry mount. An integral part of the steel launch mount was the blast deflector. The cone-shaped deflector directed the launch blast down and away from the missile preventing possible blast damage.

Various cables and connections supporting the launch process were laid within below grade trenches located on both sides of the shelter. The sensitive cabling and equipment attached to and surrounding the missile during the launch were coated with an ablative material, nicknamed "pucky", a urethane-based compound intended to protect the cables long enough for the missile to be launched. The majority of this cabling was incinerated by the blast, necessitating its replacement after every launch.

Fueling System[159]

A two-part propellant system was used to launch the Thor missile: oxidizer and fuel. The propellant transfer system consisted of LOX storage tank, LOX pipeline outfit, fuel storage tank, fuel pipeline outfit and associated checkout and maintenance equipment installed at the launch emplacement. The propellant transfer system performed three major functions: the storage of propellants, their loading into and unloading from the launch vehicle tanks. The oxidizer, LOX, was a highly explosive light blue transparent liquid, much more flammable than gaseous oxygen.[160] The fuel was RP-1, a light cut kerosene with a high burn factor. Because of their volatility, both the LOX and RP-1 required careful handling and storage in steel and aluminum tanks and distribution lines. To minimize the chance of the LOX and the RP-1 coming in contact with each other prior to launching, the two systems were located on opposite sides of the launch pad, approximately 275' apart. (See photograph CA-296-F-31.)

Liquid Oxygen Storage and Pumping Facility

The Liquid Oxygen (LOX) facility was located approximately 135' north of the Missile Shelter. The facility consisted of a 13,500-gallon steel vacuum tank, valve transfer unit, transfer piping, valves, gauges regulators, filters, check valves, relief valves that controlled the transfer of the liquid oxygen to the launch vehicle (Figure 45). These components were located behind a reinforced concrete blast wall in an open-ended rectangular concrete pit approximately 3' deep. The recessed location and concrete wall protected the tank and supporting equipment from the launch blast. The Trailer-Mounted Vacuum Pump, also located adjacent to the LOX facility, maintained air-free conditions within the liquid oxygen storage tank annular space.

The skid-mounted valve transfer unit calibrated, monitored, and pumped the LOX through a series of pipes to the Missile Shelter. To prevent the LOX from turning to gas it was stored at extremely low temperatures and, as a result, all receiving containers were gradually cooled to

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[159] Much of the information discussed in the Fueling System section was obtained T.O. 21M-437-2-5, 1-1 thru 1-4. Refer to Figure 37 for location of propellant equipment at the launch pad.
[160] Handbook of Liquid Propellants, 10.

prevent thermal shock.[161] Extreme care was required to ensure that the liquid was stored properly, was free of contaminants, and the tank was equipped with relief vents to prevent pressure build-up. The steel piping extended through the blast wall and was suspended in U-shaped concrete trenches with spring-loaded canisters and turnbuckles allowing for flexing of the pipes that might occur during LOX transfer. In some areas, the trenches were covered with steel access grates for both environmental and blast protection. Electrical and communication cables, extending between the LOX facility and the Missile Shelter, were housed in a separate instrumentation trench. A sunken effluent area lies adjacent to the trench. A second L-shaped blast wall is located on the opposite side of the trench. (See photographs CA-296-H-26 through CA-296-H-29.)

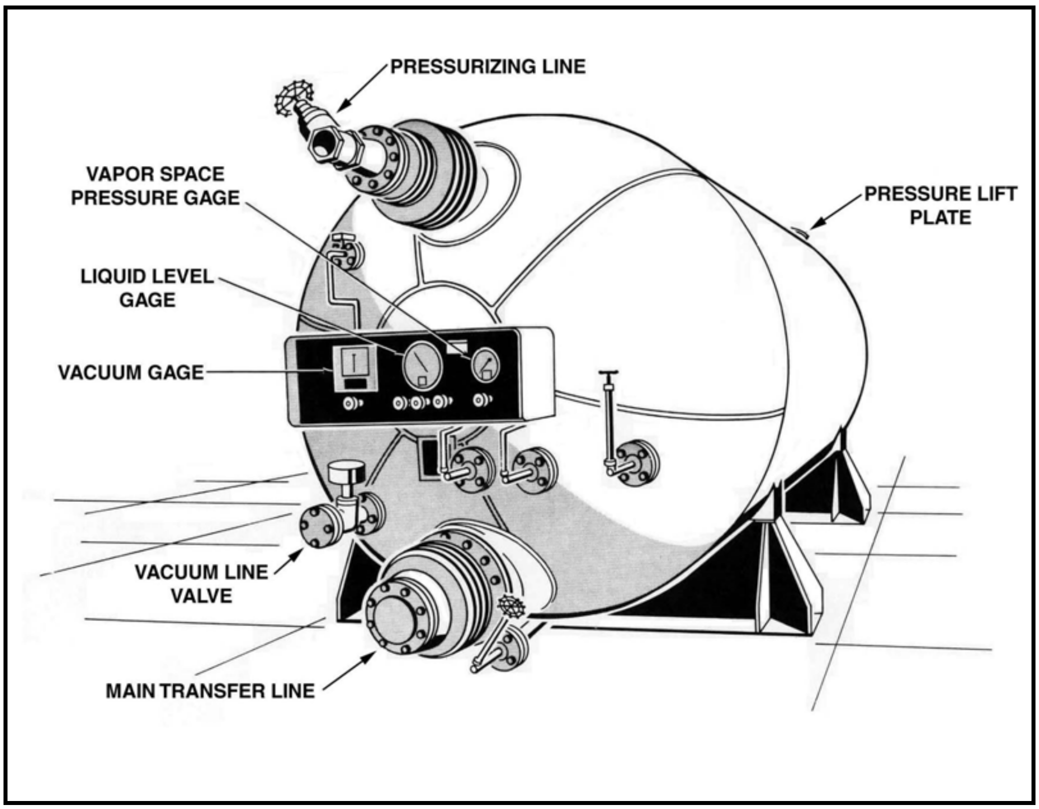

Figure 45: Liquid Oxygen Storage Tank – End View

The Compressed Gas Cylinder Semi-Trailer, located adjacent to the LOX storage facility, stored compressed nitrogen gas that pressurized the liquid oxygen storage tank and prepressurized the vehicle liquid oxygen tank. The compressed nitrogen gas also supplied purge pressure to the LOX transfer equipment when the transfer operations were not being performed. The gaseous

[161] Ibid., 12.

nitrogen pipeline outfit connected the compressed gas cylinder semi-trailers to the liquid oxygen pipeline outfit.

Fuel Storage and Pumping Facility

The fuel transfer facility, RP-1, was located approximately 110' south of the Missile Shelter. Similar to the LOX facility, the RP-1 facility consisted of a 6,500 gallon steel vacuum tank, fuel transfer unit, transfer piping, valves, gauges, regulators and filters used for the controlled fuel loading into and out of the vehicle fuel tank. These components were located behind a reinforced concrete blast wall in an open-ended rectangular concrete pit approximately 3' deep. The recessed location and concrete wall protected the tank and supporting equipment from the launch blast.

RP-1 was delivered to the launch complex in tanker trailers. Technicians backed the tankers up to the RP-1 pumping car that then transferred the fuel to the steel storage tank. The skid-mounted valve transfer complex calibrated, monitored and pumped the fuel, with the aid of pressurized gaseous nitrogen, to the Missile Shelter through a series of pipes set within U-shaped concrete trenches. The pipes were suspended with spring canisters and turnbuckles allowing for any flexing of the pipes that might have occurred during the RP-1 transfer. The trenches were covered with steel and concrete access grates for both environmental and blast protection. Electrical and communication cables, extending between the RP-1 facility and the missile, were housed in a separate concrete instrumentation trench. (See photograph CA-296-H-31.) A necessary safety measurement required that all equipment be electrically grounded to prevent the buildup of any static charge that was generated by the flow of RP-1 through the lines and in passing from one storage container to another. A resultant spark discharge could have ignited any air / vapor mixture present.[162]

The Compressed Gas Cylinder Semi-Trailer, located behind the L-shaped blast wall just to the south of the Missile Shelter, stored compressed nitrogen gas used to pressurize the fuel storage tank, pre-pressurize the launch vehicle fuel tank, operating the pneumatic valves throughout the system, and for checkout and maintenance requirements. The High-Pressure Gas Storage Tank, also located behind the south side L-shaped blast wall, stored high-pressure nitrogen gas for pressurizing missile bottles.

Gaseous Nitrogen Facility

The Gaseous Nitrogen (GN_2) Facility, located adjacent to and north of the LOX tank, was used to both purge the supply lines providing an oxygen-free environment and provide pressure for the pumping system. The GN_2 was originally supplied by portable tube, bank-type trailers. In response to the increasing regularity of launches from the West Pad, these tanks were replaced in 1976 with permanent GN_2 tanks.

[162] Ibid., 39.

The original 34' x 38' unreinforced concrete slab was enlarged to 59' x 72'. The new tanks were tied down to reinforced concrete cradles resting on reinforced concrete piers measuring 8' wide by 15'-9" long and 1'-8" deep. The concrete cradles measured 1'-0" wide by 6'-6" in length. Four tanks were oriented in the north-south direction while a fifth, larger tank, was oriented in the east-west direction.[163] (See photograph CA-296-H-32.)

Camera Stands[164]

The Blockhouse was not equipped with a direct line of sight to each of the three launch pads. To allow Blockhouse technicians to view proceedings, cameras were strategically located throughout the complex. Several different types of cameras and mountings or stanchions were located throughout the launch complex. (See photographs CA-296-H-35 and CA-296-H-36.)

Cameras were mounted atop open square platforms, supported on a 12' tall single steel column, and surrounded by a steel railing. A steel-rung ladder provided access to the camera platform. A second type of camera stand was either a 12' or 18' tall square tower with an interior stairway. Both the top and three sides of these towers were enclosed with 26 GA. corrugated aluminum. The open fourth side faced the launch area. A third type of camera mount measured 4' tall with a single pole supporting a rectangular camera base. Blast-proof cameras were also located atop blast walls and poles to provide for close-up viewing of launch proceedings.

Theodolite Shelter

The West Pad contained two electrotheodolite shelters and an azimuth alignment set. The long-range electrotheodolite shelter was located 400' east of the center of the missile on a center line with the erecting-launching mount. The short-range electrotheodolite shelter was located approximately 66' west of the center and slightly to the north of the Missile Shelter. The short-range structure had a target sighting angle of 135 degrees. The azimuth alignment set and target collimator were located inside the Missile Shelter on the west end.

The long-range electrotheodolite shelters were small concrete and steel structures used for alignment and tracking of the rocket before and during flight. A reinforced concrete pedestal supported on an oversized concrete foundation prevented the theodolite from vibrating and thereby corrupting the alignment readings. (See photographs CA-296-H-38 and CA-296-H-39.)

The Azimuth alignment site, located southeast of the launch pad, consisted of two reinforced concrete piers separated by a reinforced concrete slab oriented in a northeast/southwest direction. The center line of the site was oriented 22 degree northeast of true north (Figure 46).

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[163] "Nitrogen Tank Farm Plan and Sections, SLC-10W Alteration", Drawing Number: S 6, Specification No. DACA09-76-8-0016, (Vandenberg Air Force Base, CA, S&T Western, Inc. Consulting Engineers, A Unit of STV, Inc., Long Beach, CA, February 1976).

[164] "Install Camera System Cmpl. 75 Pad 6 – Structural", Drawing Number: 166-4, Sheet 1 of 2, Filed under 1658-5-1, (Strategic Air Command, Vandenberg Air Force Base, CA, August 1964).

The azimuth alignment site consisted of a theodolite pier and Porro prism pier located 36' apart. The foundation of the theodolite pier was 5'-4" square, 2' thick and constructed of reinforced concrete with #5 rebar at 6" each way. The theodolite pier itself was 10'-3" tall and 18" in diameter with #4 rebar at 18" on center. The total height of the theodolite pier was 12'-3". The Tribrach plate, furnished by RCA, was located 3'-9 ½" above the top of the dead level concrete slab spanning between the Theodolite Pier and Porro Prism Pier.

The foundation of the Porro Prism pier was 5'-4" square, 2' thick and constructed of reinforced concrete with #5 rebar at 6" each way. The Porro Prism pier itself was 11' tall and 18" in diameter with #4 rebar at 18" on center. The total height of the theodolite pier was 13'. The Prism plate, also furnished by RCA, was located 4'-7" above the top of the dead level concrete slab spanning between the two piers.

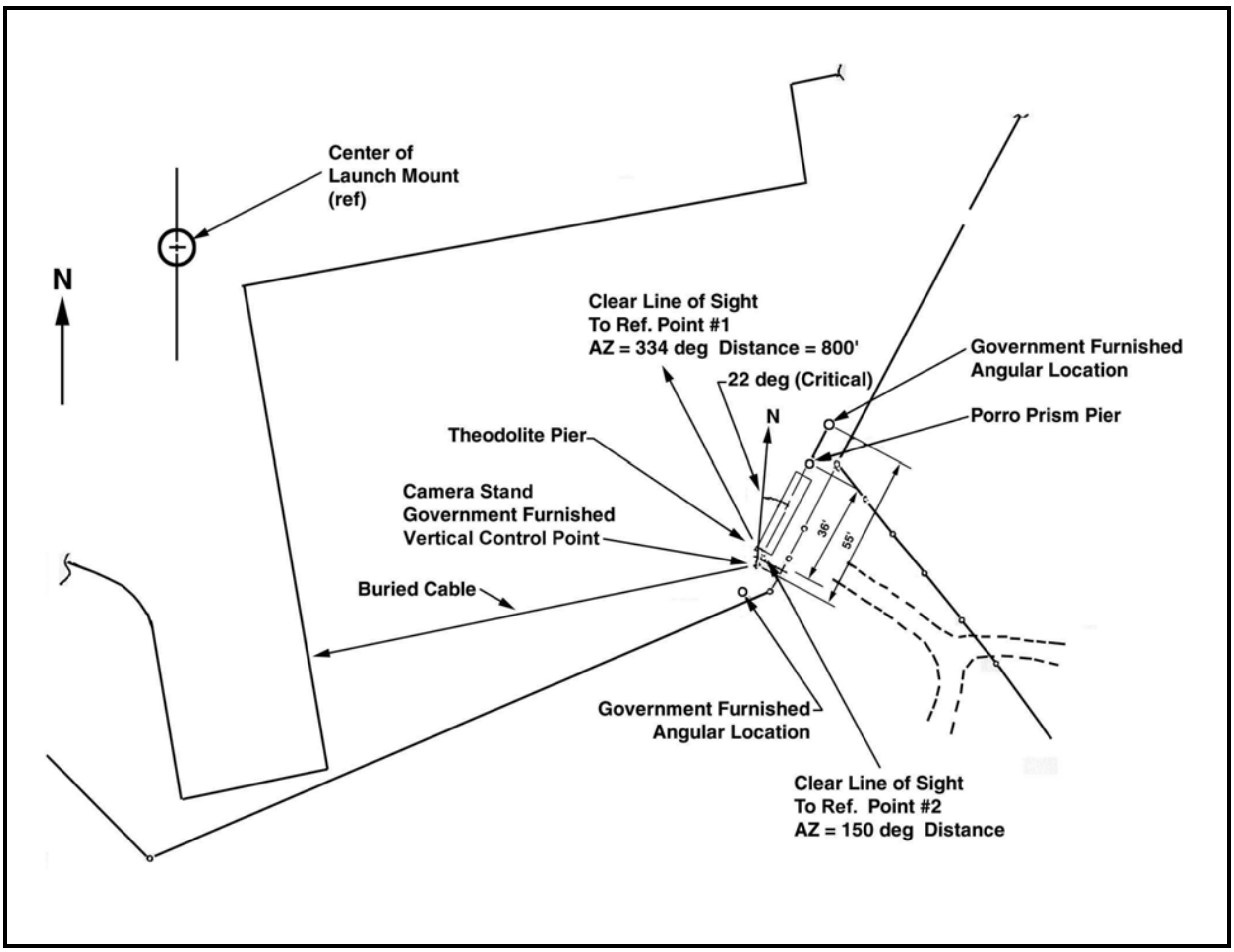

Figure 46: Azimuth Alignment Site, Plan View

Facility 1663: Storage and Administration Facility[165] (HAER No. CA-296-I)

This building was constructed in 1966 to provide storage space for equipment and spare parts for the West Pad. The building is located northwest of the launcher building (Building 1658) at the entrance to the pad, and oriented in an east-west direction. (See photograph CA-296-I-1.)

The building, 40'-4" wide by 20' in length, is constructed with a 4" poured reinforced concrete foundation with a turned-down footing and 6x6 10/10 wire mesh over compacted sand and gravel. The walls are constructed of 26 gauge galvanized steel siding (corrugated) over 2"x4" wood studs located at 24" on center. The structure consists of 4"x4" wood columns located at 8' on center supporting 4"x14" beams, also located at 8' on center, providing a clear height of 9'-10" to bottom of beams. The slightly pitched shed roof, sloping from east to west, is constructed with 24 gauge corrugated galvanized steel with corrugated roofing sheets over 2"x8" rafters located at 5' on center.

The main façade, or east façade, contains two solid core wood doors and a pair of 4'x8' metal sliding doors to allow technicians to move large pieces of equipment in and out of the building. The façade also contains a single 2'-8" x 4'-1" steel awning window. The interior of the building is divided into three areas – the main shop area, an office area, and restroom. The office area, located on the north end of the building, is 10'-6" wide and extends the depth of the building from east to west. The office has been framed with 2"x4" wood studs at 24" on center sheathed with 5/8" gypsum board. The restroom is located in the southeast corner of the building and measures 5'-4" wide by 10' deep. The restroom was outfitted with a stool, urinal, lavatory, and six gallon electric water heater. Both the office area and restroom were framed with 2"x4" wood studs at 24" on center and sheathed with 5/8" gypsum board.

Facility 1669: Power Substation (HAER No. CA-296-J)

The Power Substation, built in 1977, is located at the west entrance to the pad. The substation, constructed on a concrete pad, is surrounded by a chainlink fence. The function of this facility was to "step down" the incoming 12KV power supply to a usable 480v for distribution throughout the launch pad. (See photograph CA-296-J-1.)

[165] "Construction Storage Building, Plans, Elevations, Sections and Details", Drawing Number: 313-5 (1663-1-2 and 1663-1-3), Project No. VAFB 313-5R1, (Strategic Air Command, Vandenberg Air Force Base, CA, February 1966).

Modifications to the West Pad

The West Pad underwent modifications before being decommissioned. When the mission of the West Pad was changed to support the DMSP and the launching of satellites it required modification of the Missile Shelter and surrounding support facilities. The Missile Shelter was enlarged to accommodate the added length of the launch vehicle, the installation of a clean room in the Missile Shelter, and the lengthening of the existing steel rails to accommodate the new shelter extension. Several additional modifications occurred on the pad including the installation of a new GN_2 tank farm, the enlargement of the Electrical Equipment Building, and the raising of an existing steel camera stand by an additional 18'. The new height allowed the camera to see over the new, extended shelter. After the modifications were completed, the West Pad contained the only launch shelter of its kind in the world.

In 1965, 150' of new rails were installed to accommodate a new west end Missile Shelter at the launch pad. The new rails, installed to continue the line of the existing shelter rails, allowed the new west end shelter to be moved from the launch area to a stowed position down range prior to launching of the launch vehicle. Foot and rail stops were installed at the west of the new rails to prevent over run of the shelter past the end of the rails.

The new Removable Shelter, Upper Stage was constructed at the west end of the original Missile Shelter. The new shelter was constructed of the same honeycomb panels and bent column ribs as in the original Missile Shelter, measured approximately 32' in length, and incorporated the original west end free-standing wall into the design. (See photographs CA-296-H-14 through CA-296-H-19.)

In 1975, to support Block 5D launches, the air conditioning system for the new west end shelter clean room, was brought into operation.[166] The Block 5D program was the latest and most modern payload at the time under the DMSP. The third stage and the satellite (enclosed in a protective shroud) were attached to the missile as a single stage within the clean room. The clean room, supplied with purified air, prevented the payload from becoming contaminated during testing and prelaunch proceedings. Full height and width curtains, installed at both the east and west ends of the clean room, provided a "seal" against airborne particulates. Conditioned and purified air was supplied to the clean room via air conditioning units installed on top of both Missile Shelter sections. The units provided negative pressure into the clean room thereby preventing outside contamination from entering into the "clean space." To visually mark the clean room area, a portion of the floor was painted white as well as (Figure 47).

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[166] Work Request, Work Order No. 05/36, SLC-10 West Missile Shelter, Air Conditioning System, (Vandenberg Air Force Base, Office Symbol: 10AERODS/LGMAS/76-9686, 4 February 1975).

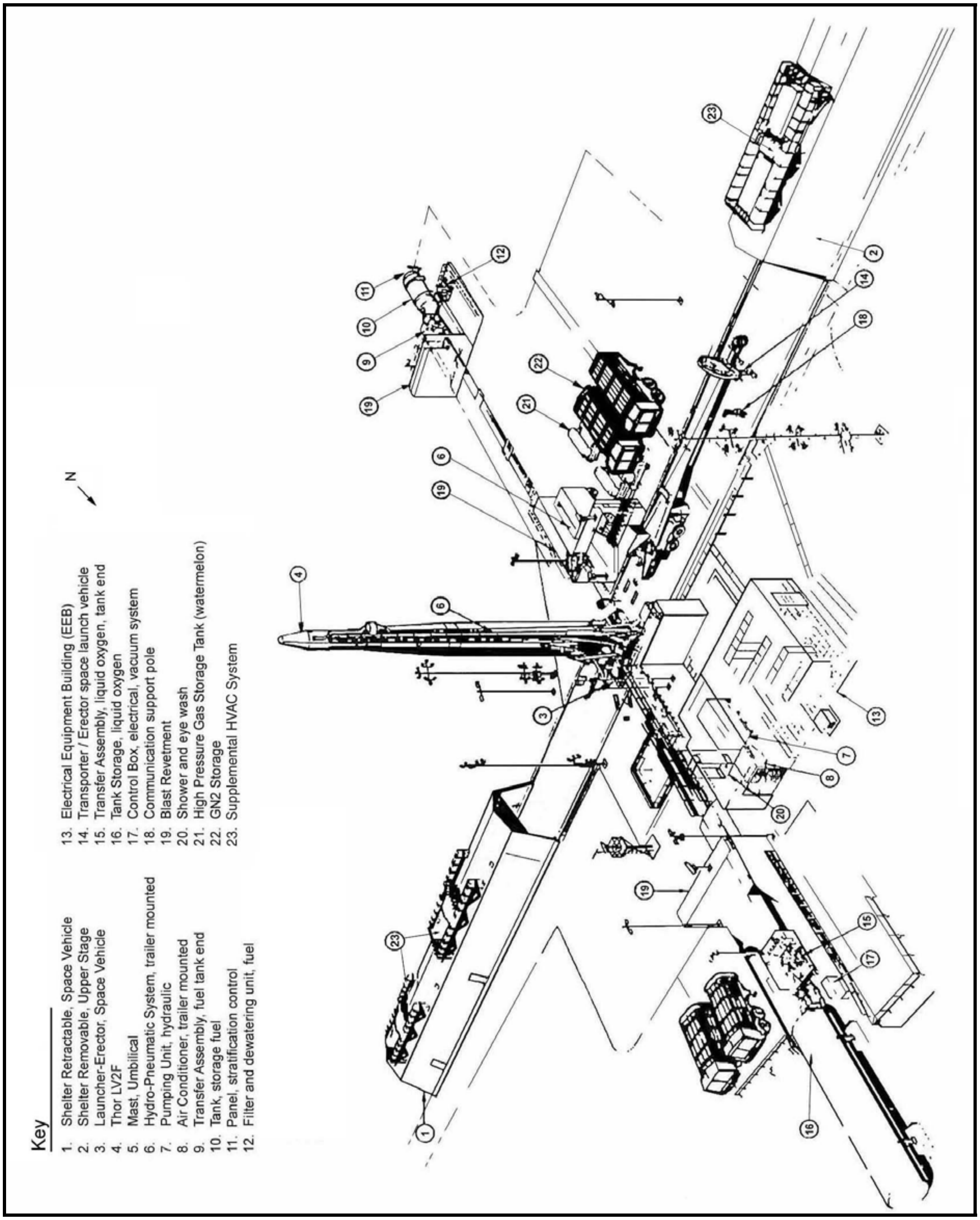

Figure 47: Launch Emplacement SLC-10 West. Note: Launch pad configuration includes non-standard components such as the Shelter Removable, Upper Stage (#2), the Electrical Equipment Building (#13), and the Supplemental HVAC System (#23).

By January 1978, the air conditioning system and filters for the clean room were in poor condition due to their age and the corrosive marine environment. These air conditioners, originally installed at SLC-1 around 1962, were moved to SLC-10 West in the early 1970s. Modifications to the clean room air conditioning system included: the relocation of a Lennox air conditioning unit from the Blockhouse to the shelter, new duct work for supply and return air, new filters that provided class 100 conditioned air to the shelter and class 15 conditioned air to the existing payload air conditioning system, environmental controls for 68^0 F. and 50% or less relative humidity.[167]

A clean area monitoring station was installed on the exterior wall of the west end shelter. The monitoring station consisted of a metal box housing the clean area temperature and humidity recorder and a warning bell. The bell would give an audio warning if the clean area particulate count exceeded a predetermined limit[168] (Figure 48).

Figure 48: View of West End Shelter. Note air conditioning units on top of Shelter and the Clean Air Monitoring Station (small metal box below center on Shelter wall)

[167] "SLC-10 Shelter Air Conditioning and Filter Installation", Ground Systems Change Request, Contract: F04701-77-C-0103, January 25, 1978.; Letter to CCQTE/Capt Goodfellow, Summary of Condition Shelter Air Conditioners on SLC10W, (Department of the Air Force, 10th Aerospace Defense Squadron, Vandenberg Air Force Base, California, 1978).
[168] "Clean Area Monitoring Station", Engineering/Maintenance Worksheet, Engineering Control No. 77-SK-042, April 1977. A copy is on file at the Vandenberg Air Force Base Space and Missile Heritage Center.

With the introduction of the DMSP to the West Pad, the launch mount was modified from a dry launch mount to a wet launch mount. Numerous water nozzles directed at the launch mount and surrounding equipment were installed primarily to attenuate the sound generated by the launch and not to suppress the fiery blast itself. Both spray fog nozzles and spreader-type deck flush nozzles were. The nozzles were positioned around the launch mount as well as fixed atop the surrounding blast walls. Several nozzles pointed towards equipment located behind the blast walls to further minimize blast damage. (See photographs CA-296-H-33 and CA-296-H-34.)

In 1976, both the fuel and LOX systems were modified. The fuel side of the pad was also modified with the installation of a new concrete trench. The trench was covered with hinged 7/8" thick steel plates for access.

The original rectangular LOX pit was back-filled and covered with a concrete slab. The new LOX overflow pit, measuring 12'-8" square, was located adjacent to the existing LOX trench. The existing 3" diameter stainless steel piping with 1" foam glass insulation was re-routed and extended to empty into the new LOX pit. An existing 1'-0" instrumentation trench, circumventing the original LOX overflow pit, remained in place.

Electronic Equipment Building (EEB)[169]
When SLC-10 was in operation, the EEB housed the launch pad's telemetry equipment, electronic equipment and hydraulic power unit. The EEB, located adjacent to the north side of the launch shelter (Facility 1658), was partially protected by an L-shaped reinforced concrete revetment wall. When originally constructed, the EEB consisted of one rectangular room measuring 32'-8" by 18'-7". The building was constructed with a reinforced concrete foundation and concrete masonry block walls. The roof is a 5" thick reinforced concrete slab with 3-ply built-up roofing material and gravel stops. The raised interior floor is constructed of 2'-2" x 8" and 2'-2" x 10" laminated boards, nailed and glued with 2"x4" blocking with 1 1/8" 2-4-1 exterior plywood with asphalt tile over the existing concrete slab. An instrumentation trench,

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[169] "Const Addn to Bldg 1654: Equipment Hut, Plans, Elevation & Sections", Strategic Air Command, Vandenberg Air Force Base, California, Drawing Number 136-4, Sheet 6 of 10, Filed under 1654-4-6, January 16, 1964; "SLC-10 W Alteration, EEB Foundation Plan & Roof Reinf. & Details", Drawing Number S-7, D.O. File No. 1801/173 (1658-11-13), Spec. No. DACA09-76-B-0016, (Vandenberg Air Force Base, CA, Department of the Air Force, Space and Missile Systems Organization, Los Angeles, CA, S&T Western, In., Consulting Engineers, a Unit of STV, Inc., Long Beach, CA, February 16, 1976); "SLC-10 W Alteration, Electronic Equipment Building, Expansion Plan and Elevations", Drawing Number A-1, D.O. File No. 1801/176 (1658-11-16), Spec. No. DACA09-76-B-0016, (Vandenberg Air Force Base, CA, Department of the Air Force, Space and Missile Systems Organization, Los Angeles, CA, S&T Western, In., Consulting Engineers, a Unit of STV, Inc., Long Beach, CA, February 16, 1976); "SLC-10 W Alteration, EBB Sections & Details", Drawing Number A-2, D.O. File No. 1801/177 (1658-11-17), Spec. No. DACA09-76-B-0016, (Vandenberg Air Force Base, CA, Department of the Air Force, Space and Missile Systems Organization, Los Angeles, CA, S&T Western, In., Consulting Engineers, a Unit of STV, Inc., Long Beach, CA, February 16, 1976); "SLC-10 W Alteration, Power, Lighting & Alarm Plans", Drawing Number E-3, D.O. File No. 1801/183 (1658-11-23), Spec. No. DACA09-76-B-0016, (Vandenberg Air Force Base, CA, Department of the Air Force, Space and Missile Systems Organization, Los Angeles, CA, S&T Western, Inc., Consulting Engineers, a Unit of STV, Inc., Long Beach, CA, February 16, 1976).

measuring 1’-6” wide by 1’-3” deep with 4” concrete walls, extends into the building. The trench is constructed with 4” reinforced concrete walls with 6”x6” #6 WWF and a 4”x12” x 1’-10” wooden cover.

When the building was altered in 1976 the building was enlarged to accommodate three separate rooms – the Payload and Upper Stage Room, the existing Booster Room, and the Mechanical AGE Room. The environmentally sealed electronic equipment, located in the Payload and Upper Stage Room and the existing Booster Room, was used to monitor missile emplacement and build-up, missile checkout, launch proceedings, and the status of the missile after the launch. Equipment included power supply assembly units, distribution panels, space vehicle simulators, and launch countdown and checkout equipment. A hydraulic power unit, located in the Mechanical AGE Bay, powered the hydraulic actuator used to erect the missile. The hydraulic lines, exiting the EEB through cable trays, terminated at the erecting equipment in the shelter. (See photographs CA-296-H-20 through CA-296-H-23.)

The enlarged building contained 4,169 square foot and is constructed with a 6” reinforced concrete foundation matching the grade and construction technique of the original EEB foundation. The interior finished floor is 1’-1” above grade. The walls are constructed of 12”x8”x16” concrete masonry units 9’-9” high and matching the existing joints and bond used on the original EEB facility. The roof is a concrete slab with 2 ½” rigid insulation and built-up roofing over a 24 gauge galvanized gravel stop.

The interior of the modified EEB was arranged with the Payload and Upper Stage Room on the north side, the existing Booster Room (the original EEB) on the south side, and a new Mechanical AGE Bay, on the east side. The Payload and Upper Stage Room measures 16’-5” wide by 31’-5” long and oriented in the east-west direction. The existing Booster Room measures 17’-5” wide by 31’-5” long and also oriented in the east-west direction. The Mechanical AGE Bay measures 17’-0” wide by 33’-10” long with a 3’-9” jog in southeast corner to accommodate the corner of the existing trailer revetment wall.

A 6’ wide aluminum ramp is installed on west side of the building providing access into Payload and Upper Stage Room via a steel door. A second existing steel door accesses the Booster Room also from the west. Both the north and south sides of the Mechanical AGE Bay contain steel roll-up doors that are approximately 10’ wide by 8’ tall.

The Payload and Upper Stage Room contains an elevated floor to allow the cables from the multiple check-out racks to span between equipment and the launch pad. The existing Booster Room is also equipped with check-out racks and an identical elevated cable floor. The Mechanical AGE Bay has an exposed concrete floor. To allow access between the three rooms two 4’-0” wide door openings were cut between the Payload and Upper Stage Room and the existing Booster Room. A third 3’-4” wide door opening was cut between the existing Booster room and the Mechanical AGE Bay.

LE-8 PAD

Facility 1661: LE-8 (HAER No. CA-296-K)

LE-8 is located approximately 400' northwest of the Blockhouse. The pad consisted of the Missile Shelter, propellant facilities, and support facilities. Surrounding the shelter were power transformers, countdown and pumping units, air conditioning units and miscellaneous support facilities. Access to the pad is possible via Porto Road and Piro Road (Figure 49).

Figure 49: Aerial View of Thor Pad With Missile Shelter Over Launcher

When originally constructed, the LE-8 pad was a typical Thor IRBM pad and identical to the other two original Thor IRBM pads at SLC-10. The Air Force dismantled LE-8 and shipped it to Johnston Island to support the Dominic series of nuclear tests in 1962. Afterwards, the Air Force rebuilt LE-8 at SLC-10. However, having never used the rebuilt LE-8, the Air Force decommissioned the pad in the early 1970s and salvaged its equipment for use elsewhere.[170]

[170] The exact date of the decommissioning and dismantlement of LE-8 is unclear as many of the Real Property records of the complex from that period cannot be located.

Today, the site consists of a large paved area and concrete blast walls. The site retains remnants of the steel guide tracks used by the removed Missile Shelter. The site is roughly symmetrical with concrete blast walls situated at 90 degree angles, similar to Pad 10E and Pad 10W. Sloped rectangular retention areas with concrete curbs flank the inside corners of the wall. Concrete retaining walls connect these blast walls to smaller blast walls located on the opposite side of the steel tracks. A helicopter pad was added at the west end of the tracks, opposite the hydrogen peroxide facility. Gaseous nitrogen was also used on the north pad. The north pad was not used on a routine basis, however, and therefore the GN_2 equipment was designed to be portable. (See photographs CA-296-K-1 through CA-296-K-8.)

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Figure 1: National Aeronautics and Space Administration

Figure 2: National Aeronautics and Space Administration

Figure 3: Vandenberg Air Force Base Space and Missile Heritage Center

Figure 4: US Army Engineering Research and Development Center, Construction Engineering Research Laboratory

Figure 5: Vandenberg Air Force Base Space and Missile Heritage Center

Figure 6: Vandenberg Air Force Base Space and Missile Heritage Center

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Figure 15: Map Modified from report "Space Launch Complex 10 Condition Assessment/Engineering Study, Vandenberg Air Force Base", (Tetra Tech, Inc., Santa Barbara, CA, September 1998).

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Figure 25: Vandenberg Air Force Base Space and Missile Heritage Center

Figure 26: “Technical Manual Operation 35E3-6-11, Service and Repair, Panelized Prefabricated Building, SHU-18/E, SHU-19/E, Part Numbers 1A24547-501, 1A98984-1”, (Douglas, Aircraft Company, Inc., AF04(695)-309, F09603-76-D-0419, Published under Authority of the Secretary of the Air Force, 18 May 64, Change 4 – 15 April 1977, 2-17 and 2-20).

Figure 27: Technical Manual 21-SM75-01, “Missile and Equipment SM75 Weapon System”, AF04(645)-65, AF04(607)6498, (Rocket Dyne, Division of North American Aviation Inc., 28 September 1962).

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Figure 45: Diagram 75031-150 (1802-6), n.d.. Copy on file at the Vandenberg Air Force Base Space and Missile Heritage Center

Figure 46: "Space Launch Complex 10W, Azimuth Alignment Site, Site Plan", Drawing No. SK2278102, (RCA, 1973).

Figure 47: Defense Meteorological Satellite Program, Block 5D launch, n.d., 23. Copy on file at the Vandenberg Air Force Base Space and Missile Heritage Center.

Figure 48: Photograph by Mr. Donald J. Prichard, Vandenberg Air Force Base Space and Missile Heritage Center, 2001.

Figure 49: Figure 227, "US Launch Complex Handbook, Vol III, Part I", 1963. Handbook on file at the Vandenberg Air Force Base Space and Missile Heritage Center.

APPENDIX 1: SLC-10 LAUNCH SUMMARY, 1959-1960[171]

Date	***Pad***	***Launch Configuration***	***Launch Name***	***Program Association***	***Comments***
16 April 1959	75-2-8	Thor DM-18A (Initial Operational Capability program)	Lion's Roar	Thor IRBM CTL IWST (RAF)	First Thor launched by RAF crew; Successful
16 June 1959	75-2-7	Thor DM-18A	Rifle Shot	Thor IRBM CTL IWST	RAF launch; Failure
14 August 1959	75-2-6	Thor DM-18A	Short Skip	Thor IRBM; IOC missile	Failure
6 October 1959	75-2-8	Thor DM-18A	Foreign Travel	Thor IRBM; CTL WS-315A	RAF launch; Successful
2 March 1960	75-2-8	Thor DM-18A	Center Board	Thor IRBM; CTL WS-315A	RAF launch; Successful
22 June 1960	75-2-7	Thor DM-18A	Clan Chattan	Thor IRBM; CTL WS-315A	RAF launch; First missile returned from UK for launching at VAFB; Successful
11 October 1960	75-2-8	Thor DM-18A	Left Rudder	Thor IRBM; CTL WS-315A	RAF launch; Second missile returned from UK for launching at VAFB; Successful
13 December 1960	75-2-8	Thor DM-18A	Action Town	Thor IRBM; CTL WS-315A	RAF launch; Successful
29 March 1961	75-2-7	Thor DM-18A	Sheperd's Bush	Thor IRBM; CTL WS-315A	RAF launch; Successful
20 June 1961	75-2-7	Thor DM-18A	White Bishop	Thor IRBM; CTL WS-315A	RAF launch; Successful
6 September 1961	LE-7	Thor DM-18A	Skye Boat	Thor IRBM; CTL WS-315A	RAF launch; Successful
5 December 1961	LE-8	Thor DM-18A	Piper's Delight	Thor IRBM; CTL WS-315A	RAF launch; Successful
19 March 1962	LE-7	Thor DM-18A	Black Knife	Thor IRBM; CTL WS-315A	RAF launch; Failure
18 June 1962	LE-8	Thor DM-18A	Blazing Cinders	Thor IRBM; CTL WS-315A	RAF launch; Last CTL operational test launch; Successful
19 January 1965	4300 B-6	Thor-Burner I	Astral Lamp	DMSP	Payload failed to separate from 2nd stage
18 March 1965	4300 B-6	Thor-Burner I	Astral Body	DMSP	Successful
20 May 1965	4300 B-6	Thor Burner I	Royal Eagle	DMSP	Successful

[171] Data provided by the Vandenberg Air Force Base Space and Missile Heritage Center.

Date	***Pad***	***Launch Configuration***	***Launch Name***	***Program Association***	***Comments***
10 September 1965	4300 B-6	Thor-Burner I	Victoria Cross	DMSP	Successful
8 January 1966	4300 B-6	Thor-Burner I	Persian Lamb	DMSP	2nd stage did not separate from Thor
31 March 1966	4300 B-6	Thor-Burner I	Resort Hotel	DMSP	Last Thor-Altair (Burner I); Successful
16 September 1966	4300 B-6	Thor-Burner II	Irish Duke	DMSP	Successful
8 February 1967	4300 B-6	Thor-Burner II	Arrow Point	DMSP	Successful
29 June 1967	LE-6	Thor-Burner II	Deer Foot	*	Science, geodesy
23 August 1967	LE-6	Thor-Burner II	*	DMSP	Successful
11 October 1967	LE-6	Thor-Burner II	*	DMSP	Successful
23 May 1968	SLC-10W	Thor-Burner II	*	DMSP	Successful
23 October 1968	SLC-10W	Thor-Burner II	*	DMSP	Successful
23 July 1969	SLC-10W	Thor-Burner II	*	DMSP	Successful
11 February 1970	SLC-10W	Thor-Burner II	*	DMSP	Successful
3 September 1970	SLC-10W	Thor-Burner II	*	DMSP	Successful
17 February 1971	SLC-10W	Thor-Burner II	*	DMSP	Successful
8 June 1971	SLC-10W	Thor-Burner II	*	*	Tested new celestial infrared sensors, spacecraft attitude sensing device
14 October 1971	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
24 March 1972	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
9 November 1972	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
17 August 1973	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
16 March 1974	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
9 August 1974	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
24 May 1975	SLC-10W	Thor-Burner IIA	*	DMSP	Successful

Date	***Pad***	***Launch Configuration***	***Launch Name***	***Program Association***	***Comments***
19 February 1976	SLC-10W	Thor-Burner IIA	*	DMSP	Failed to reach operational orbit
11 September 1976	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
1 May 1978	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
6 June 1979	SLC-10W	Thor-Burner IIA	*	DMSP	Successful
15 July 1980	SLC-10W	Thor-Burner IIA	*	DMSP	Failure

APPENDIX 2: ACRONYMS

AAF	Army Air Forces
AC	Alternating Current
ADC	Air Defense Command
ADCOM	Aerospace Defense Command
ADG	Aerospace Defense Group
ADS	Aerospace Defense Squadron
AEC	Atomic Energy Commission
AFMTC	Air Force Missile Training Center
AGE	Aerospace Ground Equipment
ARPA	Advanced Research Projects Agency
ATW	Aerospace Test Wing
AFBMD	Air Force Ballistic Missile Division
AFSC	Air Force Systems Command
ARDC	Air Research and Development Command
ASAT	Anti-Satellite
BMDTTP	Ballistic Missile Defense Test Target Program
CIA	Central Intelligence Agency
CTL	Combat Training Launch
DC	Direct Current
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
DSCS	Defense Satellite Communications System
EEB	Electronic Equipment Building
F	Fahrenheit
FLATSATCOM	Fleet Satellite Communications
FOBS	Fractional Orbit Bombardment System
GA	Gauge
GPS	Global Positioning System
GN_2	Gaseous Nitrogen
HAP	High Altitude Program
HAER	Historic American Engineering Record
ICBM	Intercontinental Ballistic Missile
IDSCS	Initial Defense Satellite Communication System
IOC	Initial Operational Capability
IRBM	Intermediate-Range Ballistic Missile
IWST	Integrated Weapons System Training
KH	Keyhole
KV	Kilovolt
LOX	Liquid Oxygen
MIDAS	Missile Defense Alarm System

MTS	Missile Training Squadron
NASA	National Aeronautics and Space Administration
NHL	National Historic Landmark
NMFPA	Naval Missile Facility at Point Arguello
NOAA	National Oceanic and Atmospheric Administration
NSC	National Security Council
OSO	Orbiting Solar Observatory
RAF	Royal Air Force
RAND	Research and Development Corporation
RP-1	Rocket Propellant
SAC	Strategic Air Command
SALT	Strategic Arms Limitation Treaty
SAMOS	Satellite and Missile Observation System
SAMTEC	Space and Missile Test Center
SDP	Special Defense Program
SLC	Space Launch Complex
SMS	Strategic Missile Squadron
SMW	Strategic Missile Wing
TACSAT	Tactical Communications Satellite
TIROS	Television and Infrared Observation Satellite
TMGS	Telemetry Ground Station
TO	Technical Order
TSB	Technical Support Building
UK	United Kingdom
US	United States
USAF	United States Air Force
V	Volt
VAFB	Vandenberg Air Force Base
WS	Weapon System
WTR	Western Test Range
WWF	Welded Wire Fabric