Chapter 2: U.S. Strategic Missile and Armament Systems (1950s–60s)

Intercontinental Ballistic Missile Program Beginnings

The Minuteman program was a Cold War story, but development of the missile system offers its own history. This section explores the evolution of America's ballistic missile program, of which the Minuteman would play a vital role. By the time of the Cuban Missile Crisis in 1962 the United States had succeeded in developing nuclear missiles with intercontinental range. However, America's early forays into strategic missiles suffered from a lack of funding, bureaucratic infighting, and interagency tensions that slowed early research into missile armament systems.[i] Although the progression from piloted weapons systems to missiles seems obvious in retrospect, that conclusion remained uncertain at the onset of the Cold War.

Many high-level politicians and military officers began to think more seriously about Intercontinental Ballistic Missile (ICBM) development in response to these tensions, leading the Air Force to initiate a crash program in ICBM development through the newly formed Air Research and Development Command (ARDC).[ii] The ARDC and the new crash program built on previous missile research conducted by the Consolidated Vultee Aircraft Corporation (Convair) for Air Force contract MX-774. Convair's contract had been canceled in 1947 as part of the Air Force's post-Word War II cuts in military spending.[iii]

The news in 1949 that the Soviets had tested an atomic bomb sparked revived interest in air defense systems, though of course, in an age of aerial warfare, the potential for long-range Soviet strikes upon American soil had never been far from the minds of Washington strategists.[iv] "Attacks can now come across the arctic regions, as well as across oceans, and strike deep…into the heart of the country," General Carl Spaatz, commander of American strategic bombing in World War II told a Senate Committee in 1945. "No section will be immune," he warned, "the Pearl Harbor of a future war might well be Chicago, or Detroit, or Pittsburgh, or even Washington."[v] North Korea's 1950 invasion of South Korea–an attack perceived by many Western strategists as part of a concerted global strategy by the Soviets–made Western fears of attack seem all the more prescient.

Air Research and Development Command

The Air Force established the ARDC in 1950 specifically for development of the Air Force missile program.[vi] Many issues remained to be solved before the ICBM could get off the ground. Development of the ICBM program was hampered by resistance on the part of one branch of the Air Force, the Air Force Air Staff (Air Staff), and inefficient cooperation between different branches of the military.[vii] The Air Staff was the planning body within U.S. Air Force Headquarters. As a Major Command, the ARDC (later known as the Air Force Systems Command) was below the Air Staff in the hierarchy of the U.S. Air Force.[viii] Initially the Air Force opposed further research and development on the grounds that available technology was not advanced enough for the successful development of missiles with intercontinental range. Members of the Air Staff questioned the reliability and effectiveness of ICBMs.[ix] Additionally, the culture within the Air Force at the time favored development of bombers and the integration of missiles with aircraft

development. Achievement of high rank in the service required pilot training and command of squadrons or wings, and only officers could be pilots. These flyers were thus naturally hesitant to endorse a new and potentially significant weapons system that carried the potential of diminishing the value of their skills (as pilots) to the Pentagon. Indeed, the Air Force went so far as to designate its missiles "pilotless aircraft," implicitly signifying that any real aircraft carried a human commander. The lack of an integrated development plan further hampered missile research and development and budgetary issues resulting from President Truman's economy drive compounded the problems of
developing the ICBM program. Only after the Air Force began to integrate its missile program with its aircraft program did it become apparent that missile development needed a separate, focused effort.[x]

The Air Force had competition in missile development from both the Army and the Navy. Missile development programs underway at the beginning of the 1950s included the Army's Redstone project, headed by Wernher von Braun and the Jupiter Intermediate Range Ballistic Missile, as a joint venture between the Army and Navy.[xi] The Air Force found itself in a position of losing its defensive capabilities and therefore stature in the armed forces if it did not keep up with missile technology.

Rather than allowing themselves to fall behind technologically, the Air Force overcame its reticence and approved a contract with Convair in January 1951 for development of a ballistic missile carrying a heavy nuclear payload with a five thousand-mile range and a circular error probable (acceptable radius of target error) of 1,500 feet.[xii] This new missile project, known as the MX-1593 or Atlas, was largely based on Convair's earlier Air Force project, the MX-774. Convair now built on earlier engineering efforts to create the Atlas ICBM.[xiii]

In 1952 Trevor Gardner, Special Assistant for Research and Development to Air Force Secretary Harold E. Talbot, asked the Air Force for performance specifications and a justification of the deployment schedule for the Atlas. The response from the ARDC asserted that "the ballistic rocket appears, at present, to be the ultimate means of delivering atomic bombs in the most effective fashion."[xiv] Funding for the Atlas remained limited, however, and important logistical problems had to be overcome in its development before it could meet the Air Force's requirements.

Bomb weight, maximum range, and nose cone design to withstand reentry were three formidable early problems faced by missile developers. However, scientific advances created thermonuclear devices that were lighter than earlier generations of nuclear weapons while possessing more destructive capability–in 1952 the validity of thermonuclear detonation was proven. During this same period, more powerful liquid-fuel engines became available and it became clear that ICBMs with a range of over five thousand miles could be built. The combination of more powerful engines and lighter bombs solved the problem of limited missile range. The development of a blunt, copper heat-sink in 1952 to absorb the fierce heat of the reentry vehicle solved the third problem.[xv] Now the ARDC and Convair needed to transfer these new technologies to its Atlas missile system

The Air Staff did not agree with the ARDC on Atlas development and funding and refused to commit the necessary funds for full-scale development. The ARDC refused to give up, citing the urgent need for an ICBM in the interest of national security. The ARDC favored full-scale development on an accelerated schedule, whereas the Air Staff preferred additional research before committing more funding to the program. After two years of political maneuvering, the Air Staff and ARDC reached a compromise in 1953. This agreement produced a development plan that called for the research and development phase for the Atlas to be completed by "sometime after 1964" and for an operational missile by 1965.[xvi]

Teapot Committee and RAND Report

While American leaders worked to develop their own strategic missile force, they also strove to evaluate United States military defense capabilities in relationship to their closest rival. Two committees were formed during this period to study the Soviet Union's potential threat. The Strategic Missiles Evaluation Committee, code name Teapot Committee, was formed in 1953 by Trevor Gardner and was chaired by famed mathematician Dr. John von Neumann of the Institute for Advanced Studies. The Teapot Committee was developed to evaluate current programs and the level of technology of potential enemies (mainly the Soviet Union), and to recommend solutions for identified problems. A concurrent study focusing on similar questions was conducted by the RAND Corporation, a security studies think-tank with long ties to the Air Force.[xvii]

Both studies produced alarming findings. They each independently determined that Soviet missile technology had advanced significantly in the short period since World War II, and that only a major push in missile development in the United States could overcome this technology gap. Policymakers of this period fervently believed that falling technologically behind the Soviets in the defense arena would be inviting the disaster of a Soviet attack.[xviii] The reports also concluded that development of an operational ICBM system within six years was an attainable goal if the Air Force would commit the appropriate talent, funds, and management strategies to the project.[xix] According to Teapot, the Atlas program in particular–as the most advanced American missile program then under development–had to be accelerated for the sake of national security. President Eisenhower took these findings most seriously, and ordered work on the ICBM program accelerated by assigning it "the highest national priority."[xx] The Western Development Division (WDD), an extension of the ARDC, was created and assigned to spearhead the development of ICBMs.

Western Development Division

Trevor Gardner, Air Force Chief of Staff General Nathan F. Twining, and Lieutenant General Donald Putt received approval for a management agency within the Air Force, the WDD, whose primary purpose would be to develop an ICBM.[xxi] The WDD was created "solely for the prosecution of research, development, test, and production leading to a successful intercontinental ballistic missile."[xxii]

The WDD facilitated the rapid development of the Atlas system, and its employees worked long hours to get the job done. For example, Lieutenant General Otto Glasser reported that a normal work-week consisted of ten-hour days, six days a week, with extra time often being put in on Sundays.[xxiii] The main function of this working group was not to actually build an ICBM, but to work together with private contractors to design the new weapon as quickly and cheaply as possible.[xxiv] The project became a race against time, with the goal of an operational ICBM by the end of the 1950s–the estimated date for an operational Soviet ICBM.[xxv] To many of the workers, the very safety and security of the United States seemed to hinge on the success of their program.

To help meet its goals, the WDD contracted with the Ramo-Wooldridge Corporation of Los Angeles, California to provide technical direction. This joining of forces speaks to the increased size and importance of the ICBM program in the Air Force's eyes. The number of Ramo-Wooldridge staff members assigned to assist the WDD on the ICBM project started with 170 staff members at the beginning of 1954 and grew to 5,182 by the end of 1960.[xxvi]

The WDD opened its office in a former elementary school in Inglewood, California, in 1954 with General Bernard A. Schriever, a forty-three year-old well respected brigadier general, appointed as its head. In an attempt to maintain a low profile for this top-secret project, military staff stationed at the WDD wore civilian clothes.[xxvii] ICBM chronicler and journalist Roy Neal described the WDD headquarters in these words, "No sign identified the white schoolhouse as the Western Development Division… The windows were frosted and heavily barred. All outside doors, except one, were locked. The only entrance was across a chain-link fenced parking lot. A security guard manned the door… Some of the old-timers recall… the comment of the school boy who was sauntering by the school buildings. Eying the frosted glass and steel-barred windows, he said to a chum, 'Boy am I glad I don't go to school here.' "[xxviii]

The WDD staff began their work designing and coordinating the construction of the Atlas ICBM. In 1955, the WDD requested and received Air Force approval to develop a second ICBM, the Titan, concurrently with the Atlas. The WDD initiated the research and development on the Titan in the hope that if Atlas was delayed, Titan with slightly different engineering could be made operational by the end of the 1950s and keep the United States from falling behind in the missile race.[xxix]

Liquid-Fuel Intercontinental Ballistic Missiles: Atlas and Titan

One of the most important early problems tackled by missile developers working with the WDD was that of fueling the rocket, or more accurately, of finding a fuel that would be effective in flight, but also safe on the ground. Early ICBMs were powered by a highly volatile liquid-fuel mixture of liquid oxygen and kerosene or nitrogen tetroxide.[xxx] This mix powered both the early ICBMs–Atlas and Titan. Problems with liquid fuel were evident from the early days of development and posed challenges and safety issues for on-site crews. Liquid fuel was heavy and unstable and dangerous to handle and store. Other practical issues included the need to store the fuel outside the missile, loading the fuel just prior to launch. This complication made it necessary to develop a safe system of pumps, storage tanks, and mixing chambers to store the fuel.

The other option for powering the new ICBMs was solid fuel, which was only in the beginning stages of research and development when the Atlas missile program began in earnest in 1954.[xxxi] Given the mission of the WDD to produce a working ICBM in the shortest possible timeframe, liquid fuel was the only viable option for the first ICBMs.[xxxii]

Atlas

The Atlas missile was the first ICBM activated by the Air Force. The development and deployment of this ICBM was the result of a massive, fast-tracked effort on the part of the WDD, the ARDC, and its contractors. By December 1955, one year after the Atlas development program was taken over by the WDD, there were fifty-six contractors working on the Atlas program.[xxxiii] By 1957 the list of contractors had grown to 157.

Early specifications for the Atlas missile required a 240,000 pound vehicle with two 135,000 pound booster engines and a sixty thousand pound sustainer engine. Although Atlas development utilized certain elements of existing technology, including propulsion systems designed for the canceled Navaho cruise missiles, the Atlas design was state-of-the-art.[xxxiv] The Atlas missiles had to be pressurized while on alert, because the stainless steel shell was so thin–a requirement of flight–that only pressure kept it in place while on the ground. If the missile was fueled and launched, the liquid oxygen fuel inside the missile created the necessary pressure to hold the missile's shape. This system allowed for a much lighter airframe, but required continual maintenance to prevent structural collapse. In layman's terms, an unpressurized Atlas missile might best be understood as a deflated balloon.[xxxv]

The first Atlas ICBM was tested successfully on 17 December 1957 and the first Atlas missile went on alert at Vandenberg Air Force Base in California on 31 October 1959.[xxxvi] Atlas missile crews were in place at numerous air force bases by 1961, and a year later, twelve Atlas squadrons were on alert, in addition to the missile at Vandenberg.[xxxvii]

Three generations of the Atlas missile were deployed by the Air Force–Atlas D, E, and F. Technological advances would be seen in each new generation of Atlas produced, most notably through improvements in thrust, launch, and guidance system. As the Atlas is the direct predecessor of the Minuteman missile, some key details of the progression of this system will shed useful light on the Minuteman's origins.[xxxviii]

Atlas D

- First deployed in 1959.
- First deployed at Vandenberg Air Force Base in California, F.E. Warren Air Force Base in Wyoming, and Offutt Air Force Base in Nebraska.
- F.E. Warren Air Force Base had two squadrons with six missiles. Vandenberg Air Force Base and Offutt Air Force

Base had three squadrons for a total of nine missiles at each base.

- Possessed 360,000 pounds of thrust and measured eighty-two feet long.

- Propelled by a one-and-one-half stage liquid-fuel rocket.

- The missile was stored horizontally and housed aboveground in soft complexes with gantries or “coffins.”

- To launch, the missile roof was pulled back, the missile raised to a vertical position, fueled, and fired.

- The launch sequence began when the two boosters and the sustainer engine were lit. Two small vernier engines above the sustainer ignited shortly after lift-off (2.5 seconds). Booster engines burned once in flight, and these, along with the turbo-pumps, were discarded quickly once a signal was received from the ground station. The sustainer engine was the last to extinguish and the vernier engines were responsible for course and velocity corrections.[xxxix]

- Three missiles, a control center, and a radio guidance system were controlled by a single missile crew.

- The radio guidance system was accurate to one and one-half miles and could only control one missile at a time.

- Armed with a one-megaton thermonuclear warhead.

- Range of approximately 6,400 miles.

Atlas E

- First deployed in 1961.

- First deployed at Fairchild Air Force Base in Washington, Forbes Air Force Base in Kansas, F.E. Warren Air Force Base, and Vandenberg Air Force Base.

- Nine missiles comprised a squadron. Fairchild, Forbes and F.E. Warren Air Force Bases had three squadrons. Vandenberg had one squadron.

- Atlas E was more powerful than Atlas D, with 389,000 pounds of thrust.

- Range of approximately 9,400 miles.

- Controlled by a self-contained, automatic inertial guidance system accurate to within one and one-half miles.

- Armed with a one-megaton thermonuclear warhead.

- Missiles were stored in aboveground coffins.

- To launch, the Atlas E was raised to a vertical position and fueled.
- A separate launch crew staffed each missile site.

Atlas F

- Placed on alert in 1962.
- First deployed at Schilling Air Force Base in Kansas, Lincoln Air Force Base in Nebraska, Plattsburg Air Force Base in New York, Altus Air Force Base in Oklahoma, Dyess Air Force Base in Texas, and Walker Air Force Base in New Mexico.
- Twelve silos and a support base formed a squadron.
- One squadron was deployed at each of the six bases mentioned above.
- More powerful than Atlas E, with 390,000 of thrust.
- Range of approximately 9,400 miles.
- Armed with a one-megaton thermonuclear warhead.
- Controlled by self-contained, automatic inertial guidance system accurate to within one and one-half miles.
- Missile stored vertically in hardened underground silo.
- Missile raised to surface on elevator during launch sequence.
- A single missile was housed in the Atlas F silo with an adjoining underground launch control facility.[xl]

By 1962 the number of Atlas missiles scattered across the country had grown to 126.[xli] Though first, the Atlas was never intended to be the only American strategic missile. It was destined to be eclipsed in its role by the more advanced Titan and Minuteman systems to follow. The last Atlas missile was launched at Vandenberg on 24 March 1995. Rather than a nuclear payload, this Atlas E carried a Defense Meteorological Weather Satellite to orbit.[xlii]

Titan I

The development of the Titan missile resulted from the decision of the WDD and the Eisenhower administration in 1955 to move forward with the development of a second ICBM, in case the Atlas ran into delays.[xliii] The WDD developed Titan ICBMs concurrently with the Atlas.[xliv] Titan I had several distinct advantages over the Atlas, including greater range, speed, and warhead size. As with the information detailed on the Atlas above, some key moments and statistics for the Titan program will help provide context for the more exhaustive Minuteman discussion to follow. Features of the Titan I include:

- Combat crews began working at the Titan I missile sites in 1961.

- First Titan I went on alert in 1962 at Lowry Air Force Base in Colorado.

- In 1962 Titan I ICBMs were deployed in six squadrons having three missiles each.

- Deployments were located at Beale Air Force Base in California, Ellsworth Air Force Base in South Dakota, Larson Air Force Base in Washington, Mountain Home Air Force Base in Idaho, Vandenberg Air Force Base in California, and Lowry Air Force Base.

- Measured ninety-eight feet long and possessed a self-supporting frame.

- Three missiles were housed in adjacent silos and controlled by a single launch control facility, thereby making this system more efficient for the Air Force to operate.

- A single Titan I, with a range of over 6,300 miles, was capable of launching fifteen minutes after the order was received.

- Two additional Titan I ICBMs in the squadron launch at seven-and-a-half-minute intervals after the first missile.

- Propellant consisted of a two-stage liquid oxygen and kerosene system.

- Missile housed in a 165-foot-deep silo and was raised to the surface for launch.

- Armed with a single four megaton thermonuclear warhead.

- Used to successfully test a “hot” launch directly from the silo. The ability to launch directly from the silo without raising the missile to the surface resulted in a quicker launch time.[xlv]

Titan I remained on alert for only three years–from 1962 until 1965–before being replaced by the Titan II.

Titan II

Titan II was approved for development in 1959 and was designed to correct some of the perceived shortcomings of the Titan I system. Fifty-four Titan II ICBMs, deployed at Davis-Monthan Air Force Base in Arizona, Little Rock Air Force Base in Arkansas, and McConnell Air Force Base in Kansas, remained on active duty until deactivation began in 1982 and was completed in 1987.[xlvi]

Features of Titan II include:

- Improved inertial guidance and fuel systems.

- Armed with a nine megaton thermonuclear warhead.
- A maximum range of nine thousand miles.
- Employed storable propellants.
- Ability to launch in two minutes.
- Improved rocket engines featured 432,000 pounds of thrust in the first stage and a second stage with 100,000 pounds of thrust.
- Based on the successful tests conducted with Titan I, the Titan II could be launched directly from the silo without having to be raised to the surface.
- Squadrons consisted of nine missiles, each in an underground silo and controlled by a neighboring underground Launch Control Center.
- Two officers and two enlisted combat crew staffed the Launch Control Facility. Beginning in 1978 the first female crewmembers served on the crew of Titan II, setting the precedent for the later mixed-gender Minuteman crews.

As the above discussion demonstrates, both the Atlas and Titan programs offered significant improvements over the manned strategic weapons systems that preceded them. However, each had its shortcomings. The Minuteman was designed to overcome these deficiencies. It is to the Minuteman itself that we next turn.

Plate 5. Air Force Assistant Secretary for Research and Development Trevor Gardner (*left*) and Major General Bernard Schriever (*right*)–two champions in the development of the ICBM
(Courtesy U.S. Air Force, History Division)

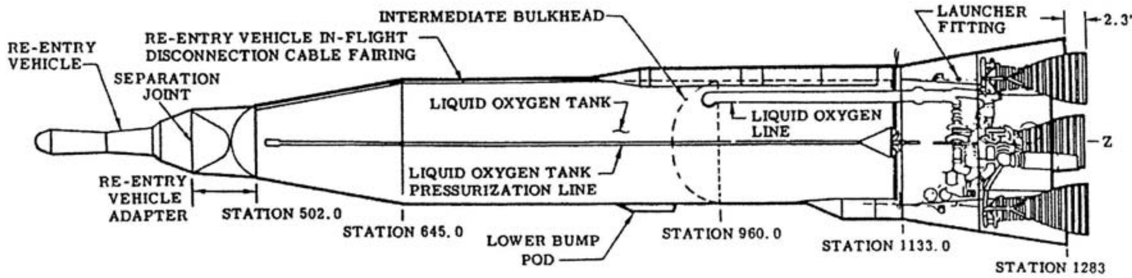

Plate 6. Cutaway drawing of an Atlas D ICBM. Later Atlas E and F missiles used the same airframe but added more powerful engines *(John C. Lonnquest and David F. Winkler, To Defend and Deter: The Legacy of the United States Cold War Missile Program (Washington, D.C.: Department of Defense, Legacy Resource Management Program, 1996), 210)*

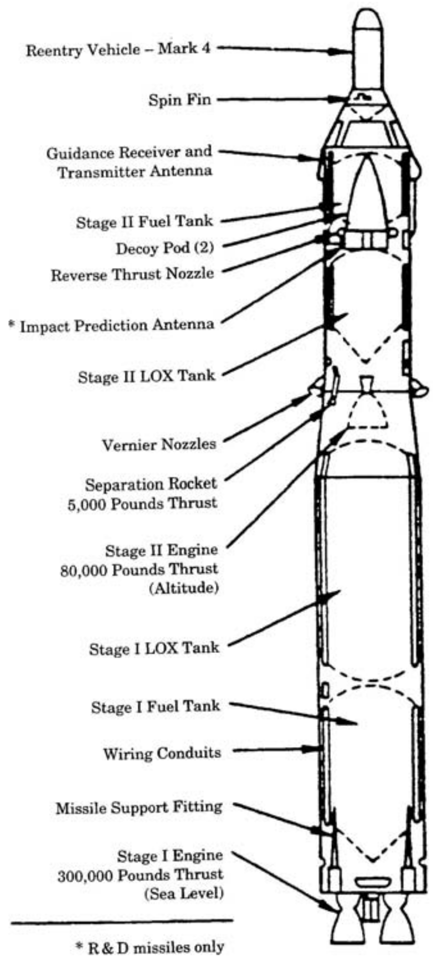

Plate 7. Drawing of Titan I, the United States' first two-stage ICBM *(Lonnquest and Winkler, To Defend and Deter: The Legacy of the United States Cold War Missile Program, 228)*

Plate 8. Titan I missile with crew *(Photograph No. B-13-026-2, "Guided Missiles–Martin Titan," U.S. Air Force Photo, Record Group 342, National Archives, College Park, Md.)*

[i] Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945-1960* (Washington, D.C.: Office of Air Force History, 1990), 239.
[ii] G. Harry Stine, *ICBM: The Making of the Weapon that Changed the World* (New York, N.Y.: Orion Books, 1991), 147-149.
[iii] Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945-1960,* 240-241.
[iv] John C. Lonnquest and David F. Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program* (Washington, D.C.: Department of Defense, Legacy Resource Management Program, 1996), 29.
[v] M. J. and Mason R. A. Armitage, *Air Power in the Nuclear Age* (Chicago, Ill.: University of Illinois Press, 1983), 16.
[vi] Ernest G. Schwiebert, *A History of the U.S. Air Force Ballistic Missiles* (New York, N.Y.: F.A. Praeger, 1965), 70, 78.
[vii] "Big Week for Pushing Missile Buttons: U.S. Tries Hard to Catch Up," *LIFE* 43, no. 19 (4 November 1957): 31.
[viii] See Lonnquest and Winkler, To Defend and Deter: The Legacy of the United States Cold War Missile Program, 30 and Bernard C. Nalty, ed. *Winged Shield, Winged Sword: A History of the United States Air Force*, vol. 2 (Washington, D.C.: Air Force History and Museums Program, 1997), 206 and U.S. Air Force organizational chart at the end of Section II, Chapter 2.
[ix] Lonnquest and Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program,* 31.
[x] Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945-1960,* 66-67.
[xi] Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945-1960,* 151, 210.
[xii] Charles Simpson, "Special History Issue - Land Based USAF Missiles," *AAFM Newsletter* 5, no. 1 (June 1997): 3.
[xiii] Stine, *ICBM: The Making of the Weapon that Changed the World,* 143-144, 152.
[xiv] Schwiebert, *A History of the U.S. Air Force Ballistic Missiles,* 70.
[xv] Schwiebert, *A History of the U.S. Air Force Ballistic Missiles,* 60-61, 69.
[xvi] Lonnquest and Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program,* 31.
[xvii] Luther L. Stenvick, *The Agile Giant: A History of the Minuteman Production Board* (Seattle, Wash.: Boeing Company, 1966), 19.
[xviii] Stenvick, *The Agile Giant: A History of the Minuteman Production Board,* 19.
[xix] Stine, *ICBM: The Making of the Weapon that Changed the World,* 166; Stenvick, *The Agile Giant: A History of the Minuteman Production Board,* 19-20.
[xx] Simpson, "Special History Issue - Land Based USAF Missiles," 3.
[xxi] Stine, *ICBM: The Making of the Weapon that Changed the World,* 169.
[xxii] Stenvick, *The Agile Giant: A History of the Minuteman Production Board,* 20.
[xxiii] Lieutenant General Otto J. Glasser, interview by Lieutenant Colonel John J. Allen, typed transcript, 5 January 1984, 55.
[xxiv] Stine, *ICBM: The Making of the Weapon that Changed the World,* 170.
[xxv] Stine, *ICBM: The Making of the Weapon that Changed the World,* 171.
[xxvi] Schwiebert, *A History of the U.S. Air Force Ballistic Missiles,* 90.
[xxvii] Schwiebert, *A History of the U.S. Air Force Ballistic Missiles,* 79-80.

[xxviii] Roy Neal, *Ace in the Hole* (Garden City, N.Y.: Doubleday & Company, 1962), 64-65.
[xxix] Lonnquest and Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program,* 70.
[xxx] Neal, *Ace in the Hole,* 27; Stine, *ICBM: The Making of the Weapon that Changed the World,* 230.
[xxxi] Neal, *Ace in the Hole,* 27.
[xxxii] Stine, *ICBM: The Making of the Weapon that Changed the World,* 230.
[xxxiii] Schwiebert, *A History of the U.S. Air Force Ballistic Missiles,* 93.
[xxxiv] The Air Force canceled the Navaho cruise missile in 1957 in favor of developing a supersonic, air-breathing guided missile. For more information on the engineering of the Atlas, see Stine, *ICBM: The Making of the Weapon that Changed the World,* 191.
[xxxv] Charles Simpson, "Atlas - Then and Now," *AAFM Newsletter* 7, no. 1 (March 1999): 7.
[xxxvi] Simpson, "Atlas - Then and Now," 7.
[xxxvii] "The ICBM Force in the Early 1960s," *AAFM Newsletter* 9, no. 4 (December 2001): 1.
[xxxviii] Unless otherwise noted, these statistics come from Simpson, "Special History Issue - Land Based USAF Missiles," 1, 7.
[xxxix] Lonnquest and Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program*, 211.
[xl] Simpson, "Special History Issue - Land Based USAF Missiles," 4.
[xli] Stine, *ICBM: The Making of the Weapon that Changed the World,* 227.
[xlii] "Vandenberg Launches Last Atlas E," *AAFM Newsletter* 3, no. 2 (April 1995): 1.
[xliii] Colonel Edward N. Hall, interview by Jack Neufeld, typed transcript, 11 July 1989, 8.
[xliv] Simpson, "Atlas - Then and Now," 1.
[xlv] Stine, *ICBM: The Making of the Weapon that Changed the World,* 229.
[xlvi] Simpson, "Special History Issue - Land Based USAF Missiles," 1; Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945-1960,* 194, 239; Stine, *ICBM: The Making of the Weapon that Changed the World,* 230.