AIR FORCE PLANT PJKS, SYSTEMS INTECRATION LABORATORY
(Clenn L. Martin Company)
(Martin Marietta Corporation)
(Lockheed Martin Astronautics)
Waterton Canyon Road and Colorado Highway 121
Lakewood Vicinity
Jefferson County
Colorado

HAER No. CO-88

PHOTOCRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINCS

HISTORIC AMERICAN ENGINEERING RECORD
Rocky Mountain System Support Office
National Park Service
P.O. Box 25287
Denver, Colorado 80225-0287

HISTORIC AMERICAN ENGINEERING RECORD
AIR FORCE PLANT PJKS, SYSTEMS INTEGRATION LABORATORY
(Glenn L. Martin Company)
(Martin Marietta Corporation)
(Lockheed Martin Astronautics)

HAER No. CO-88

Location: The Systems Integration Laboratory is located near the intersection of Waterton Canyon Road and Colorado Highway 121, Lakewood Vicinity, Jefferson County, Colorado.

USGS 7.5 Minute Quads: Littleton, Colorado, 1994.

UTM Coordinates: 13/489600/4373500.

Dates of Construction: 1960-1961; Periodic technological modifications 1965-Present.

Present Owners: United States Air Force.

Present Use: The Systems Integration Laboratory complex functions as an integrated facility with various buildings contributing to overall testing of Titan missile propellant systems.

Significance: The Systems Integration Laboratory was constructed on Air Force property adjacent to the Glenn L. Martin Company to conduct system integration evaluations for the fuel (hydrazine-based) and oxidizer (nitrogen tetroxide) supply systems of the Titan II intercontinental ballistic missile (ICBM) -- the largest and most powerful weapon in the U.S. nuclear arsenal during the Cold War (1962-87). The hypergolic propellants that fueled the new missile ignited upon contact with each other and were storable at room temperature, thus enabling the missile to be fired instantaneously from a hardened underground silo launcher. Therefore, construction of a new facility which largely duplicated the function of the Cold Flow Laboratory was necessary due to the selection of these new propellants to fuel the Titan II. The testing conducted within the Systems Integration Laboratory was critical to the success of the Titan II program, and this was the only site in the United States where such testing was conducted. Subsequent to Titan II testing, the laboratory facilities have been used to conduct propellant system integration evaluations of the Titan III and Titan IV launch vehicles.

Historian: Harlan D. Unrau, National Park Service, Denver Service Center, 1999.

This Historic American Engineering Record study describes the Titan intercontinental ballistic missile Systems Integration Laboratory facilities on Air Force property adjacent to the Glenn L. Martin Company (Martin Marietta Corporation; Lockheed Martin Astronautics), Jefferson County, Colorado. These facilities have been determined eligible for listing on the National Register of Historic Places. The recordation is the result of an interagency agreement between the National Park Service and the Department of the Air Force, and was completed in conjunction with environmental mitigation of the site by the Air Force.[1]

INTRODUCTION

On October 4, 1957, the Soviet Union announced that it had used a liquid fuel intercontinental ballistic missile (ICBM) to launch a 185-pound artificial satellite called "Sputnik" into orbit around the Earth. This demonstration of Russian technological prowess caused many American scientists and politicians to fear that the Soviet Union had opened a significant "Missile Gap" that would give them a commanding lead in the arms race during the Cold War. Thus, the United States began an effort to narrow the perceived gap.[2]

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[1] This project was undertaken by the Cultural Resources and National Register Programs Office of the National Park Service's Intermountain Support Office - Denver. Under the direction of Lysa Wegman-French, Historian, the narrative was completed by Harlan D. Unrau, Historian, Denver Service Center, and the measured drawings were prepared by Hugh A. Duffy, Landscape Architect, Denver Service Center. The photographs were taken by Lisa Lynch, Photographer, Curecanti National Recreation Area. In 1993, John F. Lauber and Jeffrey A. Hess of Hess, Roise and Company, Minneapolis, prepared Historic American Engineering Record, Glenn L. Martin Company, Titan Missile Test Facilities, HAER No. CO-75, documenting the Titan missile test facilities adjacent to the Martin Denver Division plant (Air Force Plant PJKS). This report supplements that study with recordation of the Titan Systems Integration Laboratory.

[2] For more information on the development of U.S. ballistic missiles within the context of the Cold War, see U.S. Department of the Air Force, Air Force Materiel Command, Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio and U.S. Department of the Army, Fort Worth District, Corps of Engineers, Fort Worth, Texas, Historic Building Inventory and Evaluation, Air Force Plant PJKS, Jefferson County, Colorado, prepared by EARTH TECH, Colton, California, and William Manley Consulting, San Diego, California, February 1997, pp. 3-1 to 3-18; 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); Ernest G. Schwiebert, A History of the U.S. Air Force Ballistic Missiles (New York, Washington, London: Frederick A. Praeger, Publishers, 1965); and United States Air Force Oral History Program, Interview No. 676, General Bernard A. Schriever by Major Lyn R. Officer and Dr. James C. Hasdorff, 20 June 1973, Washington, D.C., Typed transcript,

Facing severe criticism for allowing the United States to fall behind the Soviet Union in the arms race, the Eisenhower administration responded that its missile programs had never been intended to merely "put something together" in a hurry. The programs were carefully designed, according to a spokesperson, first to "attain perfection," and then to "develop the ability to produce in volume once that perfection is achieved."[3]

But America's first-generation ICBMs were neither perfect nor mass producible. The Atlas and Titan missiles, according to the November 21, 1957, issue of the Wall Street Journal, were extraordinarily complex, hand-crafted machines, containing as many as 300,000 components, each of which had to be maintained in perfect operating condition in order for the missile to successfully complete its mission. The liquid oxygen that was the oxidizer for their engines was volatile and cryogenic (-297 degrees Fahrenheit), and could not be placed into the missiles' tanks until immediately before launch. Although the missiles were stored with their tanks full of fuel, they still needed to be loaded with volatile liquid oxygen so that the fuel could be ignited. This loading process could only be done after the missiles had been raised from their underground silos to the surface, and it was a slow, delicate operation that increased the weapon's vulnerability and restricted its reaction time. The fueling process could take as long as two hours. Consequently, instead of being "stable weapons in a state of permanent readiness," the early ICBMs would "require the desperate and constant attention

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K 239.0512 - 676, and Space and Missile Systems Organization, Chief of Staff, History Office, "Space and Missile Systems Organization: A Chronology, 1954-1976," AFSC Historical Publication, K 243.052 - 13, 54/00/00 - 76/00/00, in United States Air Force (USAF) Collection, Air Force Historical Research Agency (AFHRA), Maxwell Air Force Base (AFB), Montgomery, Alabama. For an analysis of the interactions of science, technology, warfare, and American actions and reactions to world events during the Cold War era, see Melvin Kranzberg, "Science-Technology and Warfare; Action, Reaction, and Interaction in the Post-World War II Era," pp. 123-70, in Science, Technology, and Warfare: The Proceedings of the Third Military History Symposium, United States Air Force Academy, 8-9 May 1969, ed. by Lt. Col. Monte D. Wright and Lawrence J. Paszek, Office of Air Force History, Headquarters USAF and United States Air Force Academy.

[3] Roy Licklider, "The Missile Gap Controversy," Political Science Quarterly 85 (December 1979): 605, and John Prados, The Soviet Estimate (New York: Dial Press, 1982): 77.

accorded a man receiving artificial respiration." A missile unit would not be a "push-button affair" but would "require a highly trained crew . . . several times as large as the largest bombing crew." Many of these problems could be solved, according to the Wall Street Journal, by developing a greatly simplified "second generation" of missiles powered by solid-fuel rocket engines.[4]

While the Atlas and Titan missiles moved into large scale production and began deployment to operational squadrons, "vaulting technology was harshly altering the shape of the total [ballistic missile] program." Three circumstances were chiefly responsible: renewed recognition of the need for "hardened" launch sites that would offer reasonable protection against an enemy first strike; progress toward the long-term goal of developing storable propellants, so that a liquid-fuel missile need not be exposed to the extra hazards of last minute fueling or, alternately, to difficulties inherent in the use of liquid oxygen as a principal propellant; and the refinement of single-grain solid rockets substantially larger than anything conceived before Sputnik.

The first two of these factors, "hard siting" requirements and the recognized need for non-cryogenic propellants, led to creation of Titan II, a substantially improved version of the original Titan ICBM, which had been conceived as a two-stage vehicle to serve as a backup to the Atlas. Apart from reducing missile-reaction time by the many minutes needed to fuel each missile, the adoption of non-cryogenic propellants eliminated one of the most troublesome items of missile technology -- high-rate-of-flow propellant loading equipment. Seizing the opportunity provided by incorporation of such a radical change, the Air Force also programmed

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[4] Wall Street Journal, 21 November 1957. Also see Neufeld, Development of Ballistic Missiles, 192. For more information on how the Titan I missile's most important subsystems operated, see Technical Training and Scientific Relations Group, Guided Missile Research Division, The Ramo-Wooldridge Corporation, "Notes on Technical Aspects of Ballistic Missiles," Air University Quarterly Review 9 (Summer 1957): 34-68.

for Titan II such innovations as in-silo launching from hardened sites, all-inertial guidance, and a substantially more powerful second stage.[5]

The Air Force took an important step toward achieving its ideal missile basing system on December 1, 1959, when it approved the development of the Titan II ICBM. In 1960, it began to develop the Titan II -- a second-generation missile that was designed to use completely storable liquid propellants. These missiles could be kept ready with fully loaded propellant tanks and could be instantaneously fired directly from their hardened underground silos.[6] Later on April 10, 1961, the Air Force issued Specific Operational Requirement 184, separating program management control of the Titan II from that of the Titan I.[7]

TITAN II MISSILE

Even before the Titan I became operational, the Air Force began funding research for a more powerful, longer-range intercontinental ballistic missile. As a result of this research program, the Glenn L. Martin Company of Baltimore, Maryland,[8] proposed a four-part improvement program for the Titan I missile during the winter of 1959-60. The proposed improvements included: (1) base simplification, the biggest part of which was an in-silo

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[5] Robert L. Perry, "The Atlas, Thor, Titan, and Minuteman," in The History of Rocket Technology, ed. by Eugene M. Emme (Detroit: Wayne State University Press, 1964): 155, and Edmund Beard, Developing the ICBM: A Study in Bureaucratic Politics (New York: Columbia University Press, 1976): 210-11.

[6] Schwiebert, History of the U.S. Air Force Ballistic Missiles, 137, and Office of the Historian, Headquarters Strategic Air Command, Offutt Air Force Base, Nebraska, From Snark to Peacekeeper: A Pictorial History of Strategic Air Command Missiles (May 1, 1990): 23.

[7] "History, Volume III, Headquarters Second Air Force, Barksdale Air Force Base, Louisiana, 1 January 1962 - 30 June 1962," p. 3-1, K 432.01, Jan.-Jun. 1962, Vol III, in USAF Collection, AFHRA.

[8] For a history of the Martin Company (and its Denver Division plant where the Titan II would be manufactured) which would merge with the American Marietta Company to become the Martin Marietta Corporation in October 1961, see William B. Harwood, Raise Heaven and Earth: The Story of Martin Marietta People and Their Pioneering Achievements (New York, London, Toronto, Sydney, Tokyo, Singapore: Simon & Schuster, 1993), and U.S. Department of the Air Force and U.S. Department of the Army, Historic Building

launching proposal that would enable the missile to be launched "hot" out of a reinforced concrete silo; (2) adoption of all-inertial guidance to replace the radio-inertial system of the Titan I, thus simplifying base design by eliminating ground-based transmitter antennas; (3) redesign of stage two of the missile from an eight-foot diameter to a ten-foot diameter, thus offering more propellant tankage and therefore greater thrust and either greater range or greater payload (the Titan II would carry the largest warhead ever flown on an American ICBM) inside a larger ablative reentry body and probably both; and (4) adoption of hypergolic liquid propellants that could be stored in the missile tanks indefinitely and ignited spontaneously upon contact, thus requiring no ignition system to bring reaction time down from minutes to seconds.[9]

On June 20, 1960, the Air Force's Air Research and Development Command (ARDC), Ballistic Missile Division (BMD) in Los Angeles awarded the Martin Company a new contract to develop and manufacture an advanced version of the Titan I (to be known as Titan II [SM-68B]) at its Denver Division plant some twenty miles southwest of the city near Littleton, Colorado. The contract provided that Martin would serve as systems integrator for the Titan II program. In addition, the company was responsible for airframe design fabrication and manufacture as well as integration, assembly, and testing of the missile. As airframe contractor, the Martin Company, with technical direction provided by Space Technology Laboratories, Inc., was responsible for the missile's installation, checkout, and operation of the airframe, autopilot, and propulsion components. Then, as each subsystem was added, having

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Inventory and Evaluation, Air Force Plant PJKS, Jefferson County, Colorado, pp. 3-19 to 3-31. In 1995, Martin Marietta would merge with Lockheed to form Lockheed Martin Astronautics.

[9] Russell Hawkes, "Part I: Titan ICBM Fabrication, Martin Proposes Improved Titan System," Aviation Week and Space Technology 72 (11 January 1960): 56. The major portion of this article (pps. 56-57, 59, 61, 63, 65, 67) included a detailed description of the existing Titan I ICBM. Also see G. Harry Stine, ICBM: The Making of the Weapon That Changed the World (New York: Orion Books, 1991): 229.

been first thoroughly tested by the subsystem contractor, the Martin Company assumed responsibility for the entire missile configuration.[10] The new missile would, according to the July 2, 1960, issue of Business Week, constitute "a major design changeover." The "most remarkable feature" of the new missile was "a propulsion system using storable liquid rocket fuel, which can remain in the rocket tanks the way ordinary gasoline is stored in an automobile," enabling the missile to "be fired in seconds."[11]

The new Titan II missile was described in a series of articles in the September 5, 1960, issue of Missiles and Rockets. According to one article written by James Baar, a reporter for the periodical, the Titan II would "provide SAC [Strategic Air Command] with a missile capable of delivering the largest nuclear warhead in the nation's ICBM arsenal." The missile, powered by fast-reaction storable fuel, would "be SAC's main assault missile for obliterating the enemy's hardened targets." In addition, Titan I and Titan II would "provide the Air Force with boosters capable of hurling Dyna-Soars and other space vehicles and satellites into orbits around the earth and into lunar space." In the words of their manufacturer, they would be the "military 'space trucks' of the future."

Baar went on to state that the main research and development effort in the Titan program "is rapidly swinging to Titan II." He explained how the new contract with Martin had come about:

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[10] Denver Post, 21 June 1960, p. 5. Also see Denver Post, 29 May 1960, pp. 1A, 11A. Further information on this topic may be found in Ernest G. Schwiebert, "USAF's Ballistic Missiles - 1954 - 1964," Air Force and Space Digest 7 (May 1964): 131-32. According to Air Force documents, the Martin Company had responsibility "for the design, tooling and fabrication to the sub-assembly level of the Titan II airborne structure less systems installations, building the battleship tanks, major assemblies of the Denver Captive, Design Engineering Inspection Mockup, and design of a number of items of the Ground Operating Equipment/Ground Support Equipment for Titan II." Semi-Annual Historical Report, AF Plant Representative, The Martin Company, Baltimore, Maryland, 1 Jul 1960 - 31 December 1960, Air Force Plant Representative Office, Martin Company, Baltimore, Air Force History, Narrative, 60/07/01-60/12/31, K 243.0707-23, in USAF Collection, AFHRA.

[11] "ICBM Speedup Brings U.S. Gain in Missile Race," Business Week, 2 July 1960: 19.

> The division of the [Titan] program into two distinct missiles is a sharp break with the step-by-step manner in which Atlas was developed.
>
> Because of the pressure on the Atlas program, improvements generally were introduced into the production line as quickly as possible. This was not done with Titan. Instead, a cut-off point was established for the introduction of further modifications into Titan I, and these were collected for introduction into Titan II.
>
> The result is that Titan II is for all practical purposes a second-generation missile.

Baar elaborated further on the strategic advantages of the Titan II:

> Only Titan II among the nation's big strategic missiles will have the striking power to knock out a hardened target without expending large numbers to ensure success.
>
> For example, assume the largest is a Soviet missile site hardened to withstand pressures of 100 lbs. per square inch. Also assume the missile to be launched against it has a one-megaton warhead and a CEP [circular error probable] of about two miles.
>
> In order to have a 90% chance of destroying the missile site, about 19 missiles would have to be launched against it.
>
> On the other hand, a 10-megaton ICBM with the same CEP greatly reduces the number needed. About six missiles could do the job of the 19.[12]

With greater range and a larger thermonuclear warhead, the Titan II would be targeted to strike against strategic complexes of major size -- and major importance -- deep in the enemy heartland, more than 6,000 miles from the launch site.[13]

By late 1960, the new missile's specifications had been further refined,although they would continue to be fine-tuned as research and development continued. The specifications were described and discussed in a series of articles comprising a "Titan Special Report" in the aforementioned September 5, 1960, issue of Missiles and Rockets. The Titan II would be "developed with tooling, testing and electronic facilities based on those designed for Titan I,

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[12] James Baar, "SAC Getting ICBM 'Crusher,'" Missiles and Rockets 7 (5 September 1960): 11-12.

[13] David A. Anderton, Strategic Air Command: Two-Thirds of the Triad (New York: Charles Scribner's Sons, 1974): 134.

but with greatly improved performance, reliability and reaction time." Hence the Martin Company expected "to phase its facilities here [Denver] from the original version of the two-stage ICBM to the follow-on version with a minimum of effort and complication." The "biggest single change from a tooling point of view" was the "expanded diameter of the second stage from eight to ten feet, equalling the first stage size." Materials used in the two systems "would be identical in most cases," " jigs and fixtures" would apply to both, and "fabrication techniques" would be "equally applicable."

Although Titan II would use essentially the same structural system as Titan I, the new model would be approximately 103 feet in height compared with the Titan I's ninety-eight-foot height. Whereas the diameter of the first and second stages of Titan I's airframe were ten and eight feet, respectively, the diameter of both stages of the Titan II, as aforementioned, would be ten feet, thus greatly expanding Titan II's propellant carrying capacity. The new missile's weight would be approximately 330,000 pounds, some 110,000 pounds heavier than the Titan I. The range of the new missile would be more than 9,000 statute miles, some 3,000 miles more than that for Titan I, and its speed would be 17,000 miles per hour compared with Titan I's 15,000. The thrust of the Titan II's first stage would be 430,000 pounds compared with Titan I's 300,000, and Titan II's second stage would have a thrust of 100,000 pounds compared with 80,000 pounds for its predecessor.

The new missile was also designed to be much simpler and more powerful than the Titan I, its liquid-propellant engines built by the Aerojet-General Corporation of Sacramento, California, having only about one-half as many control components and moving parts as Titan I while having the capability of developing nearly 50 percent more thrust. The Titan II's first stage would include modification to allow second stage ignition before the stages were separated, permitting more acceleration from launch to burnout. The more powerful single-booster first stage and the independent propulsion system in the second stage would permit complete separation of the first stage as a unit. Furthermore, the advanced Titan was to be equipped with an unjammable, self-contained, airbome all-inertial guidance system that required no ground-station support. The system had been developed by the Massachusetts Institute of Technology and would be produced by the AC Spark Plug Division of the General Motors Corporation at its Milwaukee, Wisconsin, plant. The inertial system enhanced the new missile's dispersion and thereby increased its survivability from surprise attack. Development of the Mark 6 reentry vehicle, an ablation-type nose cone produced by General Electric, reduced missile weight and permitted the missile to carry a larger nuclear "warhead of at least ten megatons energy -- the biggest that can . . . be carried by any U.S. missile."[14]

But the most significant differences between Titan II and its predecessor were found in the new missile's propellant system -- "a highly-advanced fuel system, featuring storable liquid propellants and combining the brute power of liquid fuel engines with the storability and quick-start features of solid fuel systems." This new fuel mixture (of 51.9 percent by weight of hydrazine and 46.1 percent unsymmetrical dimethylhydrazine (UDMH) and 2

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[14] The following articles comprised the "Titan Special Report" in Missiles and Rockets 7 (5 September 1960): Frank G. McGuire, "Titan II Will Get More Range and Payload in Production Line Modification," pp. 24-26; "Parts Reduced in Titan II Engine," p. 27; Dan M. Tenenbaum, "Safety Stressed in A-G's Storable Test Facilities," pp. 28-29; Charles D. LaFond, "Guidance Designed to be Fail-proof," pp. 35-36; Hal Gettings, "Support Equipment Highly Integrated," pp. 37-39; and "Major Titan Subcontractors and Suppliers," p. 40. For more data on the specifications of the Titan II missile see "Air Force Orders Titan II Improvements," Aviation Week and Space Technology 72 (27 June 1960): 34; "Martin Wins Air Force Green Light For Titan II With Larger Payload," Army Navy Air Force Journal 97 (2 July, 1960): 26; "Titan II To Be Static-Fired in Silo," Missiles and Rockets 6 (June 27, 1960): 11; Schwiebert, History of the U.S. Air Force Ballistic Missiles, pp. 131, 244-46; Anderton, Strategic Air Command, p. 281; Martin Marietta Corporation, Technical Training Department, "Weapon System Familiarization," 16 November 1962, Revised 8 May 1964, K 416.861 - 6, 1962-1965, and "History, Volume III, Headquarters Second Air Force, Barksdale Air Force Base, Louisiana, 1 January 1962 - 30 June 1962," Parts 3 and 5, K 432.01, Jan.-Jun. 1962, Vol. III, in USAF Collection, AFHRA; Aerojet-General Corporation, Technical Support and Training, Technical Services Division, "Equipment Central Source Data, Titan II Propulsion Systems," 1 June 1964, Ballistic Missile Office Records, L-6, and Headquarters Air Force Systems Command, "Titan II Fact Sheet," November 1961, Ballistic Missile Office Records, Titan 1961, Misc., L-3, in USAF Collection, AFHRA.

percent impurities and an oxidizer of nitrogen tetroxide) increased thrust and allowed instantaneous launch from an underground silo, eliminating the need to raise the missile to the surface and then fuel it before liftoff.[15]

The March 30, 1962, issue of Time provided additional information on the unique qualities of the Titan II's propellant system. What made the system unique was

> a storable fuel that requires no LOX (liquid oxygen) and enables the missile to be ready to fire at a moment's notice. LOX, which is used in the Atlas and Titan I, is cheap and an efficient oxidizer, but its extreme cold (-297 [degrees] F.) and its eagerness to boil away make it troublesome and unreliable. Instead of this chemical bad actor, Titan II uses nitrogen tetroxide as an oxidizer and a mixture of hydrazine and UDMH (unsymmetrical dimethylhydrazine) as fuel. Both are liquids that can be stored for long periods at ordinary temperatures in the missile's own tanks, requir[ing] no last-minute transfusions of rebellious, bubbly LOX. . . .

The article went on to describe the advantages of the new propellantsystem. Besides being storable, Titan II's fuels were "hypergolic." This meant that the two liquids started "burning furiously as soon as they come in contact." No igniting system was needed, thus eliminating "a missile designer's nightmare." Kerosene and LOX, the most common missile fuels, did not ignite on contact; furthermore, if they did not burn promptly, they formed "a powerful explosive mixture that can blow a missile to shreds." Other advances resulted from the abolition of LOX. Although missile designers had learned how to make ultra-cold liquid oxygen flow dependably through tubes, pumps, and valves, this was accomplished by "elaborate and costly tricks" that were not necessary on the Titan II. After Titan II climbed for about two minutes, its second-stage engine would ignite spontaneously when the fuels were turned on and came in contact with one another. Thus, there was "no delay between second

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[15] "2nd Stage Firing Begins Titan II Captive Tests," Martin Mercury 18 (June 16, 1961): 1, and Charles D. Bright, ed., Historical Dictionary of the U.S. Air Force (New York, Westport, Connecticut, London: Greenwood Press, 1992): 570. Also see Martin Marietta Corporation, Technical Training Department, "Weapon

stage separation and ignition." Because of its great thrust and the lack of heavy valves and thick walls, Titan II would have a payload estimated at three tons.[16]

According to the June 16, 1961, issue of Martin Mercury, the Martin Company newspaper, the storability of the propellants would give Titan II "virtual push-button operational capabilities." The missile could thus be "serviced in advance and remain launch-ready over extended periods."[17]

TITAN II SYSTEMS INTEGRATION LABORATORY FACILITIES

The Systems Integration Laboratory, sometimes referred to as the "Titan II Systems Test Laboratory," was constructed to test the integration of the fuel and oxidizer propellant supply systems of the new missile. While the propellants that powered the Titan I were cryogenic, the propellants that powered the Titan II were storable at room temperature. Additionally, while the Titan I propellants required an external source of ignition, those fueling the Titan II were hypergolic and ignited upon contact with each other. Therefore, construction of a new test facility on Air Force property adjacent to the Martin Company's Denver Division plant, largely duplicating the function of the existing Cold Flow Laboratory (Building T-6) that had been constructed for Titan I testing, was necessary due to the selection of the new propellants to fuel the Titan II.[18]

System Familiarization," 16 November 1962, Revised 8 May 1964, K 416.861 - 6, 1962-1965, in USAF Collection, AFHRA, pp. 35 ff.

[16] "Triumphant Titan II," Time 79 (30 March 1962): 68.

[17] "First Titan II Propulsion System Test Firing at M-D," Martin Mercury 18 (June 16, 1961): 2C.

[18] U.S. Department of the Air Force and U.S. Department of the Army, Historic Building Inventory and Evaluation, p. 4-4. For more information on the Cold Flow Laboratory, see its individual structure report (HAER No. CO-75-G) in Historic American Engineering Record, Glenn L. Martin Company, Titan Missile Test Facilities, HAER No. CO-75.

Some two months prior to its contract with the Air Force to develop and manufacture the Titan II, the Martin Company began preparations for the construction and development of testing facilities for the new missile. On April 15, 1960, the Cold Flow Laboratory Facilities Group, consisting of Martin Company Denver Division personnel, prepared a document entitled "Criteria For the Design of XSM 68B Cold Flow Systems Test Laboratory and Components Test Laboratory." The design criteria, consisting of a technical description of the facilities, features, and procedures required for testing the hypergolic propellants of the new missile's fuel system, were prepered to assist the architect/engineer in the testing facilities' design. The criteria provided a general description of the testing procedures that would be conducted in the facilities and a technical description for the design of the principal features of what would become known as the Systems Integration Laboratory.

The testing procedures involved the flowing of fuel and oxidizer through the numerous components and systems associated with the firing of the Titan II. The components to be tested in the laboratory complex included valves, transfer lines, metering devices, and pumps, while the systems to be tested included plumbing, control devices, ordnance, and electronics. The components and systems were to be tested for form, fit, and function as well as reliability to minimize failure of the expensive Titan II missiles that were designed to become the backbone of America's nuclear arsenal. Following completion of the components and systems tests, the Titan II would be ready for captive test firing which represented the culmination of the testing program.

The new facilities were to be located in the northeast portion of the 464-acre Air Force property (designated as Air Force Plant PJKS[19]) adjacent to the Martin Company's Denver

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[19] The Air Force-owned property became known as AFP PJKS; however, it is unclear to whom or what the initials "PJKS" refer. It is possible that they relate to contractors Peter J. Keweit and Sons, who reportedly built a

Division plant that had been acquired from Martin by the Air Force in 1957. Under this arrangement, the Martin Company-owned property at the plant was utilized for the design and manufacture of missiles and other space vehicles, while the Air Force-owned property housed the test facilities for all levels of component, system, and missile testing up to and including captive live-firing of completed missiles and provided critical support for the manufacture and continued development of missile and space vehicle technology. The entire Martin Company and Air Force complex operated synergistically, Martin operating the Air Force-owned missile testing facilities and static test stands within Air Force Plant PJKS.[20]

According to the design criteria, the Systems Integration Laboratory complex would conduct system integration evaluations for the fuel (hydrazine-based) and oxidizer (nitrogen tetroxide) supply systems of the Titan II. The complex would consist of a Components Test Laboratory (later designated as Building T-27) and a Systems Integration Laboratory complex (later designated as T-28). The Components Test Laboratory would consist of three test cells (oxidizer, fuel, and environmental); oxidizer and fuel storage areas; control, equipment, safety

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portion of the plant (although the George A. Fuller Company was reportedly the general contractor for AFP PJKS). The initials could also refer to Martin Project Director for Plant Construction, P.J. Ketelhut, Sr. No documentation for the origin of the acronym "PJKS" was found during research for this report. For further information on this topic, see U.S. Department of the Air Force and U.S. Department of the Army, Historic Building Inventory and Evaluation, p. 3-20.

[20] The Systems Integration Laboratory complex would be constructed at an elevation of some 6,100 feet on a bench approximately 500 feet east of the Cold Flow Laboratory and immediately west of a Fountain Formation outcrop known as the Hogback Ridge. Headquarters Department of the Air Force, Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio, Air Force Plant PJKS, Final, No Further Response Action Planned Document, Building T-28D Equipment Room Floor Drain, Site SS48, prepared by Chem-Nuclear Geotech, Inc., Under DOE Contract No. DE-AC04-861D12584, October 1991, p. 2. For more information on the history of AFP PJKS, see U.S. Department of the Army, Fort Worth District, Corps of Engineers, Fort Worth, Texas and U.S. Department of the Air Force, Aeronautical Systems Center, Office of Environmental Management, Wright-Patterson Air Force Base, Ohio, Cultural Resources Investigation for Air Force Plant PJKS, Jefferson County, Colorado, prepared by EARTH TECH, Colton, California, November 1996, pp. 1-1, 1-2, 2-9 to 2-10; United States Air Force, Air Combat Command and Department of Defense Legacy Program, Cold War Project, Forging The Sword: Defense Production During the Cold War, USACERL Special Report 97/77, prepared by Dr. Philip Shiman, July 1977, pp. 118-19; and U.S. Department of the Air Force and U.S. Department of the Army, Historic Building Inventory and Evaluation, Air Force Plant PJKS, Jefferson County, Colorado, pp. 3-1, 3-21.

equipment locker, and valve rooms; and area paving. The Systems Integration Laboratory complex would consist of five principal structures: (1) Systems Integration Laboratory Building (T-28) housing two test cells and containing propellant tanks and a gas generator enclosure; (2) Signal Transfer Building, also known as the Blockhouse Building (T-28A); (3) Long-Term Oxidizer Silo (T-28B); (4) Oxidizer Conditioning Structure (T-28D); and (5) Long-Term Hydrazine Silo (T-28E). The design criteria also included a technical description of the modifications to be made to the existing Cold Flow Laboratory (T-6) to accommodate testing of the Titan II.[21]

According to the design criteria, the "XSM 68B test program" for both system and component testing would "include basic evaluation, development, confirmation, verification and improvement evaluation." Each "type of test" would "evolve the establishment of methods and procedures, as well as the actual test data, to aid in the development of the XSM 68B program." Concerning the details of the tests, the document stated:

> The time duration required for each test depends upon the type of test and the quantity of test results required. The system and component tests have the same basic individual program cycle for evaluation and development tests. This cycle may require several months for preliminary planning, design, test fixture fabrication, procedure writing, instrumentation planning, fixture installation, actual testing, data review, test fixture removal and final report writing. The actual test time involved in this type of test may be only several seconds or a few hours, depending upon the objectives of the test. The system test time requires a longer period of cell time because of the size and complexity of the test. The component test time is a relatively short period of time. The component tests are repeated more rapidly than are the system tests primarily because a shorter period of time is required between tests for preliminary data review, test fixture adjustment and facility recycle.

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[21] For more information on the design modifications in Building T-6, see "XSM 68B Instrumentation for The Cold Flow Laboratory, The Martin Company, Denver Division, Denver, Colorado," Contract TTO-70701, Hallamore Electronics Company, Englewood, Colorado, a division of The Siegler Corporation, July 8, 1960, and "Design Specification For Cold Flow Facility Modification 'SM68B,' Martin Company, Denver Division, Denver, Colorado, December 9, 1960," Prepared by Cold Flow Laboratory, Archives, Engineering Propulsion Laboratory, Lockheed Martin Astronautics.

The confirmation type tests may be repeated very rapidly for both system and component tests after the initial planning and the test fixture installation. The confirmation type tests are functional operation type tests. The duration of these tests depends completely upon the test article and the objectives of the test. The component tests are repeated more often than are the system tests to establish reliability and functional operation on many missile components of the same type. The system confirmation tests are conducted to verify operational suitability of a complete missile system or a sub system.[22]

In May 1960, the Martin Company let a contract to the Kaiser Steel Corporation, Fabricating Division, of Montebello, California, to prepare the design specifications for and construct the new Systems Integration Laboratory facilities on the Air Force Plant PJKS property. The Kaiser Steel Corporation, in turn, let a contract to ARCAL Engineers-Constructors of Pasadena, California, to prepare the specifications and associated architectural drawings. The specifications and drawings were prepared between June and September 1960.[23] Initial construction operations on the laboratory complex began in late June or early July 1960.[24]

In November, while construction of the Systems Integration Laboratory was underway, the Kaiser Steel Corporation prepared a "Cold Flow Test Procedure," also known as a

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[22] The Martin Company, Denver Division, Denver, Colorado, "Criteria For the Design of XSM 68B Cold Flow Systems Test Laboratory and Components Test Laboratory," April 15, 1960, Archives, Engineering Propulsion Laboratory, Lockheed Martin Astronautics.

[23] Design Specifications, "Storable Propellants," Prepared by ARCAL, Engineers-Constructors, Pasadena, California, Job 310, Dated June-September 1960, Contract No. FO-99950, Contractor -- Kaiser Steel Corporation, Fabricating Division, Montebello, California, Approved by the Martin Company and the U.S. Air Force, Archives, Engineering Propulsion Laboratory, Lockheed Martin Astronautics. Under a subcontract (No. M20-3139, dated August 12, 1960), ARCAL prepared design drawings and specifications for a toxic vapor detection system for the T-27 and T-28 complexes. "Toxic Vapor Detection System, Systems and Components Laboratories Area, Prepared for The Martin Company, Denver Division, Denver, Colorado, Contract No. FO-99950, Under Kaiser Steel Corporation, Fabrication Division, Montebello, California, Subcontract No. M20-3139, Engineering Job No. 110, August 12, 1960, ARCAL, Engineers-Constructors, Pasadena, California," 2 vols. Also see "History of the Air Force Plant Representative Office, The Martin Company, Denver, Colorado, 1 January 1960 – 30 June 1960," p. 12, K 208-29, Jan.-Dec., 1960, in USAF Collection, AFHRA.

[24] Photographs Nos. DA 005676-DA 005681, Progress of New Cold Flow Construction, July 8, 1960, Photographic Laboratory, Reproduction Services Department, Lockheed Martin Astronautics.

"Storable Propellants Facility Checkout Procedure," for the complex. The document provided a plan for testing each system in the complex to determine if it would perform as designed. The plan also provided a systematic check and test, including a functional test, for each of the "propellant support divisions" in the complex.[25]

During the late spring or early summer of 1960, while construction of the laboratory complex continued, personnel of the Flight Certification Division at the Martin Company began to modify Test Stand D-1, one of four static firing stands that had been erected at AFP PJKS to test the Titan I, to accommodate captive test firings of the larger Titan II missile.[26] The stand was modified to accommodate the larger Titan II configuration, with its new fuel and ground support equipment, and it was "slated to perform facilities checkout and certain other functions involving Titan II system and design verification."[27]

While conversion of Test Stand D-1 continued in early 1961, modification work was commenced on Test Stand D-2.[28] According to an article in the March 10, 1961, issue of Martin Mercury, "final touches" were being "applied to test stands D-1 and D-2 which have been converted to Titan II needs." Both "stands and supporting facilities" had been "extensively rebuilt." The article noted, however, that "the most eye-catching addition to the

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[25] "Martin Cold Flow Test Procedure," "Storable Propellants Facility Checkout Procedure For the Martin Company, Denver Division, Denver, Colorado, Contract #FO-99950, Prepared by Kaiser Steel Corporation, Montebello Fabricating Division, Job #310, Dated November 2, 1960, Revised, November 16, 1960," Archives, Engineering Propulsion Laboratory, Lockheed Martin Astronautics.

[26] "History of Air Force Plant Representative Office, The Martin Company, Denver, Colorado, 1 July 1960 - 31 December 1960," p. 9, K 208-29, July-Dec. 1960, in USAF Collection, AFHRA, and United States Air Force, Air Combat Command and Department of Defense Legacy Program, Cold War Project, Forging The Sword, pp. 118-19. During this period, "a mixing facility for the blending of Unsymmetrical Dimethylhydrazine (UDMH) and Hydrazine propellant fuels" was completed for the Air Force at the Rocky Mountain Arsenal east of Denver.

[27] "Test Stand Conversion Efforts Highlighting Test Area Activity," Martin Mercury 18 (11 November 1960): 2A.

test area was the Titan II cold flow laboratories" or Systems Integration Laboratory complex. The facility, on a hillside above the Titan I cold flow facility, included "a systems test laboratory, a cell building, a components test laboratory and a variety of tanks to hold Titan II's propellants." The Systems Integration Laboratory complex was completed by early March 1961,[29] and conversion work on Test Stands D-1 and D-2 was completed within two months.[30]

TITAN II TESTING OPERATIONS

The Martin Company commenced its captive testing program for the new missile with the firing of a second-stage engine on Test Stand D-1 on June 7, 1961.[31] The captive test firing constituted the culmination of the testing program for the Titan II. According to the June 16, 1961, issue of Martin Mercury, more than 100 first- and second-stage Titan II engine firings had been conducted in recent months by the Aerojet-General Corporation at its Sacramento, California, plant. The June 7 test at Air Force Plant PJKS, however, was the "first test firing to

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[28] "History of Air Force Plant Representative Office, The Martin Company, Denver, Colorado, 1 January 1961 - 30 June 1961," K 243.0708 - 39, Jan.-June 1961, in USAF Collection, AFHRA.

[29] "Main Area Profiles Change With Plant, Titan II Facilities," Martin Mercury 18 (10 March 1961): 2A, 2C. Photographs Nos. DA 010361-DA 010378 (dated 9 March 1961), showing the Systems Integration Laboratory facilities, are labeled "Complete Facilities of Cold Flow Area." Photographic Laboratory, Reproduction Services Department, Lockheed Martin Astronautics.

[30] Two photographs in the June 2, 1961, issue of Martin Mercury show the completed Test Stand D-1. The captions for the photos indicate that the test stand is ready "to meet Titan II test requirements" and that engines "for the advanced missile have been installed and will undergo captive testing in the near furture." "Titan II, Advanced Programs Activity at Martin-Denver," Martin Mercury 18 (2 June 1961): 2C. Photographs Nos. DA 011630-DA011638 (dated 12 May 1961) show Test Stand D-2 completed. Photographic Laboratory, Reproduction Services Department, Lockheed Martin Astronautics.

[31] Because of the duration, temperatures, noise over-pressures, and other problems created by the launching of a huge liquid-propellant rocket, there was initial concern about the ability to launch a Titan II from an underground silo. The problem was solved successfully; its solution included a test firing of a modified Titan I from an underground silo at Vandenberg Air Force Base in California on May 3. This successful firing, the first time a liquid-fueled ICBM had been launched from an underground silo, established the feasibility of launching Titan IIs from underground. "Titan Launched from Underground," Martin Mercury 18 (19 May 1961): 1, 4; "Titan II to Give USAF Well-Protected Fast-Reaction Strike Force," Aviation Week and Space Technology 75 (25 September 1961): 138; and Anderton, Strategic Air Command: Two-Thirds of the Triad, 135-36.

utilize major portions of the over-all Titan II missile system." The article described the details of the test that lasted for approximately 3-1/2 minutes:

> As in Titan I tests of the past, the Titan II engine produced a sustained, thunderous roar. To trained observers, however, two differences were readily apparent:
>
> There was no ignition system in the engine. In a Titan I engine firing, an electric spark touches off the propellants -- kerosene and liquid oxygen -- in the combustion chamber. But Titan II propellants are hypergolic -- that is, they ignite spontaneously on contact with each other.
>
> There was no flame. The combustion in Titan II engines is not a fire in the usual sense, and so the engines did not burn white-hot, as do the Titan I engines. Instead, intensely hot columns of clear gases roared out of the combustion chamber, emitting an eerie bright glow.[32]

According to the Air Force Plant Representative Office at the Martin Company, the successful "accomplishment of the first captive firing of the first Titan II Research & Development (R & D) missile . . . effectively accomplished the last step of Titan II design verification possible prior to first flight." Later in December 1961, acceptance tests of the second and third Titan II missiles were undertaken, and the "evolution of more efficient missile acceptance test procedures" were negotiated between Air Force officials and Martin Company personnel.[33]

On December 28, 1961, following the National Aeronautics and Space Administration (NASA) announcement that Titan II would be used as the booster to orbit a new two-man Mercury capsule in a series of tests of rendezvous techniques in space, a Titan II missile underwent a complete captive-fired simulated flight in a static sequence test at Air Force Plant PJKS (In October 1961, the Glenn L. Martin Company had merged with the American Marietta

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[32] "2nd Stage Firing Begins Titan II Captive Tests," Martin Mercury 18 (16 June 1961): 1. Also see Denver Post, 8 June 1961, p. 49, and "Titan II Engine Firing," Martin Mercury 18 (30 June 1961): 2C.

Company to form the Martin Marietta Corporation.)[34] According to the March 12, 1962, issue of Aviation Week and Space Technology, during the "static, sequential, compatability firing of the storable propellant Titan 2," the "two stages were positioned side-by-side, with Stage 1 firing first and Stage 2 cut in to simulate flight conditions, a carryover from testing techniques used for Titan 1."[35]

This was the first time the complete Titan II system, comprising both airborne and ground equipment, had been subjected to simulated flight conditions. The January 12, 1962, issue of M News, the renamed Martin Marietta newspaper, reported that more "than 400 separate components and systems were electronically monitored on the 100-foot-tall missile." The information was recorded "in a blockhouse (T-6) operated by Martin Marietta personnel and "verified the perfect functioning of the weapon system." In this test, the "powerful rocket engines generated a combined thrust of over one-half million pounds." In addition to checking the flight vehicle, the "test was performed using checkout and launch equipment built by Martin Marietta for the Titan II operational bases." This was the first time "operationally-designed ground equipment" had been "used during the initial phases of an ICBM research and development program." The concept "of testing the airborne and ground equipments

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[33] "History of the AF Plant Representative Office, Martin Marietta Corp., Denver, Colo., 1 July 1961 - 31 December 1961," pp. 46-47, 72-73, K 243.0708 - 39, Jul. - Dec. 1961, in USAF Collection, AFHRA.

[34] Arnold Sherman, "Martin Chairman Predicts Modest Growth," Aviation Week and Space Technology 76 (12 February 1962): 103-04, and Martin Marietta Corporation, Martin Marietta Denver Aerospace: 30 Years of Progress (1986): 8, 10. Under a contract, NASA's Manned Spacecraft Center in Houston, Texas, purchased 15 modified Titan II boosters from the Air Force, to serve as the launch vehicles for the Gemini program. The Martin Marietta Corporation, in turn, signed a contract with the Air Force's Space Systems Division to build the vehicles. A description of modifications made to the Titan II for use in the Gemini program may be found in George Alexander, "Simplicity, Duplication Will Give Titan Manned Flight Capability," Aviation Week and Space Technology 77 (3 September 1962): 38-41, 45, and U.S. Air Force, Space Systems Division, Historical Division, "History of the Space Systems Division," January - December 1964, AFSC Historical Publications Series 66-23-1, Vol. I, Narrative, K 243.013, Jan.-Dec. 1964, V. 1, in USAF Collection, AFHRA.

[35] "Missile Development Emphasis to Shift," Aviation Week and Space Technology 76 (12 March 1962): 133.

concurrently" had "reduced the Titan II development time." A crew of "35 engineers and technicians" had prepared the Titan II for the test. Their actions were observed by "a parallel launch team from Martin Marietta's [Cape] Canaveral division" which would later launch the missile on its flight down the Atlantic Missile Range."[36]

Following the December 28 test, the first flight model of the Titan II was transported by truck from the Martin Marietta plant to Lowry Air Force Base east of Denver. There the ICBM was loaded aboard an Air Force C-133B for transport to Cape Canaveral, where it arrived on January 27, 1962.[37] Less than two months later on March 16, the Titan II missile, according to the M News, "successfully passed its maiden test flight," "streaking to a south Atlantic target more than 5000 miles away." The Air Force announced that the missile "met all objectives" of a "full systems test," including the first successful test of the missile's inertial guidance system. This was the first time that a missile completely satisfied its range and accuracy specifications during its initial trial flight.[38]

The significance of Titan II's successful debut was described in the March 30, 1962, issue of Time. According to the periodical:

> Confidence surged last week through the U.S. missile program, which suddenly had a new hero: the Titan II, a radically new missile that moves the U.S. a giant step forward in space and nuclear effectiveness. Resigned to a series of test failures before they get a success, U.S. missilemen were jubilant when the giant Titan II climbed off its pad at Cape Canaveral on the very first try, lit its second stage exactly on schedule and flew

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[36] "Titan II Passes Its First Captive Firing," M News 19 (12 January 1962): 1, 3.

[37] "Titan II Makes Debut At Cape Canaveral," M News 19 (9 February 1962): 1, and Evert Clark, "Titan 2 Slated for Four Space Vehicles," Aviation Week and Space Technology 76 (19 February 1962): 28-29. For a description of the missile testing facilities at Cape Canaveral during the spring of 1961, see Paul D. Troxler, "Space Missile Facilities," The Military Engineer 53 (March-April 1961): 104-06.

[38] "Associated Press Reports Successful Titan II Launch at Cape," M News 19 (23 March 1962): 1, and "2nd Titan II Launched at Cape," M News 19 (15 June 1962): 1, 4. Also see, "Titan 2 Success Boosts Space, ICBM Capability," Aviation Week and Space Technology 76 (23 April 1962): 78-79, and Perry, "The Atlas, Thor, Titan, and Minuteman," in History of Rocket Technology, ed. by Emme, 155.

> a flawless course to the target 5,000 miles away. No big liquid-fuel rocket has ever scored such an immediate triumph.

Titan II, in the words of Aerojet-General's technical program manager, was "far more than just an improved model of the much criticized Titan I." "Titan II is considerably bigger . . . than Titan I or Atlas, has greater thrust . . . and has far fewer gadgets that can go wrong." The new missile was "the simplest, most elegant and most advanced missile we've got today."[39]

During the six-month period from July to December 1962, Titan II propellant testing at the AFP PJKS's Systems Integration Laboratory apparently reached its peak. By late December, some "special tests" were "still being conducted by [the] research and development engineering and certification test departments," but the tests had "started to phase out."[40]

During early 1963, Titan II testing continued at AFP PJKS, although the Martin Marietta plant's "storable propellant supply was a major problem." The plant had been supplied by producing plants as distant as Chatsworth, California, but delays in getting the Hercules Powder Company plant at Hercules, California, into production had exacerbated the propellant supply problem.[41]

Altogether, the Martin Marietta Denver plant produced 102 Titan II missiles between 1962 and 1964. As the production of these missiles continued, there was renewed interest in, and increased funding for, space projects that established the need for a second-generation standardized space-launch system. The Air Force version of such a satellite launch-vehicle system, designated Titan III, was designed around the Titan II missile with the addition of

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[39] "Triumphant Titan II," Time, 79 (30 March 1962): 68. For a summary of congratulatory messages received by Martin Marietta after the successful test launch, see "High Praise From High Officials On Successful Launch," M News, 19 (20 April 1962): 1, 4.

[40] "History of the AF Plant Representative Office, Martin Marietta Corp., Denver, Colo., 1 July 1962 - 31 December 1962," p. 28, K 243.0708 - 39, July - Dec. 1962, in USAF Collection, AFHRA.

powerful solid-propellant engines which would form the first stage, with the Titan II missile becoming the second and third stages. This system would meet the nation's requirements of all known and projected payload missions within the 5,000- to 25,000-pound range. Martin Marietta received a contract from the Air Force in August 1962 to produce the Titan III, and the corporation produced 150 Titan III launch vehicles between 1964 and the early 1990s to fit a variety of satellite and planetary missions for the Air Force and NASA. In 1988, the Denver plant would begin development and production of an improved space launch "core" vehicle known as Titan IV. [42]

With the termination of the Titan I program, the end of Titan II testing, and Martin Marietta's increasing focus on space technology, the four test stands (D-1- D-4) became obsolete. They were deactivated in 1964, and the metal gantry towers were torn down and the metal sold for scrap.[43]

However, the Systems Integration Laboratory complex would continue to be used for fuel propellant testing for the Titan III and Titan IV launch vehicles. As a result, the facilities in the complex would be modified and expanded to accommodate these new systems and to

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[41] "History of the AF Plant Representative Office, Martin Company, Denver, Colorado, 1 January 1963 - 30 June 1963," p. 50, K 243.0708 - 39, Jan. - June 1963, in USAF Collection, AFHRA.

[42] Martin Marietta Corporation, Martin Marietta Denver Aerospace: 30 Years of Progress, 12, 14, 71-73; Denver Post, 20 August 1962, p. 1; "Titan III, 50th Consecutive Successful Launch," Martin Marietta News, Special Issue, March 1973; Rocky Mountain News, 25 December 1962, p. 49; Denver Post Empire Magazine, 1 August 1971, pp. 10-12, 14-15; Denver Post, 10 February 1966, Clippings File, Business and Industry, Colorado, Aerospace and Aircraft, Glenn L. Martin Company, Denver Public Library, Western History Department; Harwood, Raise Heaven and Earth, pp. 600-04; and U.S. Department of the Air Force and U.S. Department of the Army, Historic Building Inventory and Evaluation, pp. 3-28 to 3-31.

[43] Information documented in individual structure histories in Historic American Engineering Record, Glenn L. Martin Company, Titan Missile Test Facilities, HAER No. CO-75, n.p.; United States Air Force, Air Combat Command and Department of Defense Legacy Program, Cold War Project, Forging the Sword, p. 119; U.S. Department of the Army and U.S. Department of the Air Force, Cultural Resources Investigation For Air Force Plant PJKS, Jefferson County, Colorado, p. 2-11; and United States Air Force, Headquarters Air Force Systems Command, Historical Division, Office of Information "History of Air Force Systems Command, 1 July

comply with expanding environmental regulations. In 1965, a Boiler Chiller Plant (T-28H), formerly a test support building, was moved to its present location immediately west of T-28B and T-28D. By 1971, a Fuel Purification Structure (T-28C), designed to purify hydrazine for long-term hardware requirements of satellites and expedition vehicles, was constructed immediately south of T-28E. During the 1970s, a Hydrazine Scrubber Structure (T-28I), designed for treatment and disposal of hydrazine vapors produced during test operations in accordance with environmental regulations, was constructed immediately north of T-28A.[44]

TITAN II OPERATIONAL FACILITIES

Construction of operational facilities for the Titan II missiles was commenced in late 1960 under the direction of the U.S. Army's Corps of Engineers Ballistic Missile Construction Office. Groundbreaking ceremonies for the first Titan II operational site at Davis-Monthan Air Force Base, Tucson, Arizona, were conducted on December 9, 1960. During the next six weeks, work began on additional installations at McConnell Air Force Base, near Wichita, Kansas, and Little Rock Air Force Base, near Damascus, Arkansas. The operational facilities were eventually assigned to three units: the 390th Strategic Missile Wing at Davis-Monthan; the 381st Strategic Missile Wing at McConnell; and the 308th Strategic Missile Wing at Little Rock. The three wings reported through the 12th Strategic Missile Division, with headquarters at Davis-Monthan, to Fifteenth Air Force. The Titan wings consisted of two squadrons, each of which was responsible for nine dispersed missiles in hardened silos. Each of the missiles was

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1964 - 30 June 1965, Fiscal Year 1965, Volume II," AFSC Historical Publication Series, 65-10-II, pp. 198ff., K 243.01, Jul. 1964-Jun. 1965, V. 2, in USAF Collection, AFHRA.

[44] U.S. Department of the Air Force and U.S. Department of the Army, Historic Building Inventory and Evaluation, pp. 4-5 to 4-6; Architectural drawings, blueprints, and site plans for T-27 and T-28 complexes, Engineering Propulsion Laboratory and Plant Engineering and Construction Department, Lockheed Martin Astronautics. Also see "Part II Valuations for Appraisal of Government-owned Test Area, Sections 20, 21, 28, 29, T6S, R69W, 6th P.M., Jefferson County, Colorado, for Martin Marietta Corporation by Blaine B. Chase, MAI, SRA, and Wilson W. Wampler, July 1, 1971," in Plant Engineering and Construction Department, Lockheed Martin Astronautics.

served by its own launch control center and each squadron had 45 crews with four members each -- two officers and two non-commissioned officers. This configuration was designed to "present . . . a potential enemy [with] nine separate targets instead of three targets in each complex of Titan I."[45] The missiles waited below ground with a full load of propellants. Ductlike flame deflectors at the bottom of each launch tube permitted firing directly from the silos.

The first Titan II wing (390th Strategic Missile Wing) and squadron (570th Strategic Missile Squadron) were activated at Davis-Monthan on January 1, The first Titan II operational missile to be accepted by the Air Force on August 31, 1962, was airlifted to Davis-Monthan on November 27, 1962, and installed in its 155-foot-deep launching silo on December 8, 1962. Later on March 30, 1963, the first Titan II operational launch facility (Site 570-2) of the 570th Strategic Missile Squadron at Davis-Monthan was accepted by the Strategic Air Command. In April 1963, the first Titan II of the 570th went on alert. On June 8, 1963, the Strategic Air Command declared the 570th to be operational, the first Titan II squadron to achieve such status, and later on November 22 the second Titan II squadron at the Air Force base was declared operational, thus completing the first Titan II wing in the Strategic Air Command.[46]

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[45] "Titan II to Give USAF Well-Protected Fast-Reaction Strike Force," Aviation Week and Space Technology 75 (25 September 1961): 139; Anderton, Strategic Air Command, 136; and Office of the Historian, Headquarters Strategic Air Command, From Snark To Peacekeeper, 25. The six Titan II strategic missile squadrons included: Davis-Monthan, 570th, activated on January 1, 1962, and 571st activated on May 1, 1962; McConnell, 532d, activated March 1, 1962, and 533d, activated on August 1, 1962; and Little Rock, 373d, activated on April 1, 1962, and 374th, activated on September 1, 1962.

[46] "1st Titan II Lowered Into Nest At Air Base," M News 20 (14 December 1962): 1; "USAF Titan 2 Installed at Tucson Site," Aviation Week and Space Technology 77 (17 December 1962): 34; Fifteenth Air Force, 1959-1969, Fifteenth's First Missile Decade (1969), n.p.; Office of the Historian, Headquarters Strategic Air Command, Offutt Air Force Base, Nebraska, SAC Missile Chronology, 1939-1988 (1 May 1990): 33, 37, 39-40.

On January 4, 1963, the first Titan II missile was airlifted from Denver to McConnell Air Force Base and soon thereafter, the first Titan II was delivered to Little Rock Air Force Base.[47] Within a month of the delivery of the missiles to these operational sites, however, "an epidemic" of highly dangerous "fuel tank leaks" was discovered at the two facilities as well as at Davis-Monthan. Pinhole fuel and oxidizer leaks were found in "fuel tanks, welds and mechanical joints." Escaping nitrogen tetroxide, combined with moisture in the atmosphere to form nitric acid, quickly corroded the missile's aluminum skins, enlarging the microscopic holes. Efforts were made to accomplish necessary repairs to the missiles at the bases, and dehumidification systems were installed in the missile silos. However, two missiles at McConnell and two at Little Rock, as well as eight at Davis-Monthan, were returned to the Martin Marietta Denver factory for a variety of modifications and repairs, including refurbishment of corrosion damage, replacement of oxidizer feed lines, repair of fuel and oxidizer tanks, and numerous hardware changes.[48] As a result, Martin Marietta reevaluated the missile's design requirements, as well as its testing and inspection criteria, and necessary "tightened criteria" were incorporated into the missile's specification requirements. Despite these difficulties, however, all missiles were back in place and free of leaks by late December 1963.[49]

The completed Titan II operational facility at McConnell Air Force Base was turned over to the 381st Strategic Missile Wing during formal ceremonies on

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[47] "Titan II Lifted to SAC Site," M News 20 (11 January 1963): 1, 3.

[48] "History of the AF Plant Representative Office, Martin Company, Denver, Colorado, 1 July 1963 - 31 December 1963," pp. 53, 66, 74, K 243.0708 - 39, Jul. - Dec. 1963, in USAF Collection, AFHRA; Col. A. Kaufman and S. R. Costanza, "Titan II: Dehumidification Silo Prevents Missile Leaks," Air Force Civil Engineer 6 (August 1965): 24-26; and Office of the Historian, Headquarters Strategic Air Command, From Snark to Peacekeeper, 25.

December 4, 1963.[50] Later on December 31, the Strategic Air Command declared the 374th Strategic Missile Squadron at Little Rock Air Force Base to be operational, thus completing the deployment of the Titan II intercontinental ballistic missile force.[51] Martin Marietta heralded this event in the January 17, 1964, issue of the M News, observing that the "combined resources of some 10,000 U.S. industrial firms [had] joined in the military-civilian operation, that, in only three years, fashioned Titan II from a remarkable concept into reality."[52]

The 54 Titan II missiles at Davis-Monthan, McConnell, and Little Rock Air Force bases would serve as the backbone of America's strategic defense for more than two decades.[53] On January 6, 1964, U.S. News and World Report announced that "America's mightiest war missile -- the Titan II -- is now on the firing line . . . carrying the most potent warhead in the U.S. arsenal." The periodical noted that the Titan IIs, along with 54 Titan I, 126 Atlas, 256 Polaris, and 300 Minuteman missiles, "drew attention to an important development in the missile race with the Soviet Union." The 790 missiles in the U.S. arsenal gave the nation a 4-1 "missile superiority over the Soviet Union."[54]

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[49] "History of the AF Plant Representative Office, Martin Company, Denver, Colorado, 1 January 1963 - 30 June 1963," p. 659, K 243.0708 - 39, Jan.-June 1963, in USAF Collection, AFHRA.

[50] "SAC Gets Two More Titan II Squadrons," M News [Denver Edition] (December 20, 1963): n.p.

[51] "Titan IIs Ready," M News (January 17, 1964): 1-2. Also see, "Titan II Turn-Over Completes Program," Army Navy Air Force Journal and Register 101 (11 January 1964): 14.

[52] "Titan IIs Ready," M News (January 17, 1964): 1-2.

[53] For a history of the politics and impact of Cold War events, such as the October 1962 Cuban Missile Crisis, on the number of missiles produced and deployed, see Desmond Ball, Politics and Force Levels: The Strategic Missile Program of the Kennedy Administration (Berkeley, Los Angeles, London: University of California Press, 1980).

[54] "With Titan II Now in Place -- 790 U.S. Missiles Ready For Action," U.S. News and World Report 56 (6 January 1964): 4.

On April 9, 1964, the Air Force concluded its Titan II ICBM research and development launch program at Cape Kennedy (formerly Cape Canaveral).[55] The M News [Denver Edition] of April 17, 1964, reported the significance of this event, noting that the

> old warhorse of the Titan II fleet -- a well-traveled missile named "N-3A" -- boomed out over the Atlantic Ocean on a 5,800-mile flight . . . in the 13th consecutive successful flight by Titan II ICBMs.

The article observed further:

> Only 29 hours earlier, a modified Titan II made its debut as a space booster and successfully hurled an unmanned Project Gemini capsule into orbit in the opening shot of the second U.S. man-in-space program. Including this shot, the string of consecutive successes for Titan II stretched out to 14.[56]

Reflecting on the conclusion of the Titan II launch program at Cape Kennedy, Brig. Gen. Harry J. Sands, Commander of the Atlantic Missile Range, noted that we "have seen the close of an era today." "It is an era which has given the free world its most powerful weapon system and a booster which will be an important part of America's manned space programs for many years to come."[57]

On September 30, 1964, the Air Force Logistics Command assumed responsibility for engineering support and service of the Titan II missiles, thereby completing the acquisition phase of the Titan II. Meanwhile, the Strategic Air Command conducted five demonstration and shakedown operational launches of the Titan II between July 30 and November 4, 1964 -- all missiles impacted within the target area. This series of launches marked the first time a

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[55] Operational test launches of the Titan II would be conducted at Vandenberg Air Force Base between March 24, 1965, and April 20, 1966. Follow-on operational tests were conducted between May 25, 1966, and May 21, 1969. Office of the Historian, Headquarters Strategic Air Command, SAC Missile Chronology, 47, 50, 54.

[56] "Thirteen Straight For Titan II's," M News, [Denver Edition] (April 17, 1964): n.p. Later on March 23, 1965, the first successful manned launch of the Gemini/Titan program occurred when two men were launched into Earth orbit. Martin Marietta Corporation, Martin Marietta Denver Aerospace: 30 Years of Progress, 12.

[57] "Thirteen Straight For Titan II's," M News, [Denver Edition] (April 17, 1964): n.p.

completed demonstration and shakedown operations test series had been carried through without a single malfunction.[58]

TITAN II PHASE OUT PROGRAM

Although the initial predicted service life of the Titan II missiles was ten years, the 54 Titan II missiles at Davis-Monthan, McConnell, and Little Rock Air Force bases served as the "backbone of America's strategic deterrence capability" for more than two decades. However, the missiles and their operational sites were plagued by continuing maintenance problems and frequent and often serious mishaps despite a vigilant program of preventative maintenance.[59] Serious accidents occurred, and in 1980 it was reported that some people living near the silos "were convinced that the Titan II missiles that are supposed to help them sleep better at night pose more dangers to them than to the Russians."[60]

Meanwhile, American military leaders buttressed the U.S. nuclear arsenal by deploying approximately 1,000 solid-fuel Minuteman missiles across America's heartland and 656 Polaris and Poseidon ICBMs that were carried by the 41-ship Polaris submarine fleet. The unattended, simple, mass-produced, solid-fueled Minutemen were relatively inexpensive and easy to maintain, thus making their liquid-fueled Titan II ancestors seem hopelessly obsolete.[61]

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[58] United States Air Force, "History of Air Force Systems Command, 1 July 1964 - 30 June 1965, Fiscal Year 1965, Volume II," AFSC Historical Publication Series 65-10-II, p. 121, K 243.01, Jul. 1964 - Jun. 1965, V. 2, in USAF Collection, AFHRA.

[59] Kaufman and Costanza, "Titan II: Dehumidification Silo Prevents Missile Leaks," 24-26, and Office of the Historian, Headquarters Strategic Air Command, From Snark to Peacekeeper, 25.

[60] "Titan a Big Threat -- But to Whom?" U.S. News & World Report 89 (29 September 1980): 8. Ironically, Martin Marietta reported in June 1963 that its personnel had handled 10 million pounds of storable propellants at its Denver plant during the Titan II testing program "with only six accidents of minor skin burns." "Titan Fuel Handling Safety Record Cited," M News [Denver Edition] (15 July 1963): 1.

[61] "Liquid-Fuel Titan IIs Will Leave Inventory," Air Force Times, 27 (22 February 1967): 11, and Mark Bearwald, "Requiem For The Titans," Denver Post Sunday Empire (26 February 1967): 8-10.

The final blow for the Titan II program occurred on September 18, 1980, when a Titan II missile exploded in its silo at Little Rock Air Force Base, killing one Air Force maintenance man and hurling its thermonuclear warhead into a nearby field. A three-pound wrench socket that had been dropped by a worker knocked a hole in the missile's pressurized fuel tank skin. Although crewmen drenched the missile with water, some fuel escaped and turned into explosive gas. The explosion injured 22 Air Force personnel, and homes within 80 square miles were evacuated. Following the incident, President Jimmy Carter asked the Pentagon for a "complete evaluation" of the cause of the accident and the status of the other 53 Titan II missiles, and U.S. Senator Robert Dole of Kansas renewed his call for a Senate investigation of the Titan II's safety, noting that there had been 125 reported fuel leaks since 1975, including two in 1978 that resulted in the death of two Air Force personnel and injury to 29 others.[62] Following the Little Rock incident, Time described the aging Titans as "geriatric giants," and hinted that it might be time for them to be retired.[63] A number of prominent politicians concurred, and on October 2, 1981, Deputy Secretary of Defense Frank Carlucci ordered the Air Force to begin inactivation of the Titan II weapon system "as soon as possible."[64]

On July 2, 1982, the Titan II at Site 9 in the 570th Strategic Missile Squedron et Davis-Monthan Air Force Base was removed from alert for testing, thus becoming the first Titan II to be inactivated in the phase out program. Several months later, on September 30, the deactivation program, designated Rivet Cap, formally began with the removal of Site 571-6 from alert at Davis-Monthan. The 570th Strategic Missile Squadron was inactivated on July

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[62] "Titan a Big Threat -- But to Whom?," p. 8, and Office of the Historian, Headquarters Strategic Air Command, SAC Missile Chronology, p. 68. Also see Chuck Hansen, US Nuclear Weapons: The Secret History (New York: Orion Books, 1988): 229.

[63] "Geriatric Giants," Time, 116 (6 October, 1980): 29.

[64] Office of the Historian, Headquarters Strategic Air Command, SAC Missile Chronology, 70.

31, 1984. Thet same dey, the 390th Strategic Missile Wing et Davis-Monthan became the first Titan II wing to be inactivated.[65] Deactivation of the Titan II operational facilities at McConnell and Little Rock Air Force bases began on July 2, 1984, and April 24, 1985, respectively.[66] Finally, on May 5, 1987, the Strategic Air Command removed the last active Titan II missile from alert at Little Rock, ending the Titan II operational program. Later on August 18, the Strategic Air Command inactivated Little Rock's 373d Strategic Missile Squadron and 308th Strategic Missile Wing, thus completing the inactivation of all three Titan II wings.[67]

Reporting that the last of the nation's Titan II missiles had been removed from its silo and shipped to Norton Air Force Base, California, for storage, the August 17, 1987, issue of Air Force Times noted that the "usefulness of the obsolescent booster was far from over." Rather than "ready the aging rockets for the scrapheap," the Air Force was preparing the Titans "for a far more serviceable role -- as platforms for launching satellite payloads into space within the coming year."

At a ceremony in Denver on August 3, 1987, Air Force officials and Martin Marietta executives "rolled out the first remodeled Titan II expendable space launcher." The "130-foot-long booster, designed to place surveillance, military and scientific probes into low Earth orbits," was the first of "13 converted Titan IIs" that Martin Marietta had produced under an Air Force contract awarded in January 1986. The reconfigured rocket was shipped to Vandenberg Air Force Base where it was scheduled to launch a military satellite by April 1988.[68]

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[65] Ibid., pp. 71, 77.

[66] Ibid., pp. 77, 79.

[67] Ibid., pp. 86-87.

Modified Titan II missiles continue to be used for launching military and scientific satellite payloads into space. In April 1996, for instance, Lockheed Martin Astronautics, the successor corporation of Martin Marietta, received two contracts totaling $2.49 billion to prepare and launch Titan missiles. Under the two contracts, final assembly of Titan II, as well as Titan IV, launch vehicles would take place at the corporation's Denver plant through 2003, after which they would be shipped to launch sites at Cape Kennedy and Vandenberg Air Force Base.[69]

[68] "Final Titan II Goes Into Temporary Retirement," Air Force Times 48 (17 August 1987): 34. Also see Rocky Mountain News, 27 September 1986, p. 91, and 4 August 1987, p. 2B.

[69] Rocky Mountain News, 4 April 1996, p. B1.

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