Fortress

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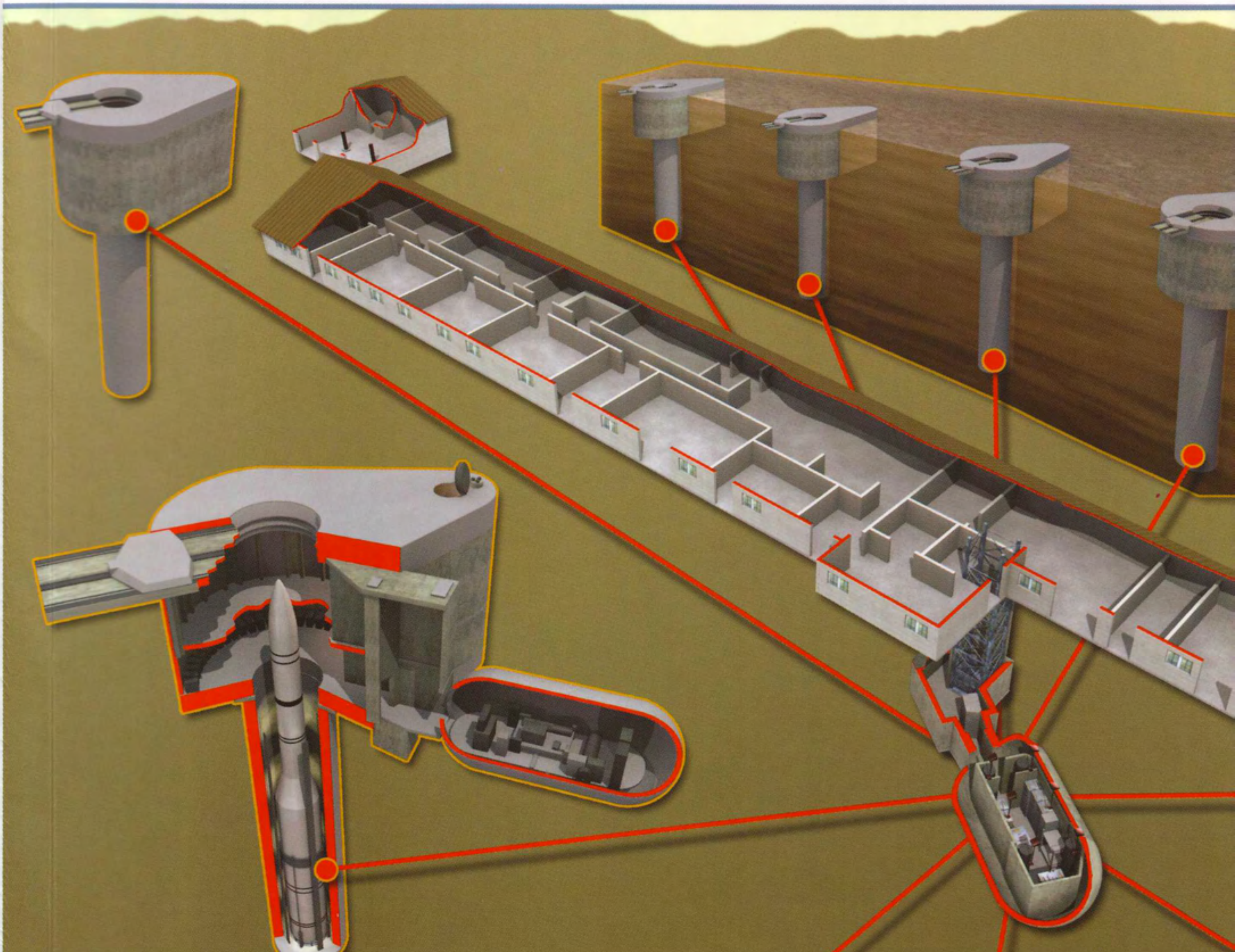
US Strategic and Defensive Missile Systems 1950–2004



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inches to centimeters	multiply inches by 2.540
feet to meters	multiply feet by 0.3048
yards to meters	multiply yards by 0.9144
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Mark Berhow, September 2004

Fortress Study Group (FSG)

The object of the FSG is to advance the education of the public in the study of all aspects of fortifications and their armaments, especially works constructed to mount or resist artillery. The FSG holds an annual conference in September over a long weekend with visits and evening lectures, an annual tour abroad lasting about eight days, and an annual Members' Day.

The FSG journal *FORT* is published annually, and its newsletter *Casemate* is published three times a year. Membership is international. For further details, please contact:
The Secretary, c/o 6 Lanark Place, London W9 1BS, UK

Coast Defense Study Group (CDSG)

The CDSG is a non-profit corporation formed to promote the study of coast defenses and fortifications (primarily but not exclusively those of the United States of America), their history, architecture, technology, and strategic and tactical employment. Membership of the CDSG includes four issues of the organization's two quarterly publications, the *Coast Defense Journal* and the *CDSG Newsletter*. For more information about the CDSG please visit www.cdsg.org, or to join write to:

The Coast Defense Study Group, Inc., 634 Silver Dawn Court, Zionsville, IN 46077-9088 (Attn: Glen Williford)

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Introduction

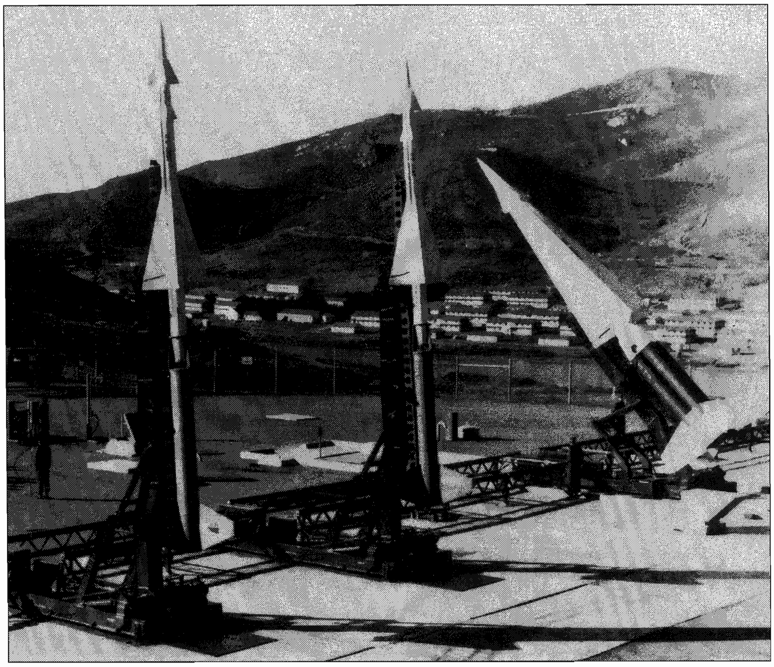
During the 40 years following the end of World War II, the Western Bloc Democracies and the Eastern Bloc Communists were locked in an ideological, political, and economic struggle known as the Cold War. While this struggle was carried out on many levels and in many arenas, the development and deployment of land-based defensive and strategic missile systems epitomizes Cold War weaponry. Both sides used the missile systems as a means to defend themselves against attack by the other. The arms race of the Cold War era was fueled by hype and uncertainty, depicted by both sides as a struggle for national survival. This was a struggle waged in a quest for technological supremacy, played out in laboratories, factories, the executive and legislative branches of the federal government and the military. It encompassed the entire spectrum of military weaponry and ultimately had a significant impact on the economy and politics of the United States.

The development of the atomic bomb dramatically changed military strategic planning, and outmoded all existing defensive systems in use at the beginning of World War II. Postwar American defensive strategy changed from defense against potential invasion to defense against potential total destruction. The new defensive strategies were centered on ways to defend against the delivery of the atomic bomb. By the 1950s, the United States had developed a series of defensive antiaircraft missile systems that were capable of delivering conventional and nuclear explosives against massed bomber formations. Simultaneously, the United States and the Soviet Union developed a series of offensive missile systems that could deliver nuclear payloads against ground targets located on distant continents. Both the United States and the Soviet Union parlayed the implied use of these weapons as a deterrent against aggression by the other power – a "defensive" role for these potent offensive weapons.

These missile systems were the ultimate weapons of this era – large amounts of economic and military resources were committed to the systems, and they were an extensive part of both internal national politics and external global politics.

This work will provide an overview of the fixed land-based launch site missile systems of the United States – these essentially became the fortification elements for the United States in the latter half of the 20th century. Both the defensive systems – the Nike programs, BOMARC, and Safeguard – and the deterrence systems – the strategic intercontinental ballistic missiles (ICBMs) systems; Atlas, Titan, Minuteman, and Peacekeeper – will be covered in this work; as will a brief discussion of the new antiballistic defenses being built by the United States today.

Nike-Hercules and Nike-Ajax on display at Nike site SF-88 during a public ceremony in 1958. (Courtesy Milton B. Halsey, Jr.)



Chronology

1945 **Truman Administration**. July: first test atomic bomb exploded by US. August: atomic bombs dropped on Japan. September: World War II ends.

1946 February: public speech by Stalin implies future wars. March: Churchill's Iron Curtain speech; MacMahan Act creates the Atomic Energy Commission; Kennan Long Telegram on future Soviet strategy; Army Air Force Commands created: SAC, TAC, ADC.

1947 Truman Doctrine to contain Soviet Expansion established; National Defense Act creates DOD and USAF; Marshall Economic Recovery Plan begun.

1948 June: Berlin Crisis; Communist government established in China.

1949 NATO formed. September: Soviets explode an atomic weapon.

1950 National Security Council (NSC) document No. 68 establishes policy to resist Soviet expansion by build up of military force; Korean War begins; US Army reorganized, ARAACOM established; AAA defenses established around key US cities and sites.

1951 Japan Peace Treaty signed; new weapon systems R&D re-established.

1953 **Eisenhower Administration**. NSC Doc No 162/2 results in "New Look" policy of threatened massive retaliation against Soviet aggression. August: Soviets detonate a hydrogen bomb; death of Stalin; end of Korean War. December: first Nike-Ajax defense deployed.

1954 Killain Report: high priority on USAF ICBM development; the French leave Vietnam; Soviets display their first long-range bomber; Continental Air Defense (CONAD) Command established.

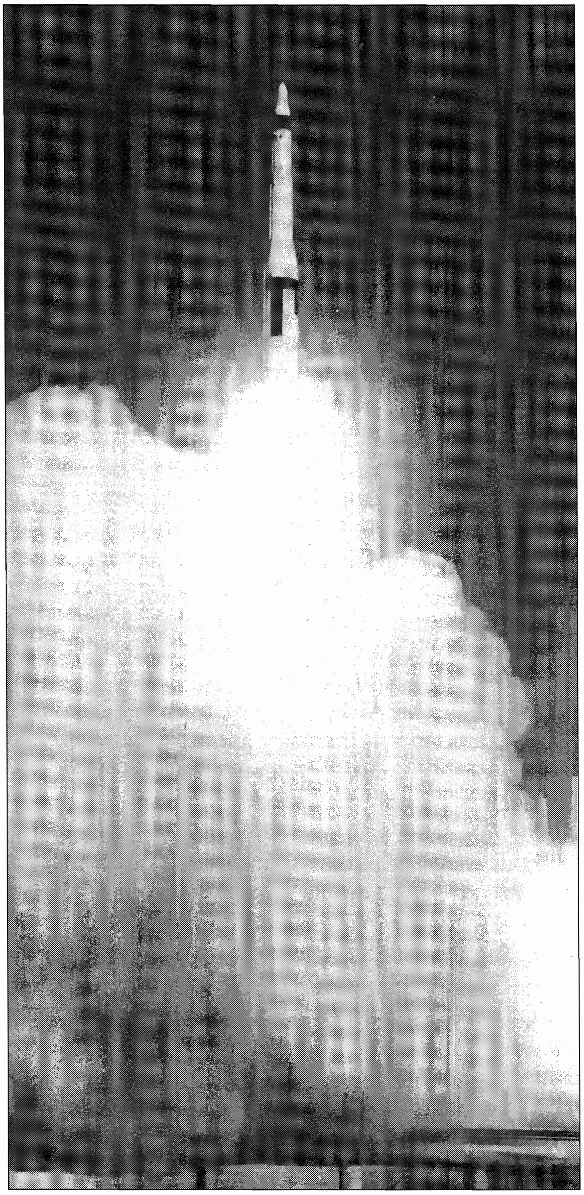
1955 NSC-5520 advocates the development of satellites; B-52 bombers deployed; radar lines authorized; SEATO established; Warsaw Pact established; Soviets display a second long-range bomber and the "Bomber Gap" scare develops; solid-fuel ICBM development authorized.

1957 Sputnik launched; Gaither Report on US civil defense engenders fear of "Missile Gap"; NORAD established; ARAACOM redesignated ARADCOM.

1958 US Explorer I satellite launched; early-warning radar lines established; Nike-Ajax phase out/replacement with Nike-Hercules begun.

1959 USAF BOMARC A SAM defense system operational; first operational Atlas D ICBM squadron at Vandenburg AFB.

A Minuteman I missile launched from Cape Canaveral. (National Archives Still Picture Branch)



1961	**Kennedy Administration.** "Flexible Response" policy advocates the potential use of limited nuclear warfare. April: Bay of Pigs incident; Berlin Wall built; Atlas E ICBM operational.
1962	Atlas F and Titan I ICBMs become operational. October: Cuban Missile Crisis.
1963	Limited Test Ban Treaty; Titan II and Minuteman I ICBMs operational; last Nike-Ajax removed from CONUS sites; Kennedy assassinated. **Johnson Administration.**
1964	Brezhnev assumes power in USSR; Vietnam War escalates; Atlas D ICBM phased out.
1965	Atlas E/F and Titan I ICBM systems phased out.
1966	Soviet ABM system deployed; Minuteman II ICBM operational.
1968	Strategic Arms Limitation Talks (SALT) begun; Nuclear Arms Nonproliferation Treaty; DOD directs gradual phase-down of Nike-Hercules system; Sentinel ABM system announced.
1969	**Nixon Administration.** Safeguard ABM system announced.
1970	Minuteman III (MIRV) operational.
1972	SALT Treaty signed by US Congress; ABM Treaty signed – limiting each power to two ABM sites; the last BOMARC retired; Nike-Hercules phase-out begun; Minuteman IA phased out.
1973	Nixon resigns. **Ford Administration.**
1974	Last CONUS Nike-Hercules sites inactivated; Congress terminates the further deployment of Safeguard; Minuteman IB ICBM phased out.
1975	ARADCOM inactivated; Stanley R. Mickleson Safeguard ABM system declared fully operational – Congress terminates operations a day later.
1977	**Carter Administration.** MX missile program authorized.
1979	SALT II agreement signed by Carter and Brezhnev, but not ratified by US Congress.
1981	**Reagan Administration.** Reagan repudiates elements of Salt I and II.
1982	Strategic Arms Reduction Talks (START) begin; MX missiles (Peacekeeper) to be deployed in Minuteman silos; Titan II phased out.
1983	START ends; Reagan proposes the Strategic Defense Initiative (SDI).
1985	Geneva Summit accords.
1986	Peacekeeper ICBMs operational; new missile system planned in Strategic Defense System (SDS).
1987	Congress decides against SDI.
1988	Glasnost.
1989	**George Bush Administration.** *Solidarity* in Poland begins process leading towards the collapse of the Soviet Union; Berlin Wall falls.
1991	Minuteman II ICBMs to be phased out; SDI system to be transformed to Global Protection Against Limited Strikes (GPALS); START II signed – elimination of MIRVs.
1993	**Clinton Administration.** DOD directs phase-out of Peacekeeper missiles and removal of MIRVs from Minuteman missiles.
1996	New missile defense system transitioned into acquisition phase for a deployable system.
1999	Minuteman II phase-out completed.
2001	**George W. Bush Administration.** Phase-out of Peacekeeper ICBMs initiated.
2002	Deployment of new National Missile Defense (NMD) ABM system to be operational in 2005.

Historical overview

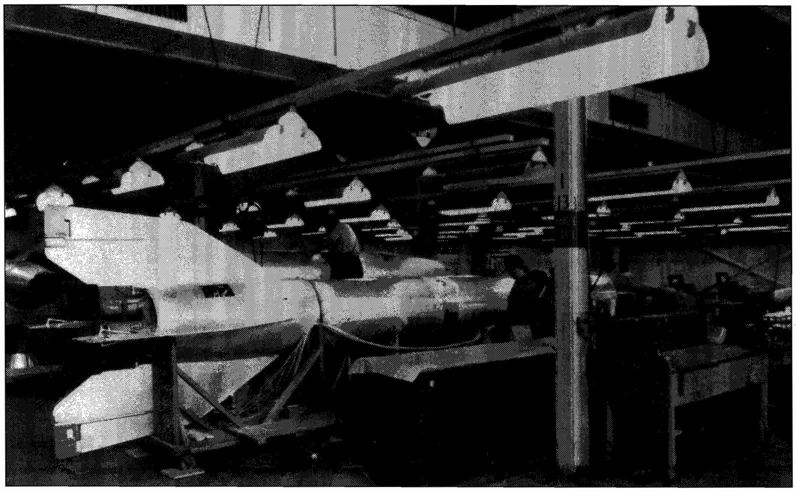
American defensive/deterrence systems and strategies in the Cold War

At the end of World War II in September 1945 the United States of America was the mightiest military and economic power in the world. Sole possessor of the atomic bomb, in possession of the finest collection of conventional military weapons in the world, and the one major power that was the least affected by the ravages of the previous years of warfare – the USA confidently demobilized its armed forces and shelved the development of new weapon systems then underway.

However, the postwar political arena changed quickly – the military alliance between the United States and the Soviet Union quickly soured. In the years immediately following the end of the war, the Soviet Union moved to consolidate its hold on the countries of Eastern Europe and backed socialist movements in other countries, especially in Asia. The United States continued to cut its military budget in 1946, despite increasing evidence that the Soviets were continuing to build their military forces. The Soviet Union had relocated and built up its industrial base during the latter part of World War II and had begun programs to develop new weapons to augment its formidable land and air armed forces. Drawing on information gathered from espionage, its own scientists, and scientists from Germany, the Soviet weapon research programs were in full swing. The Soviet leaders were moving quickly to secure their country's position as an equal rival to the United States. The political and military leaders in the West watched the developments in the East uneasily.

In March 1946 the British wartime Prime Minister Winston Churchill gave an address at Westminster College stating, "from Stettin in the Baltic to Trieste in the Adriatic, an Iron Curtain has descended across Europe." On October 23, 1947, American observers noted the existence of a number of Soviet Tu-4 "Bull" aircraft. The Tu-4 was a reverse-engineered copy of the Boeing B-29, a few of which had landed in the Far East during World War II. These bombers gave the Soviets the range to bomb targets in the United States. On April 1, 1948, the Soviet Union closed off all land approaches to the Allied sectors of Berlin, Germany. The Berlin Blockade would last until September 30, 1949. More importantly, all friendly USA–USSR interrelations had effectively ended. On September 23, 1949, President Harry Truman announced the Soviet Union had exploded an atomic bomb the month before. The United States' monopoly on nuclear weapons had ended. The deteriorating international situation in Europe and Asia during 1946 prompted concern about the United States' defenses.

In 1947, the United States government reorganized its political–military structure. The War Department was replaced with the Department of Defense, the ground forces under the



Built for the MX-774 program, Convair's RTV-A-2 missile was the forerunner of the Atlas ICBM. (USAF Museum, Research Division)

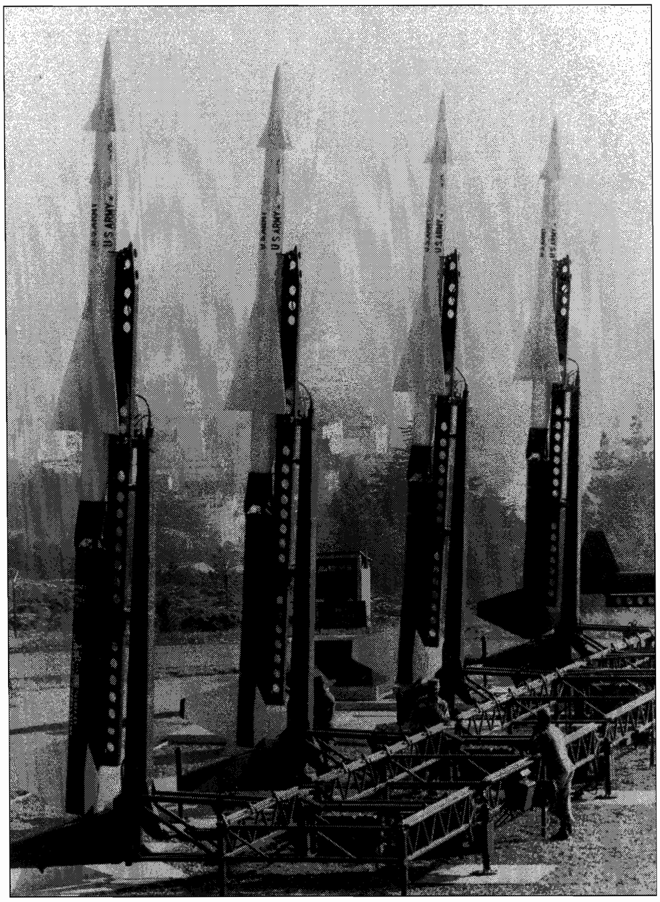
Army, the naval forces under the Navy, and the ground-based air forces under the new independent service arm – the Air Force. The Air Force flexed its new political power and was often at odds with the Army over issues of strategic control and the funding of new weapons projects. The year 1949 ended with the roles of the Air Force and the Army in air defense undefined.

The 1950s were a tumultuous decade for the US weapons development programs. Inter-service rivalry was a hallmark of this decade. The Air Force and the Army competed over the right to develop and control surface-to-air missiles and all three services fought for the right to develop the long-range ballistic missiles. Internal disputes within the Air Force slowed the development of the ballistic program as well.

The outbreak of the Korean War in 1950 finally prompted action. The Army artillery arm was reorganized and the Army Antiaircraft Command (ARAACOM) was created. ARAACOM was to deploy conventional antiaircraft artillery at 66 key locations until the new missile defenses were deployed. The Air Force was assigned control of the ballistic missile program in the mid 1950s and the Air Defense Command (ADC) became the tactical command coordinating the defense of the continental United States. Increased funds were committed to the development of advanced nuclear weapons, new long-range bombers, and the new long-range guided missiles.

Early on the backers of the development of guided missile weapon systems were divided into two camps: long-range surface-to-surface missile systems, offensive by design, which would become the "strategic defense" missiles, and surface-to-air defensive antiaircraft/antimissile-missile systems. The strategic and defensive missile systems had distinctly different roles in the Cold War: the strategic missiles would be used in a deterrence role with implied massive retaliation in response to attack; the defensive systems would constitute the final line of defense in case of attack. The role of the United States strategic missile systems as a defensive deterrent was hotly debated throughout the course of the Cold War. The military and politicians portrayed these as a way to discourage the Soviets from attacking the United States or its allies for fear of a swift and massive retaliation.

Nike-Ajax missiles in firing position at a site in the San Francisco defense area. (Courtesy Milton B. Halsey, Jr.)



The nation's strategic doctrine underwent numerous revisions during the course of the Cold War. In the mid 1950s the Eisenhower Administration sought to trim the American conventional forces by following a policy of implicit threat of massive nuclear retaliation against the communist countries in response to Soviet aggression, a defensive policy called the "New Look." Critics pointed out that there was no assurance that US strategic forces could survive a Soviet first strike and it seemed unlikely that the US would risk nuclear war over disputes in Asia or the Middle East. In 1961 the Kennedy Administration implemented a new defensive posture called "Flexible Response," a mixture of nuclear and conventional forces, which would tailor a response to threats in a proportionate manner. This remained the cornerstone of American defense planning throughout the remainder of the Cold War era.

Development of defensive missile systems

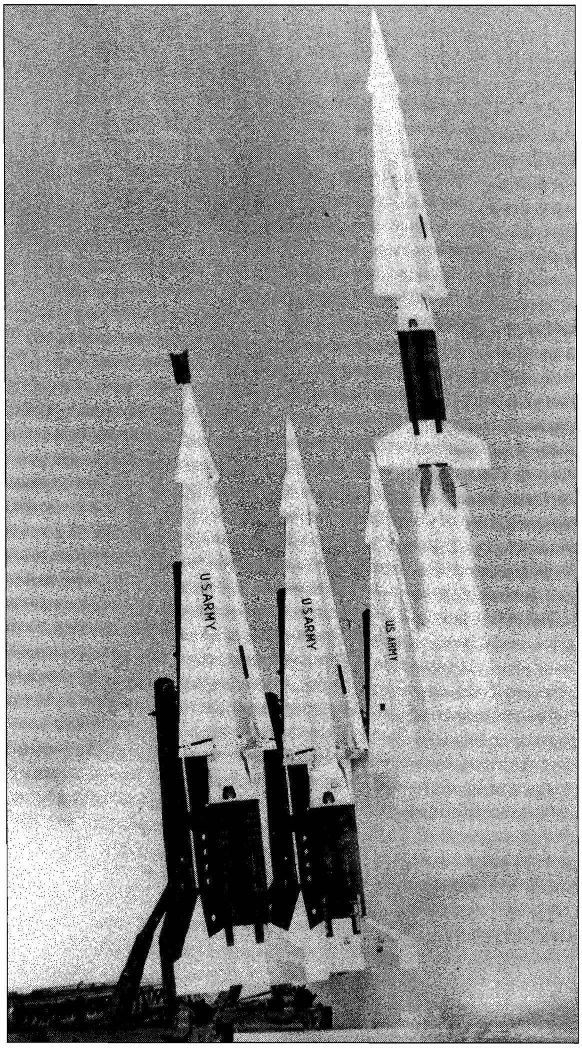
Tactical integration of American continental air defenses began during World War II. The emergence of the airplane as the ascendant offensive weapon, as demonstrated during the Spanish Civil War and first two years of World War II, forced corresponding changes in tactical considerations for the defense of the American continent. Interceptor commands, made up of units of the Army Air Force (AAF), were established in late 1941 to react to the enemy air threat. In March 1942 the Army Antiaircraft Command was created; tactical control of all Coast Artillery AA units was integrated with that of the AAF's Interceptor Commands. New larger and mobile AA weapons were developed and used during the war. Rockets also emerged as effective new weapons. And radar became the new method of detecting and tracking targets. In August 1945 there were 331 active AA battalions with 246,000 troops scattered around the world.

The Army's first surface-to-air missile defense program was based on a memorandum proposing the development of a radio-controlled antiaircraft rocket that could be used to protect large target areas from bomber attack. In June 1945, Bell Labs and its manufacturing arm, Western Electric, began the development of the new system. It was given the code name Project "Nike" after the winged goddess of victory in Greek mythology. When the war ended on August 1945 with the surrender of Japan, the Army began a general demobilization that included all of its units. During the rush, operational control of continental defense was treated as an afterthought. The Coast Artillery antiaircraft units were being demobilized with the rest of the wartime Army.

By 1948, as the Cold War developed, the United States began to hurriedly re-organize and remobilize its armed forces and restart development of the defensive missile systems stalled at the end of World War II. While the interceptor fighters and strategic bombers of the newly formed US Air Force and the aircraft carriers and submarines of the US Navy were part of an integrated continental defense plan, the final defense against Soviet bomber formations was to be surface-to-air missiles, which would replace conventional antiaircraft guns. The Army, Air Force, and Navy revamped their surface-to-air defensive missile programs. Both the Army and the Air Force vied for funds and control of these systems; inter-service rivalry would plague the missile programs for the next 20 years.

The Air Force had the primary responsibility for defending the United States against bomber attack. The Air Force developed a "defense in depth" strategy that utilized early warning radar systems, interceptor fighters, and long-range antiaircraft missiles positioned around the perimeter of the nation. If this defense was penetrated, the Army's antiaircraft missiles were positioned around key US industrial and military sites. The US Air Force developed its problematic 440-mile range BOMARC surface-to-air system, which was deployed in the 1960s on a much more limited basis than originally planned. The US Army's Nike surface-to-air system was deployed from 1953 onwards. The initial system was the partially liquid-fueled Nike-Ajax, with a range of 30 miles. By

Nike-Hercules at White Sands Missile Range. (US Army)



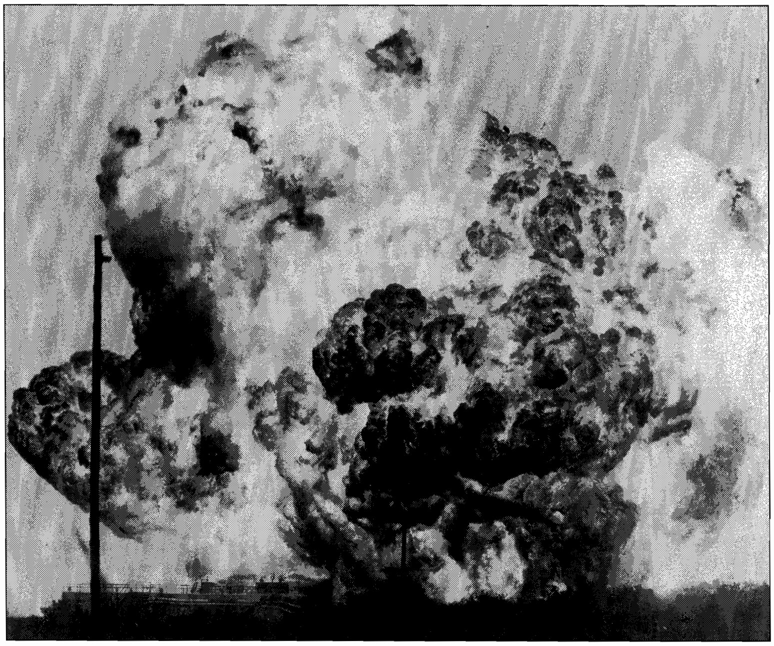
Early-warning radar systems.

1958 there were over 200 battery sites around key US manufacturing cities and nuclear research /production centers. That year the Army began to replace Ajax with the solid-fueled and nuclear warhead-capable Nike-Hercules, which had a range of over 75 miles, at about half of the original Ajax sites with added sites around Air Force Strategic Air Command bomber bases.

A key component of the defensive missile system was a functioning early warning system. The Defense Department committed early on to the deployment of a series of interlocking radars to monitor the perimeter and selected interior portions of the American continent. The goal was to get 5–6 hours of warning to respond in case of a Soviet bomber attack. The Air Force initially deployed a system of radars, designated Lash-Up, to watch over the coastal centers and major nuclear weapon productions centers in the United States. The Lash-Up system grew from 7 sites in 1949 to 50 by the end of 1951. It was gradually replaced by the Permanent System, which numbered 74 radar sites by June 1952. The US radar warning systems were supplemented by the

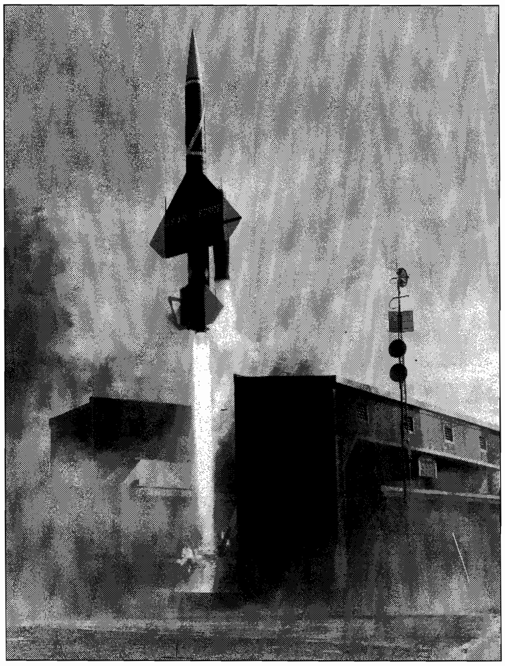
34 stations of the Pinetree Line across Canada, which provided two more precious hours of warning time.

In 1957 the Department of Defense approved its most ambitious detection programs, the Distant Early Warning (DEW) radar line and the Semi-Automatic Ground Environment (SAGE) air defense control system. The DEW Line consisted of a series of radar sites 50 miles apart stretching along the extreme northern boundary of the North American continent, several hundred miles north of the Artic Circle. Further extensions in 1962 stretched the line from Scotland to Midway Island. The DEW Line was the outermost line of early warning radars, supplemented by the Mid-Canada Line, the Pinetree Line, the Permanent Radar System and the Gap Filler Radar System in the United States. By the mid 1960s both the Navy and the Air Force had ship-borne and airborne radar picket units available as well. This impressive array of sensors was still vulnerable to jamming, and was naturally bypassed by the ballistic missile.



On September 19, 1958 the second test flight of a Thor IRBM at Cape Canaveral ends in a tremendous explosion. (Office of Air Force History)

SAGE incorporated the latest radar and computer technology to support the proposed 50 Air Force Combat Direction Centers. Through these centers the continental defense command (after 1957 the North American Aerospace Defense Command, NORAD) coordinated all weapons – the interceptor aircraft squadrons and the antiaircraft missile batteries – dedicated to US air defense. SAGE became operational in 1958, and was completed in 1961. Each massive 275-ton SAGE computer filled an entire four-story windowless building. They were the marvel of the day, but expensive to maintain and vulnerable to attack because of their above-ground location. SAGE was the Air Force system of tactical command. It linked the Air Force Air Defense Command, Tactical Air Command and Strategic Air Command as well as the Army Air Defense Command and ARADCOM's Nike missile system. This gave NORAD complete overall tactical control to detect and provide a coordinated response to an incoming airplane attack.



BOMARC being launched from Cape Canaveral, Florida in November 1958. (National Archives)

Development of strategic missile systems

Postwar evaluation of the German rocket program, especially the V-1 and the V-2, led to initial research programs by the Army Air Forces on the development of long-range missiles capable of striking land targets. By 1946 work had begun on the development of two types of strategic missile systems: the winged air-breathing missile and the ballistic missile.

Initially the Air Force favored the air-breathing winged missile systems, because it was believed they would be easier to develop and build than ballistic missiles. The missiles had

General Bernard A. Schriever was involved in all aspects of the development of the Air Force missile program and can rightly be considered the father of the United States ICBM force. (National Air and Space Museum, Smithsonian Institution)

wings for lift and control and were propelled by conventional jet engines. Two systems were developed – the Snark and the Navaho. The 70ft. long Snark had a top speed of 600 miles per hour and could carry a 7,000 lb. warhead 5,000 miles. The Navaho was equivalent in size and range to the Snark, but was propelled by two powerful ramjet engines giving it a top speed of 2,150 miles per hour. Both programs faced severe developmental problems, especially in guidance and control, which were never adequately resolved. Navaho was cancelled in 1958; Snark was briefly deployed at a single location in Maine in 1960. The air-breather surface-to-surface programs were eventually eclipsed by the ballistic missile programs and the development of the smaller, more sophisticated cruise missile.

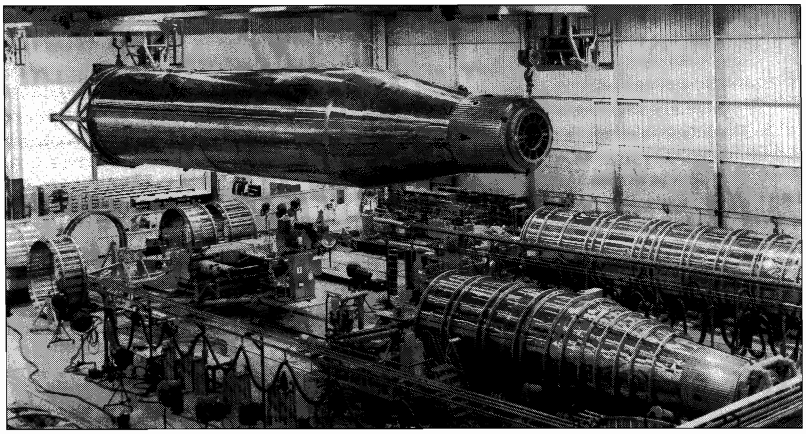
The development of the US ballistic missile program was slow starting. Ballistic missiles carried their own oxygen supply and were fired in parabolic trajectories high outside the earth's atmosphere. Once the warhead reached the apogee of its flight path, it followed a ballistic path to its target. These missiles were capable of striking targets at extremely long ranges, half way around the world. Two types were eventually developed: the intermediate range ballistic missile (IRBM) and the intercontinental ballistic missile (ICBM).

The Air Force was committed early on to the air-breathing missile program while its ballistic missile program languished in obscurity. Prominent officers dismissed the program as "science fiction" and felt it was diverting money from manned aircraft programs. The Army seized the initiative with its Redstone and Jupiter programs and was soon competing for both funds and tactical control of the ICBM programs. The inter-service squabbling finally had to be settled by the politicians who decreed the Air Force would have control of the strategic ICBM systems, while the Army would develop and deploy the defensive missile systems subject to the Air Force's tactical control, as well as short-range tactical battlefield missiles.

In 1954 the Air Force accelerated its ICBM programs, initially with the Atlas missile. The 82ft. missile was powered by three liquid-fueled rocket engines with a range of 5,500 to 6,750 nautical miles at a top speed of 16,000 miles per hour and a guidance system capable of delivering its nuclear payload to within two miles of its target. A second ICBM program, the liquid-fueled Titan, was begun in 1955 as a backup to Atlas. Three years later the Air Force began development of a third ICBM system, the solid-fueled Minuteman.

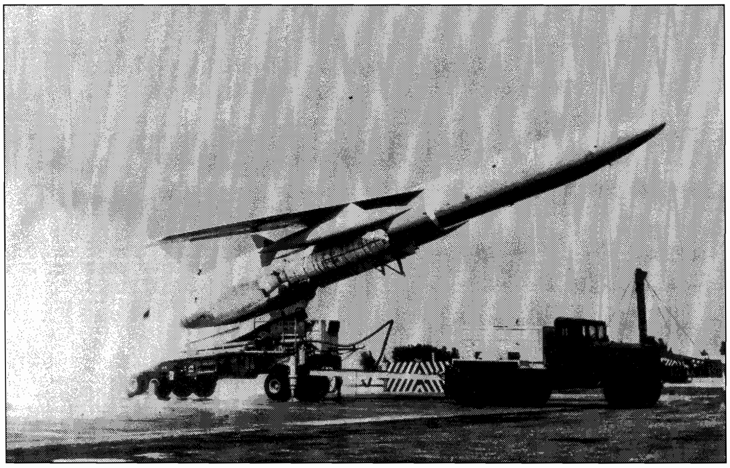
In 1957 the Soviets announced they had an operational ICBM, and the following year demonstrated that capability with the launch of Sputnik, the first orbiting satellite. Sputnik sparked concern in both military and political circles that the United States was lagging behind the USSR in missile deployment, creating a "missile gap." The US quickly began deploying its Jupiter and Thor IRBM systems in Great Britain, Italy and Turkey. The ICBM programs were accelerated: the first Atlas missiles

Atlas ICBMs being assembled at the Convair plant outside San Diego, CA, in 1960. Stainless steel sections are being welded together to form the fuselage. A completed fuselage, minus the booster section that housed the engines, hangs from a ceiling crane. (National Air and Space Museum, Smithsonian Institution)

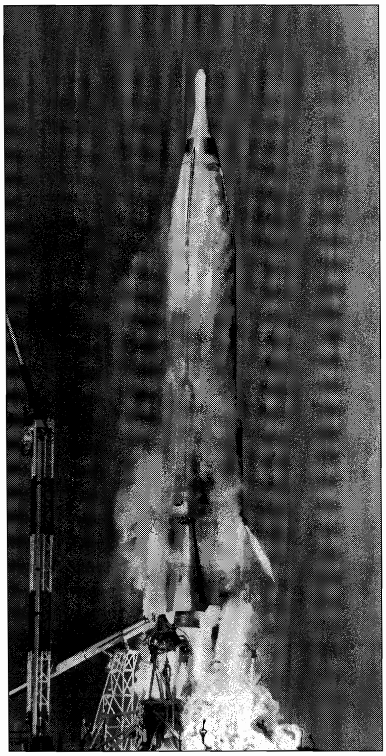


were operational in September 1959, the first Titans in April 1962, and the first Minutemans in October 1962. Further development of radar detection capability and integrated communication systems came with the three Ballistic Missile Early Warning System (BMEWS) installations and the three Position Acquisition Vehicle Entry Phased Array Warning System (PAVE PAWS) installations in the 1960s.

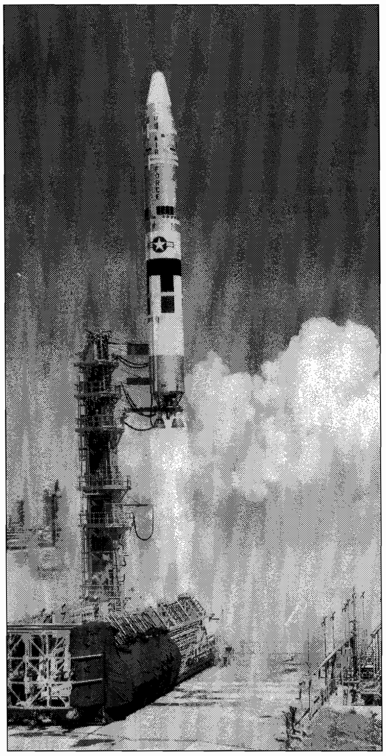
The Cuban Missile Crisis of 1962 was the most dramatic public demonstration in which the two superpowers nearly came to blows. The crisis tested and refined the Kennedy Administration's commitment to "Flexible Response." On October 3, 1962, the executive branch reported that the Soviets were deploying antiaircraft missile systems and fighter jets in Cuba. By the end of the month evidence mounted that the Soviets were building sites to deploy IRBMs. President Kennedy announced that the United States would not tolerate the deployment of offensive weapons systems in Cuba, he ordered the barricade of Cuban ports by the US Navy and brought the Air Force and Army to full alert. The two superpowers were on the brink of nuclear war. However, the Soviets finally removed their IRBMs from Cuba, and an agreement was eventually reached in which the US withdrew its IRBMs from Turkey.



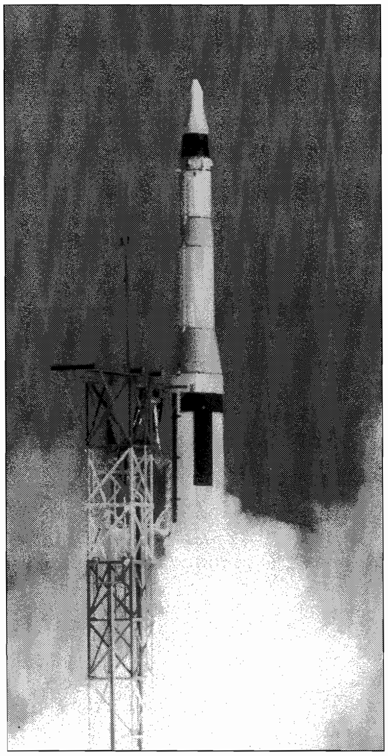
Snark test launch at Cape Canaveral, Florida. (USAF Museum Research Division)



An Atlas D lifts off from Cape Canaveral on a test flight in October 1960. (National Archives Still Pictures Branch)



A Titan II lifts off on a test flight from Cape Canaveral in October 1962. (National Archives Still Pictures Branch)



A Minuteman I missile launched from Cape Canaveral in February 1961. (National Archives Still Picture Branch)

ICBM deployment in the continental United States.

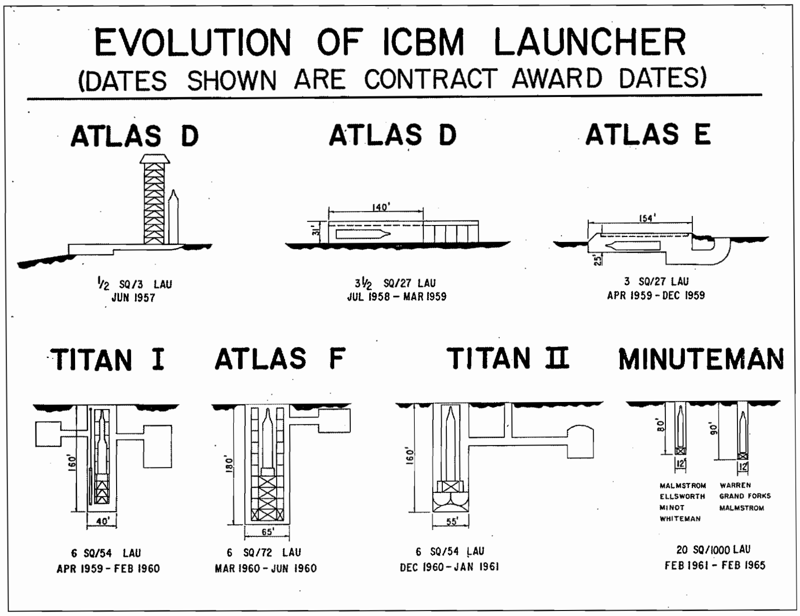
Changing strategies of missile defense

By the mid 1960s, it was apparent the Soviets were not building a large fleet of long-range bombers. The Soviets were focusing on developing large ICBM and submarine-launched ballistic missile (SLBM) forces, and in doing so, would render much of the US air defense systems obsolete. As the perceived threat turned from bombers to missiles, both the Army and Air Force began to develop plans for antiballistic missile systems (ABMs). The Army's Nike missile program produced the first ABM system, Nike-Zeus, with new longer ranged radar systems in the early 1960s. Though Nike-Zeus successfully demonstrated its ability to hit incoming ICBMs, it was not deployed due to problems with its radar systems in successfully discriminating between multiple targets. Instead, a new program was initiated – Nike-X – a dual missile program with new phased-array radar, which was capable of tracking multiple targets.

Nike-Zeus A launched from the White Sands Missile Range December 16, 1959. (US Army)

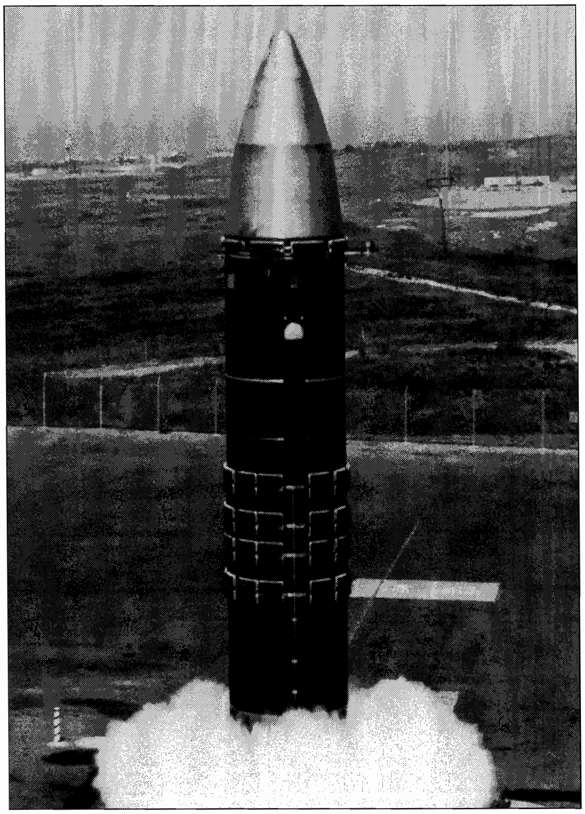
New and upgraded ICBMs continued to enter the American inventory throughout the Cold War. Initially, the ICBMs were deployed in relatively unprotected launch facilities. Over time, as new missile systems came on line, they were deployed in increasingly sophisticated underground silos, which were "hardened" to withstand a nearby nuclear blast. By 1965 the USAF had retired its temperamental liquid-fueled

Atlas missiles and Titan Is, but retained the Titan IIs with the storable liquid fuel. It also deployed 800 of the new solid-fueled Minuteman missiles, each housed in an unmanned hardened silo, ready to fire on a moment's notice. Starting in 1966, the Air Force began upgrading to the longer-range, more accurate, and more powerful Minuteman II system. By 1969 the United States had 1,054 ICBMs poised in underground silos. In 1971 the Air Force began deploying the Minuteman III, which was the first to be fitted with three multiple independently-targetable re-entry vehicles (MIRVs).



The evolution of ICBM launch facilities.

The development of the Army ABM systems moved slowly, often hampered by lack of confidence in the system, which led to lack of funding. The Army's original intent was to deploy the Spartan/Sprint system in the existing ARADCOM defense areas and, to that end, performed several site studies. However, problems with the Vietnam War effort and some nagging technical objections kept funding at only the developmental level. Events overseas, however, drove the program back into national priority. The Chinese had exploded a nuclear bomb in 1964 and by 1967 had successfully tested a missile delivery system. This meant that another nation in addition to the USSR was a potential ICBM treat. In addition, the Soviets were beginning to deploy their own ABM system.



A Peacekeeper missile being launched at Vandenberg AFB, CA. (Courtesy Michael Binder)

On September 18, 1967, McNamara announced a major drawdown of ARADCOM's Nike-Hercules strength. Concurrently, he announced the austere deployment of the ABM system, named Sentinel, to include a mix of existing and new locations. Notably, the stated purpose of the system was not to protect the United States from Soviet ICBMs, but instead from Chinese ICBMs. On November 3, 1967, McNamara released the list of 17 planned Sentinel complexes. The Army completed its initial site studies at the proposed Boston-area installation in July 1968. Initial construction began following the contract award on January 22, 1969, but a change was coming with the new Nixon Administration.

Among the issues the new Nixon Administration tackled was the deployment of Sentinel. As could be expected for the times, the outburst of public and political opposition to any sort of ABM system – which included protests and an occupation of the early Sentinel site near Boston – played a part in the new administration's assessment. The decision was soon made to halt the work on the Boston site and to relocate the ABM system away from population centers to new sites near Strategic Air Command bases.

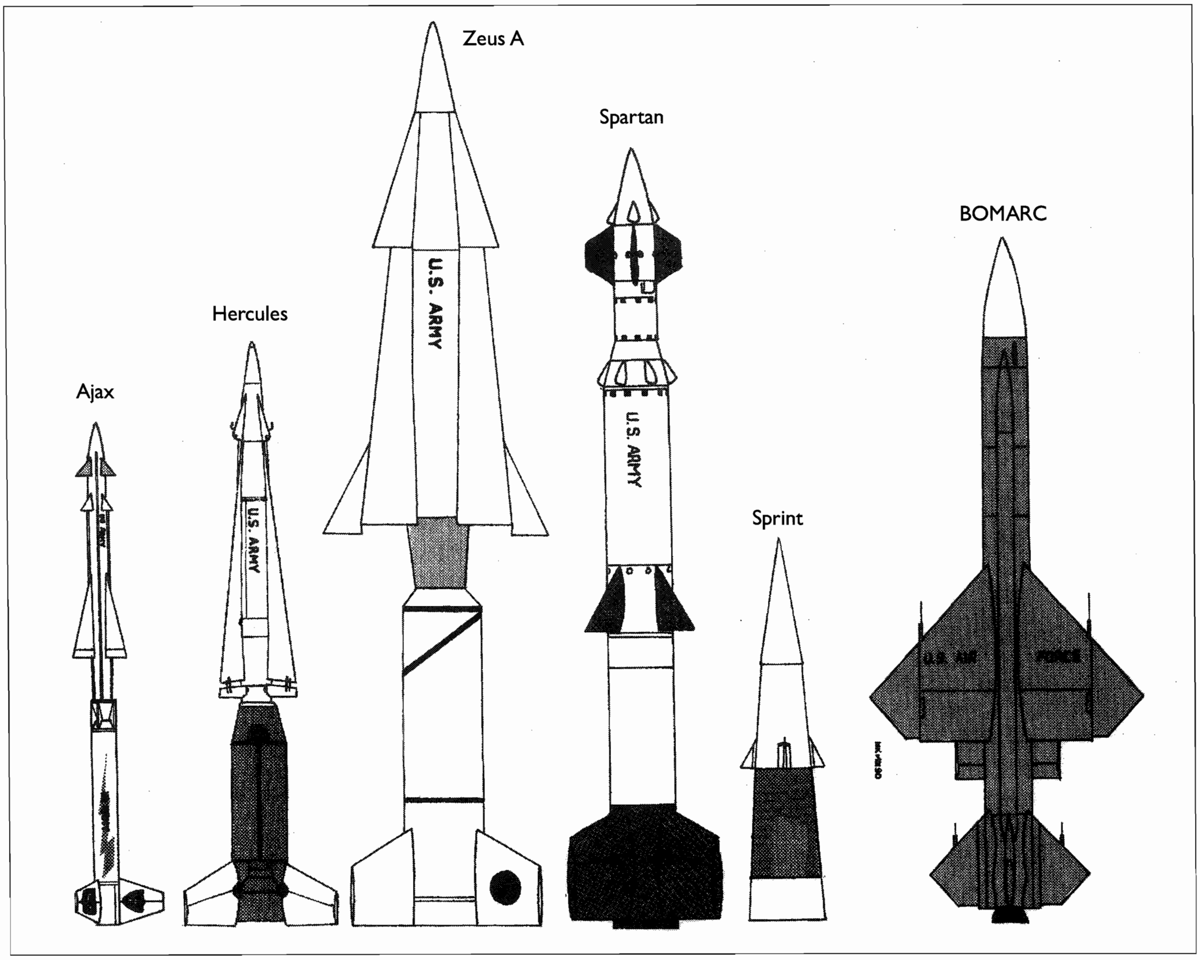
Officially, though, the shift was made in response to the slow rate of ICBM development in the People's Republic of China and the continued deployment of newer, more capable Soviet missiles. One new generation Soviet ICBM had a range of nearly 7,500 miles and was capable of delivering a 25-megaton warhead. Later Soviet variants carried MIRVs.

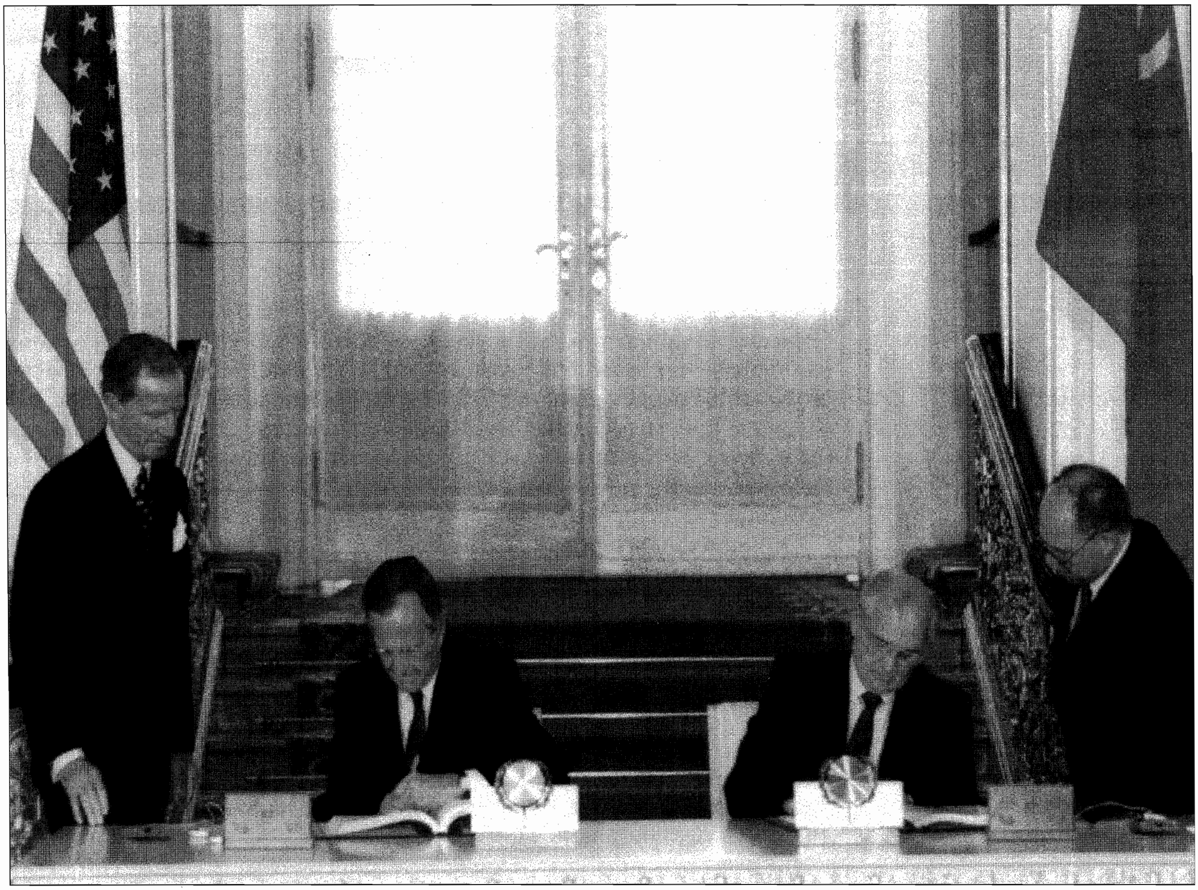
The development of the ABM systems, among other things, brought the two superpowers to the negotiating table in the early 1970s, resulting in the Strategic Arms Limitation Treaty (SALT) and the Antiballistic Missile Treaty. These treaties were the first to limit further deployment of nuclear weapons by the superpowers. The immediate result of the ABM Treaty was the limitation of the US Army Safeguard ABM system already under construction to just one site near Grand Forks, North Dakota. This site was declared fully operational in 1975, only to be shut down on the following day by Congressional order.

The final installment of the Cold War ICBM program was the MX or Peacekeeper system. Concern over the accuracy of the Soviet ICBM/SLBM led to debate over alternative basing systems, including mobile ones. Finally, 50 MX missiles were deployed in reconfigured Minuteman silos in 1986. Congress decided against any of the other basing strategies, effectively ending the Peacekeeper deployment at 50 missiles.

The cancellation of the Safeguard ABM program reflected the realization in military and political circles that the United States could do little to defend itself against an all-out Soviet ICBM attack other than to respond in kind. This form of deterrent – "Mutually Assured Destruction" (MAD) – was used by both

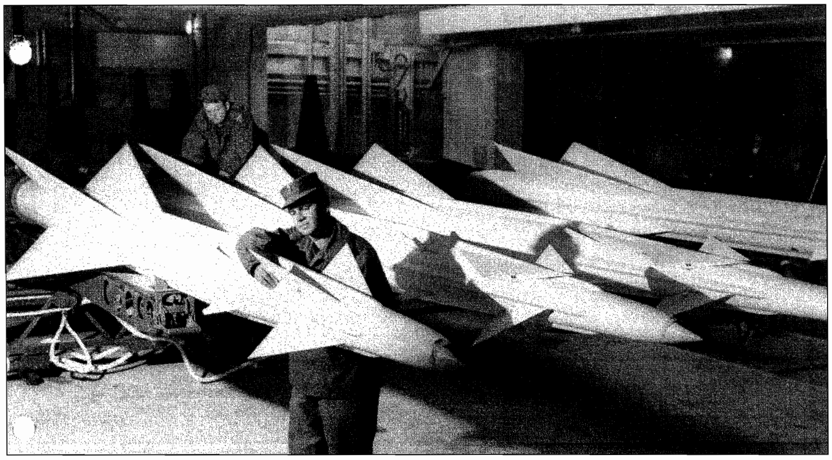
The comparative sizes of air defense missiles. (Mark Morgan)





sides into the 1980s. The search for new ABM defenses continued, however, and a new integrated defensive system was proposed by the Reagan Administration in 1983: the Strategic Defense Initiative (SDI). SDI was composed of an interlocking system of satellites, mobile radars, with both mobile and fixed defensive missiles. It was quickly dubbed "Star Wars" by the press. Despite continued research support, the initiative was eventually not deployed as the Cold War came to an end with the fall of the Soviet government in Russia.

President George H.W. Bush and Soviet President Mikhail Gorbachev signing the START II Treaty at the Kremlin in Moscow, July 31, 1991.



Inspecting a Nike-Ajax missile in an underground storage area prior to raising it to a launching site at W-64 Lorton, VA. December 9, 1954. (US Army Signal Corps)

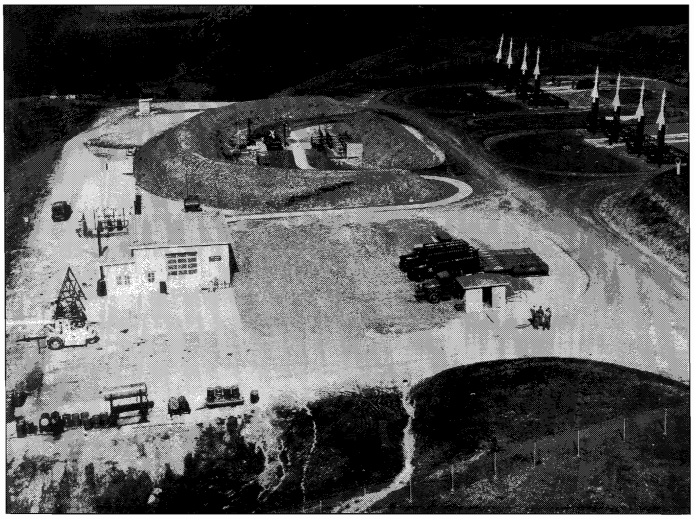
Ground-based defensive missile systems 1945–74

Nike-Ajax (MIM-3)

The first US surface-to-air missile defense program was based on an August 17, 1944 memorandum written by First Lieutenant Jacob W. Schaefer, US Army (Ordnance), a former employee of Bell Telephone Laboratories. Schaefer proposed the development of a radio-controlled antiaircraft rocket that could be used to protect large target areas from bomber attack. The proposal outlined the concept of command guidance: one radar tracking the target, a second radar tracking the missile, with steering commands provided to the missile by a computer to enable interception.

Copies of the memorandum were sent to the Radio Corporation of America (RCA) and Bell Telephone Laboratories (BTL) for their consideration and comments. In February 1945 the US Army Ordnance Corps and the Army Air Force asked Bell Labs to explore the possibility of developing a new antiaircraft system based on Lieutenant Schaefer's memorandum. In June 1945 Bell Labs and its manufacturing arm, Western Electric, began the development of the new system. Douglas Aircraft Company was selected as the major subcontractor to design and manufacture the missile, booster, and launcher equipment. It was given the code name Project "Nike" after the winged goddess of victory in Greek mythology. Research and development of the Nike project continued through the cessation of hostilities.

The development of the Nike missile system had been slowed by cuts in the post-World War II defense budget and problems with the booster design. The program was brought back up to speed following the start of the Korean War. Even though testing was still underway, a contract was let for 1,000 Nike I missiles and 60 sets of ground equipment. The first complete system test was conducted at White Sands Proving Ground, NM, on November 15, 1951; the first successful intercept of a drone aircraft by an unarmed Nike came 12 days later. Testing continued through the spring of 1952, with some 20 unarmed missiles being fired. A full-scale demonstration of the complete Nike missile system occurred on April 24, 1952, resulting in the spectacular destruction of a drone QB-17G. By the following summer the contractors were ready to turn over a complete missile battery to ARAACOM. Over the next few years regular army ARAACOM units were brought to Fort Bliss for training in "packages." By 1957, many of the Army's AAA units had been converted to missile battalions and, on March 21, 1957, ARAACOM was re-designated US Army Air Defense Command, or ARADCOM. From this point, Army air defenders would man missile systems. That same year, the governments of the United States and Canada signed the bi-national agreement that led to the formation of the North American Aerospace Defense Command, or NORAD. In 1958 NORAD assumed



A Nike-Ajax launch site in the San Francisco defense area near Fort Winfield Scott in 1956. Lined up on the left side of the photo (from top to bottom) are the entrance guardhouse, the generator building, and the missile assembly building. Protected by the earthen berm is the acid fueling and warhead assembling area. To the right are two magazine/launch area with Nike-Ajax missiles in launch position. (National Air and Space Museum, Smithsonian Institution) operational control of CONAD incorporating ARADCOM, ADC, naval forces CONAD, and the Royal Canadian Air Force's Air Defence Command.

The Nike-Ajax (eventually designated MIM-3/3A) was the first supersonic surface-to-air missile system to become operational in the Free World. It had a range of about 30 miles and could destroy targets at altitudes exceeding the operational ceilings of known Soviet aircraft. The missile had an all-weather capability, could attack from any direction, and was able to compensate for any evasive action taken by a target aircraft.

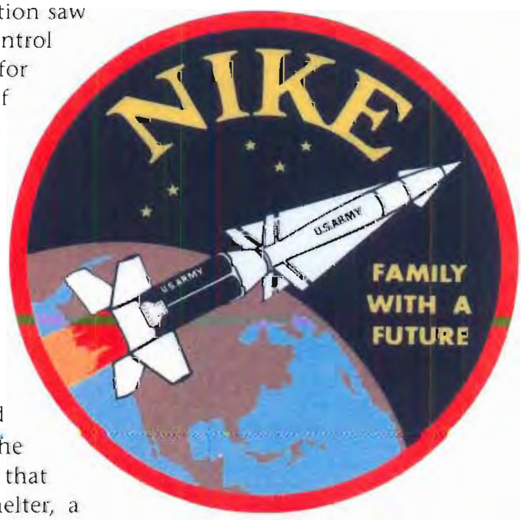
The two-stage Nike-Ajax weighed slightly more than one ton and was 32ft. 8in. long. It was powered to supersonic speed by a solid rocket booster with a liquid-fueled sustainer. The missile was designed to deliver three high-explosive (HE) warheads to the vicinity of the target aircraft and explode on command from the battery control site.

B Battery 4-43d Artillery, Battery Control Van near Fort Richardson, AK, November 10, 1960. (US Army Signal Corps)

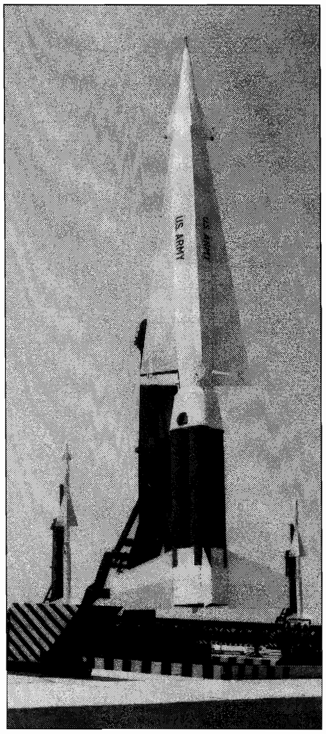
The Nike missiles were deployed in fixed firing positions in a circular pattern around key American government/industrial/transportation and military locations; the larger the defended area, the more Nike-Ajax sites constructed. For example, larger defenses, such as Los Angeles or New York, received 16 and 19 Nike-Ajax batteries respectively. Smaller defenses such as Ellsworth and Loring AFBs received four sites each. The land requirement for each firing position was cut down to 40 acres with the use of an underground magazine configuration to house the missiles. As the Nike-Ajax sites were built during 1954–56, the new magazines were changed slightly to accommodate the newer Nike B missile then being developed. The short range meant that many of these sites were located in the suburban areas around the larger American cities. The first operational Nike-Ajax unit was established in a temporary site at Fort George G. Meade, MD, in December 1953 under the auspices of Battery B, 36th AAA Missile Battalion. Conversion of other Army gun battalions to Nike-Ajax rapidly followed; construction of the Nike batteries was carried out between 1954 and 1957.

A typical Nike missile battery facility was divided into three major areas: the Integrated Fire Control (IFC) area; the magazine and launcher area (L); and the Administration area (A). The three components were often located on separate parcels of land, although the most common configuration saw the IFC and administrative sites co-located. The battery control installation was at least 1,000 yards away from the launch area for missile control and tracking reasons but still in direct line of sight. In practice, sites were constructed with many variations depending on the local conditions and geography. Where possible, existing military reservations were used, but in many cases land for new sites had to be purchased, leased, or borrowed from other government agencies, local governments, and private owners.

Nike team color patch.



The missile launch facility was a self-contained installation with all of the capabilities for independent action. The normal launch area configuration was two or three underground magazines, each with an elevator for raising the missile to the surface. Each magazine had four above-ground elevating rails for elevating the rockets into launch position. The underground interior of the magazine had a missile storage bay that held 10–12 missiles, with launcher loading racks, a crew shelter, a



Nike-Hercules (foreground) and Nike-Ajax (background) missiles at the Chatsworth site in the Los Angeles defense area, 1956. (US Army Signal Corps)

launching section control panel, ventilation equipment, test equipment, hydraulic controls, and the elevator. Upon receipt of an alert order, the missiles were pushed one at a time onto the elevator and raised to the surface, then pushed to the launch rails, and, with the proper electrical connections completed, raised to an angle of about 85 degrees for firing. Other launch area facilities consisted of buildings and facilities for the assembly and testing of the missiles, a warhead mating building, a liquid fueling area, a power generating facility, storage and repair buildings, sentry posts, and ready room for the men stationed there. The entire launch complex was surrounded by security fencing topped with barbed wire. Some locations had four or six magazines; these were known as "double sites," as they comprised two separate firing batteries, each with its own set of IFC radars.

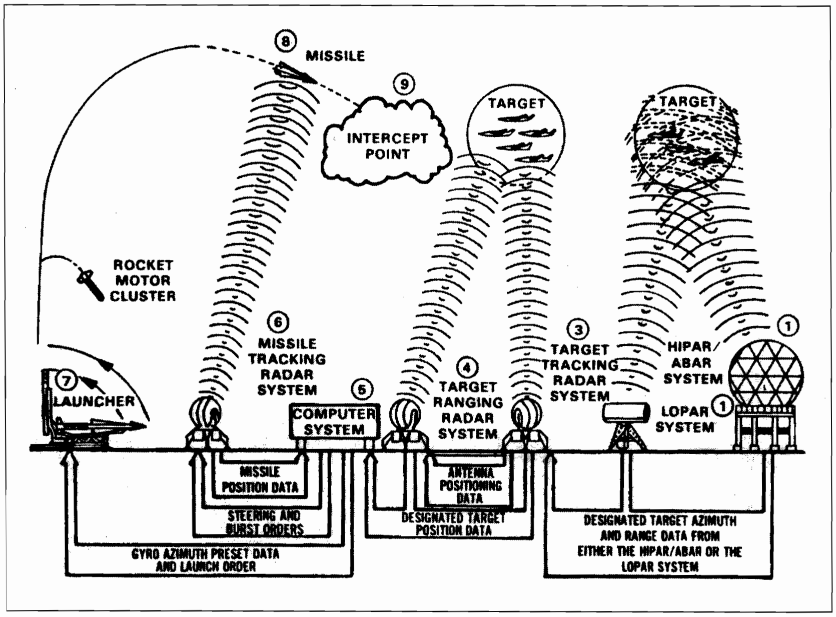
The IFC or Control site contained the radars and radar equipment for acquiring and tracking the target and missile, the battery control assembly, the computer assembly, an early warning plotting board, an event recorder, and a switchboard cabinet. Nike employed the command guidance system, in which the major control equipment was ground-based and not part of the expendable missile. Each battery had full operational control of the Nike-Ajax missile once it was launched. The site's Acquisition Radar (ACQR) acquired the incoming target aircraft at long range and provided pointing data to the Target-Tracking Radar (TTR), which locked on to the target. The site's Missile-Tracking Radar (MTR) locked on to the missile prior to firing and tracked the outbound Nike-Ajax. Data from the radars was fed to the electronic data processing equipment, which compared the position of the target and the missile and fed guidance commands to the missile to enable the intercept. The IFC area also housed the electrical generating equipment, which supplied 400-cycle power to operate the radars and consoles. The original plan was for Nike to be a "mobile" system. The operational control equipment for both the launch area and the control consoles was housed in special truck trailers. These trailers were docked at special "connector" buildings located at each site. The various components were interconnected via the Battery Control Area Cable System. The control site also had a maintenance facility, a spare parts storage facility, and was secured by patrolled fencing.

The Administrative area contained the barracks, mess hall, recreational facilities and administrative offices for the battery. In most cases, this area was located within walking distance of either the battery control area or the launch facility, as neither had provisions for housing the crews. Administrative facilities housing battalion headquarters sites were larger, to handle the increased number of staff personnel in the supply, operations and intelligence sections. Nike-era buildings were built to standard Corps of Engineers design. They were usually constructed of cinderblock with flat roofs, although the designs varied depending upon the location. For example, the sites in the San Gabriel Mountains in the Los Angeles Defense Area had buildings with steep-pitched snow roofs.

Nike-Hercules (MIM-14A/B)

In 1953, prior to the actual deployment of the Nike-Ajax system, research and development began on a more capable, longer ranged missile. Originally designated "Nike-B," it was later named Nike-Hercules (MIM-14A/B). Hercules was expected to mitigate several of the problems found with the Nike-Ajax. The Hercules booster was effectively four strapped-together Ajax boosters; the sustainer was also solid fueled, removing a major difficulty with Ajax. The larger Hercules would be able to carry a nuclear warhead, giving it the ability to knock out formations of bombers and not just individual aircraft. Finally, the new system would use as much as possible of the existing Ajax site components and support infrastructure but still have room for modifications as the threat changed.

The missile was expected to have a maximum range of 50 miles and altitude capability of 70,000ft. at a speed in excess of Mach 1. The first test firing came at White Sands in 1955; further testing resulted in a missile with a range of over 75 miles, effective ceiling of over 100,000ft. and a top speed of Mach 3. Later modifications increased the range to over 90 miles.

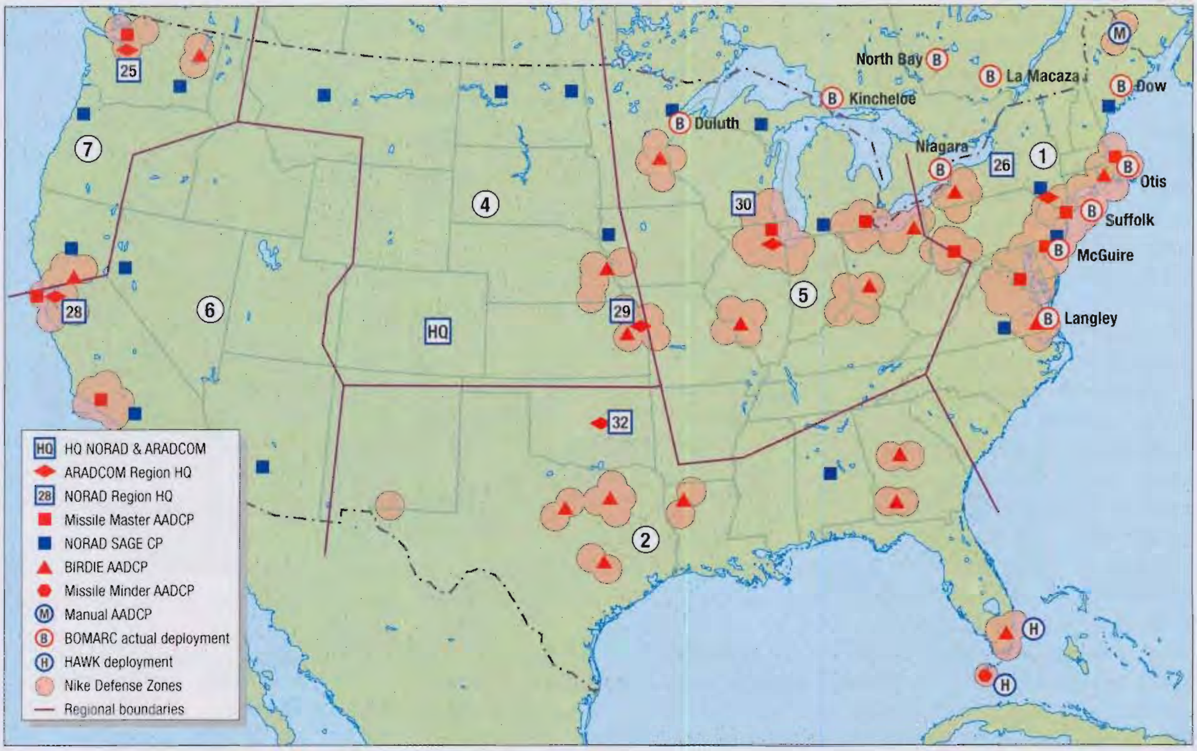


Engagement sequence for the Nike-Hercules missile defense system.

Development went forward rather rapidly, and the new Nike-Hercules was deployed into existing Ajax sites, starting with the conversion of the first Nike-Ajax site to Hercules on June 30, 1958 – Battery A, 485th Antiaircraft Artillery Missile Battalion (later redesignated Battery A, 2d Missile Battalion, 57th Artillery), at site C-03 Montrose/Belmont in the Chicago Defense Area. As the Hercules was more effective than Ajax, both in terms of range and destructive power, each defense area only required about half the number of sites. Conversion of the selected sites took place from 1958 to 1962; ARADCOM was authorized to establish 15 new Hercules-only defense areas in the Continental US. Additional Hercules battalions were deployed at new sites built around Anchorage, Alaska; Fairbanks, Alaska; on Oahu Island, Hawaii; and at Thule, Greenland. As the regular Army units were converted to Hercules, the Army National Guard took over remaining Ajax sites and continued to operate the Nike-Ajax through November 18, 1964, by which time it was also acquiring Nike-Hercules from regular units.

The Hercules received an upgraded version of the Ajax acquisition radar and an additional Target-Ranging Radar (TRR) along with the MTR and the TTR. In the early 1960s the Army upgraded the Basic Nike-Hercules system to the Improved Nike-Hercules. This program introduced new radars and electronics at several sites. The most effective (and costly) single addition was the High-Power Acquisition Radar (HIPAR), which was able to detect targets at the longer ranges attainable with Hercules. Several IFCs received Alternate Battery Acquisition Radars (ABAR): either the AN/FPS-69, AN/FPS-71, or AN/FPS-75. The original Hercules Acquisition Radar was retained and re-designated the Low-Power Acquisition Radar (LOPAR).

The new Nike-Hercules systems also brought changes in command and control of the firing batteries. With Nike-Ajax, operational combat control ultimately rested on the individual battery; for the longer range Hercules, a new system was devised to coordinate the efforts of multiple batteries. Development of an automated command and control system for Nike had commenced in the early 1950s; until 1957, all Army Air Defense Command Post (AADCP) operations were performed manually, utilizing plotting boards. The first integrated electronic air defense system developed to replace manual operations was the AN/FSG-1 Missile Master, designed by the Martin Company of Orlando, FL. The system featured its own radars, multiple computers, and electronic plotting devices that enabled the coordination of target acquisition, tracking, and battery firing. Missile Master was housed in a semi-hardened concrete blockhouse and could monitor 24 sites against 50 individual targets.



United States air defense system, 1963.

The first to go on line was at Fort Meade in 1957; the last of ten installations was at Fort MacArthur in the Los Angeles Defense Area on December 14, 1960. A less complicated (and less capable) system was the AN/GSG-5(V) BIRDIE, designed to handle 4 to 16 firing batteries. BIRDIE, which stood for Battery Integration and Radar Display Equipment, was designed specifically for the smaller defense areas; single battalion defenses that did not receive the Missile Master system received AN/GSG-5(V) installations during 1961–62. Finally a new Hughes AN/TSQ-51 Missile Mentor command and control system was deployed during the mid 1960s. Missile Mentor featured all solid-state construction and could control 24 firing batteries; it replaced seven Missile Master installations by the end of 1967.

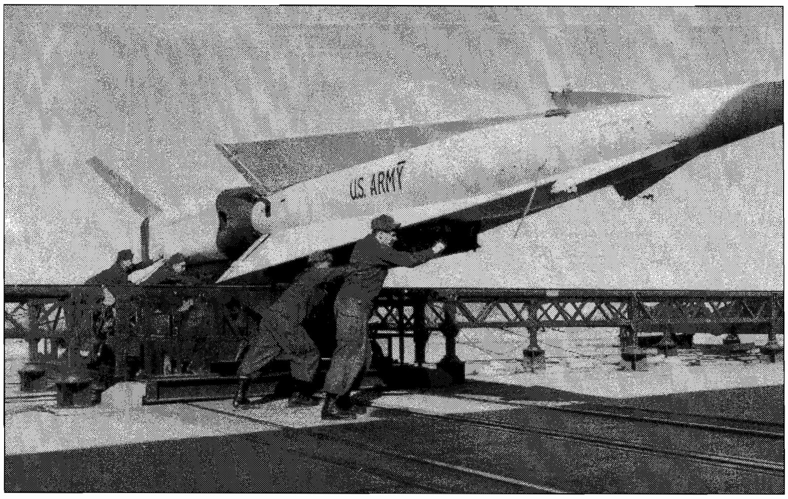
Many defense areas also had a Secondary Master Fire Unit (SMFU) and one or more Remote Radar Integration Stations (RRIS). The SMFU installation served as an alternate command post in the event the AADCP was destroyed or otherwise incapacitated; the RRISs were used to provide radar coverage to any part of the defense area that was not adequately covered by the AADCP radars.

These defense area systems operated under the overall tactical command of the Air Force's Semi-Automatic Ground Environment (SAGE) system, through the NORAD's sector directional centers (DCs) and regional combat centers (CCs). These centers received automatic detection and tracking data from a ground-based air search radar network, height-finding radars, gap-filler radars, and air and seaborne early warning assets. Information from these sources was received by telephone, radio, teletype and direct data links and programmed into a large mainframe computer. The analyzed data was then transmitted to Air Force missiles and interceptor aircraft by data link. Digital data transmissions were also passed on to the Army AADCPs for engagement by Nike missiles. Selected data was also transmitted automatically to adjacent DCs and regional CCs. The SAGE system was the centralized control network for all defensive assets. Through Missile Master, BIRDIE and Missile Mentor, each ARADCOM battery was effectively linked with the entire North American air

ARADCOM color patch.

Nike-Hercules surface-to-air missile defense battery c.1965

The launcher area (A), surrounded by high wire fences (1), is divided into two areas: the missile launch area, with the launch rails and racks (2), below which lie the underground storage magazines (3); and the missile assembly and service area (4), which contains the warhead building (4a), missile assembly building (4b), and the generator building (4c). The radar site (B) contains the High-Power Acquisition Radar (HIPAR) (5); the HIPAR building (6); power-generator building (7); Target-Tracking Radar (8); Target-Ranging Radar (9); Missile-Tracking Radar (10); antennae mast (11); and Low-Power Acquisition Radar (LOPAR) (12). The administration site (C) contains the mess hall (13), barracks (14), and administration buildings (15).



Nike-Hercules on launch rails being pushed onto the launch erector. (US Army Signal Corps)

defense system through NORAD's Combat Operations Center at Ent AFB, CO. Additional information was passed by telephone, teletype, and/or radio to civil defense agencies, Strategic Air Command, and other combat units.

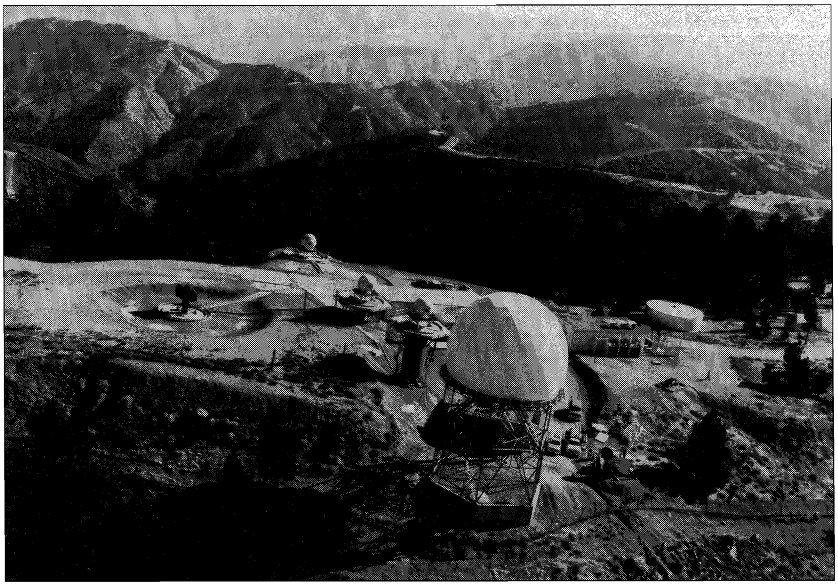
The peak year for ARADCOM came in 1963, when the command fielded 134 Nike-Hercules batteries, 77 Army National Guard Nike-Ajax batteries, and eight HAWK batteries in defense of the United States. The Nike-Hercules was designed for defense against high-altitude formations of bombers. As the perceived threat changed from bombers to ICBMs, the usefulness of the Nike-Hercules system diminished. Finally, the large manpower requirements of ARADCOM worked against it in the face of the expanding Vietnam War. A gradual decrease in Nike deployment began in 1967, with the first batteries inactivating in November 1968. By the end of 1969, several ARADCOM units had inactivated; in several defense areas, Army Guard units actually manned the majority of the surviving sites.

On November 8, 1973, ARADCOM was directed by the Army to inactivate all remaining firing batteries, with the exception of the Hercules and HAWK defenses in Florida and the single battalion in Alaska. The surviving batteries in the remaining eight defense areas – Seattle, San Francisco, Los Angeles, Pittsburgh, Washington-Baltimore-Norfolk, Chicago-Detroit, New York-

Nike-Hercules battery control site S-61 in the Seattle defense area, 1971. The administration area buildings are located to the lower right, the radars to middle left. (Courtesy Col. Milton B. Halsey, Jr.)

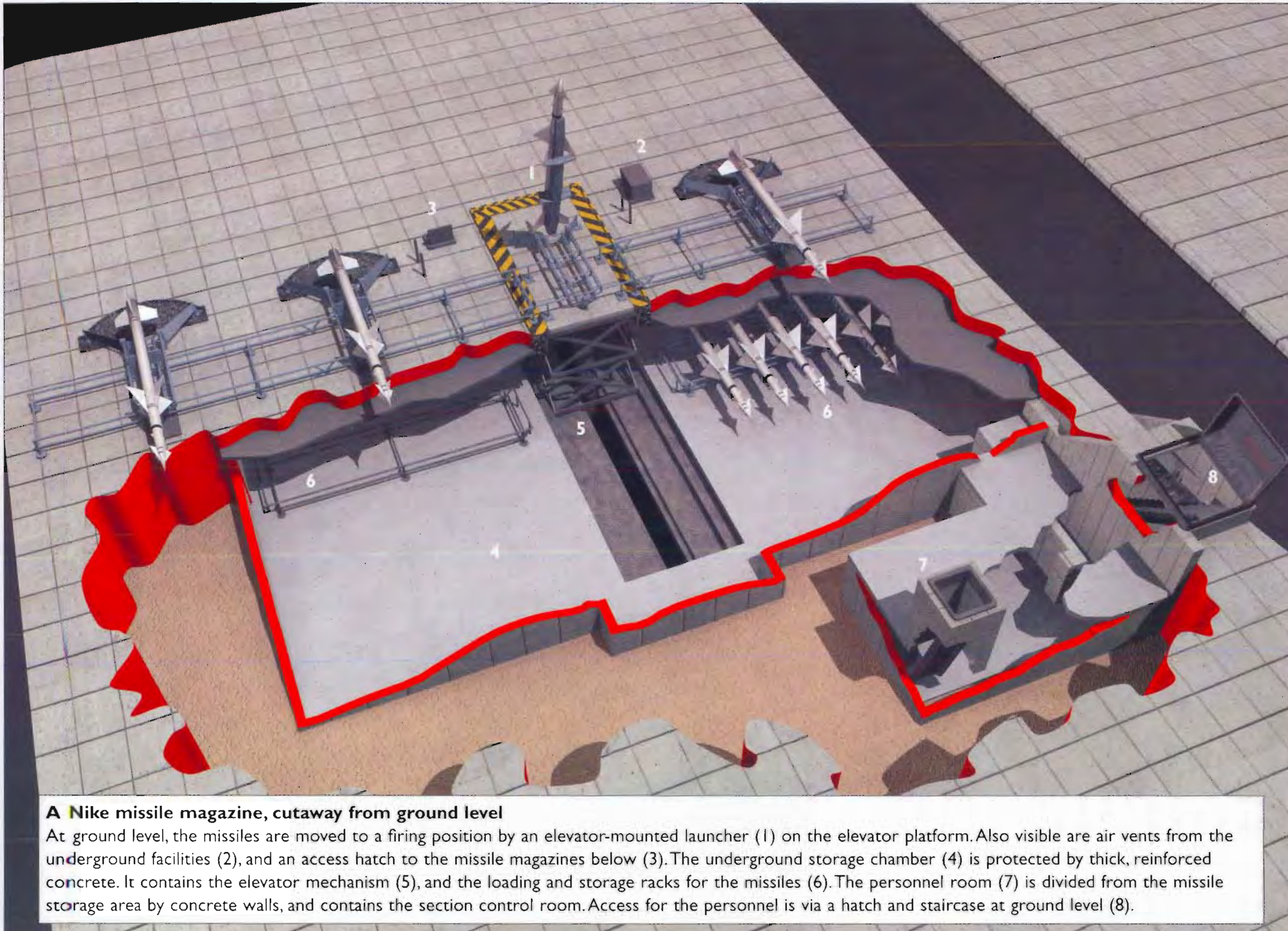
Philadelphia, and New England – were to be shut down by the end of May 1974. All units were to be inactivated by October 1, 1974, with ARADCOM itself deactivated soon after.

US Army Nike-Hercules units were also deployed overseas to Taiwan, Okinawa, South Korea, and West Germany. The Nike-Hercules system was also sold to various allied nations; their military units were trained in its use by US Army personnel. By 1979, the majority of the units had transferred their equipment to their host countries and inactivated.



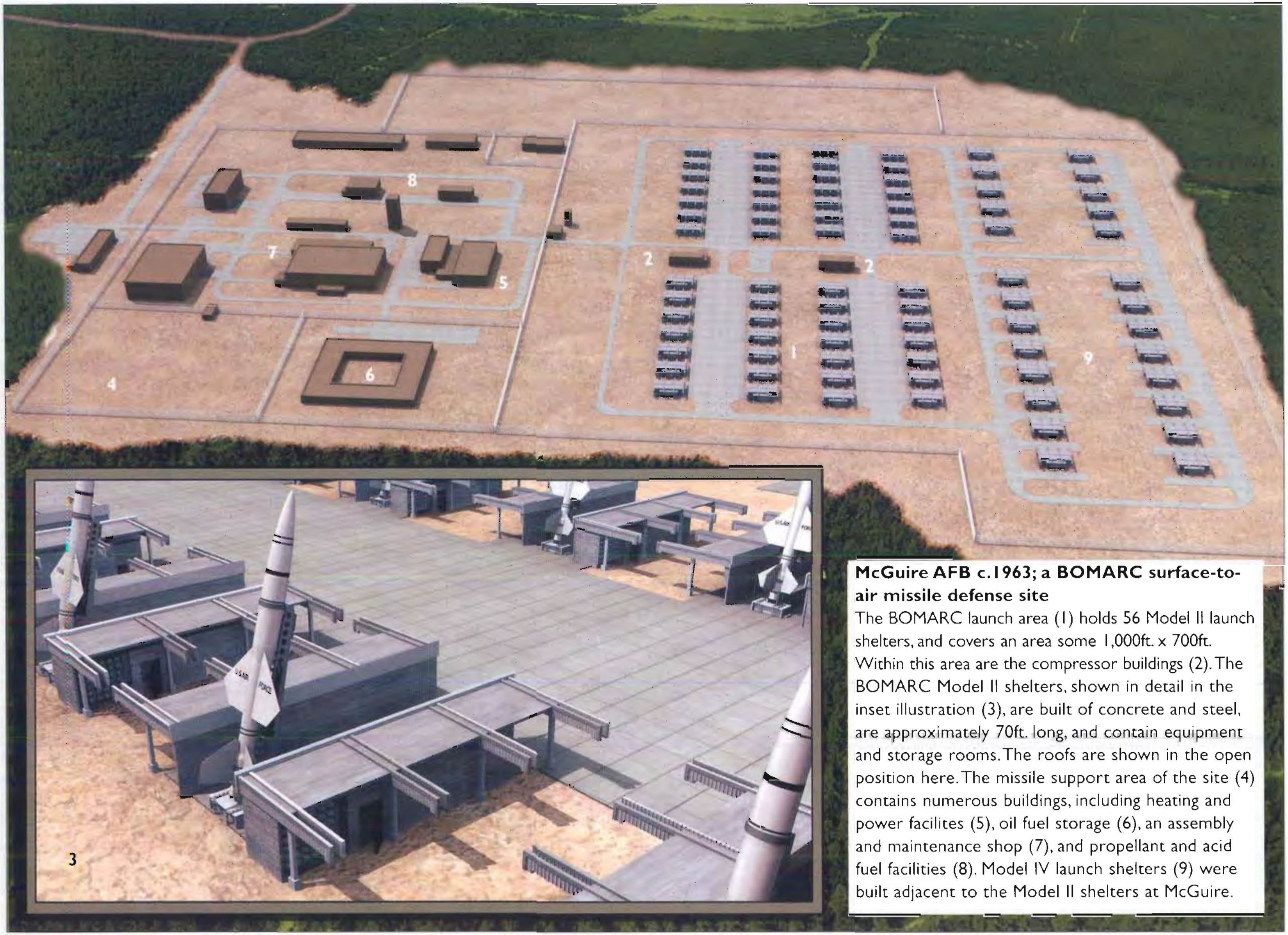
Nike-Hercules integrated fire control area at Nike site LA-04 at Mt. Gleason in the Los Angeles defense area. The radars in a row are (from the bottom) the High Power Acquisition Radar (HIPAR) atop the pedestal tower and protected by a radome, the Target-Ranging Radar (TRR), the Target-Tracking Radar (TTR), and the Missile-Tracking Radar (MTR). Standing alone at the left side of the photo is the Low-Power Acquisition Radar (LOPAR). (Courtesy Col. Milton B. Halsey, Jr.)

Nike-Hercules launched from White Sands Missile Range. (Office of History, US Army Aviation and Missile Command, Redstone Arsenal)



A Nike missile magazine, cutaway from ground level

At ground level, the missiles are moved to a firing position by an elevator-mounted launcher (1) on the elevator platform. Also visible are air vents from the underground facilities (2), and an access hatch to the missile magazines below (3). The underground storage chamber (4) is protected by thick, reinforced concrete. It contains the elevator mechanism (5), and the loading and storage racks for the missiles (6). The personnel room (7) is divided from the missile storage area by concrete walls, and contains the section control room. Access for the personnel is via a hatch and staircase at ground level (8).



McGuire AFB c.1963; a BOMARC surface-to-air missile defense site

The BOMARC launch area (1) holds 56 Model II launch shelters, and covers an area some 1,000ft. x 700ft. Within this area are the compressor buildings (2). The BOMARC Model II shelters, shown in detail in the inset illustration (3), are built of concrete and steel, are approximately 70ft. long, and contain equipment and storage rooms. The roofs are shown in the open position here. The missile support area of the site (4) contains numerous buildings, including heating and power facilites (5), oil fuel storage (6), an assembly and maintenance shop (7), and propellant and acid fuel facilities (8). Model IV launch shelters (9) were built adjacent to the Model II shelters at McGuire.

Air Force BOMARC (IM-99A/B, CIM-10A/B)

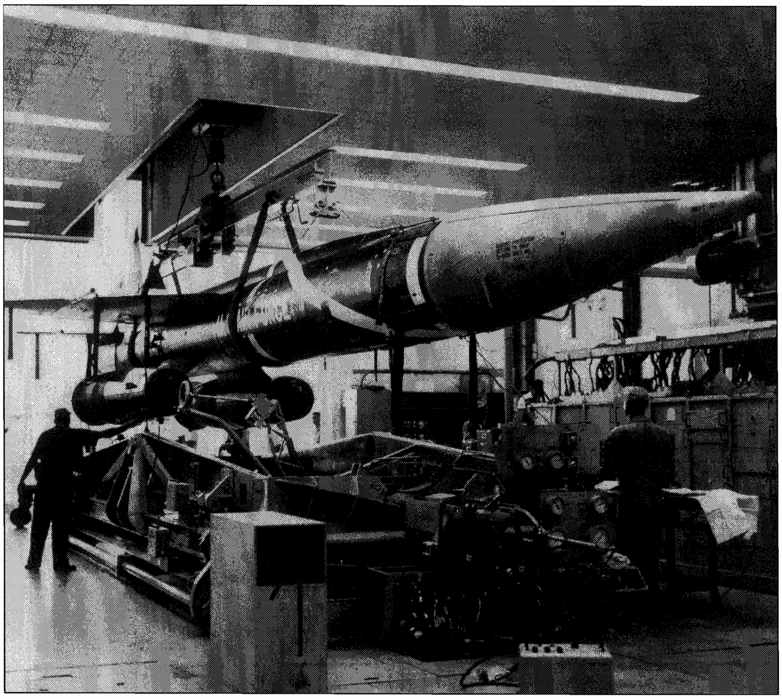
In January 1946, the Boeing Aircraft Company began a research program to design and construct a ground-to-air pilot-less aircraft (GAPA). The lessons learned from this research led to the proposal to the USAF to build a pilot-less interceptor missile. A contract to develop the IM-99 interceptor from the experimental XF-99 was established with Boeing in 1949. Two months later the Michigan Aeronautical Research Center was added as a participant in the research. The resulting missile was named BOMARC using the initials from these two organizations. A long and difficult testing period followed, during which the Air Force was competing with the Army over which system, BOMARC or Nike, would be used as the US air defense system. Even though BOMARC prototypes were still imperfect, the Air Force established a contract for its production with Boeing in November of 1957.

The resulting production missile was the IM-99A, which could contain either a conventional or a nuclear warhead. It was launched vertically and quickly rose to 60,000ft. using a liquid-fueled rocket engine. Once it achieved the cruise altitude it then flew like a plane using liquid-fueled ramjets with a range of 230 nautical miles. It was guided to its target area by the SAGE center system using information gathered by the ADC air search radar network. Once within 10 miles of the target, the internal homing radar took over and guided the missile to intercept.

In 1958, the Air Force established a testing and training facility for its BOMARC program at Hurlbert AFB in Florida and built the first dedicated BOMARC launch facility on nearby Santa Rosa Island. Work here and at other sites resulted in the development of the Model II launch facility for BOMARC, a reinforced-concrete garage-like structure in which the missile was stored horizontally. The launcher had a split roof, which was raised after the two-minute fueling process was completed, allowing the missile to be raised by an elevator arm to firing position. The mechanical and electrical components to operate this procedure were located in an adjacent room.

Initial plans in 1952 were for 52 air defense missile sites each basing 120 missiles. This was soon scaled back to 40 sites, then to 29 sites with 60 missiles each by 1959. As the result of the intense Congressional debate in 1959, it was decided to deploy both the Air Force BOMARC system and the Army Nike system in more scaled-back versions than proposed. The Air Force would get 18 BOMARC sites with 28 missiles each. However, in March of 1960, it was decided only to deploy BOMARC at eight US sites and two Canadian sites. The first BOMARC A site became operational at McGuire AFB, NJ, on September 19, 1959, followed by sites at Suffolk County, NY; Langley AFB, VA; Otis AFB, MA; and Dow AFB, ME by December 1960.

BOMARC A was plagued by the same problems of all liquid-fueled rockets – the corrosive fuel had to be mixed and stored in the missile itself, it had to be replaced frequently, and it was dangerously explosive. This was graphically



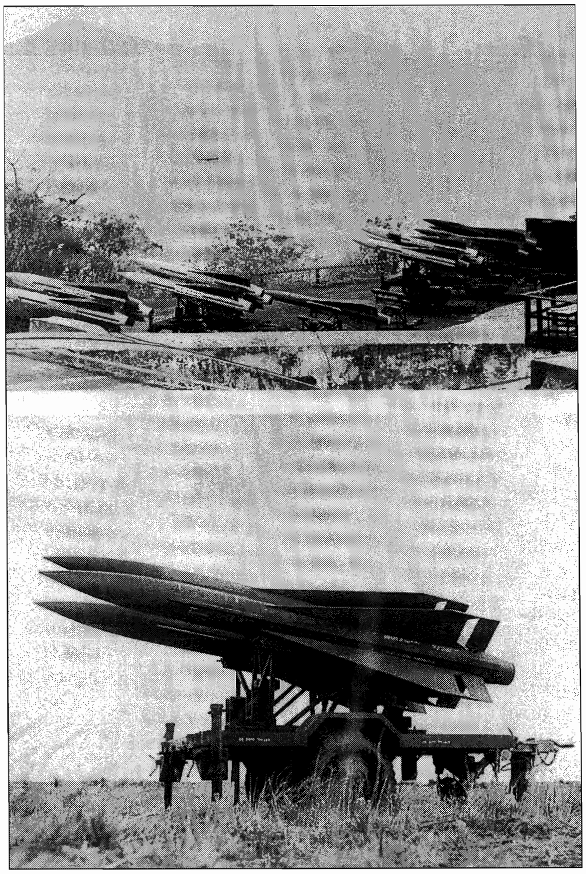
An Air Force BOMARC missile being removed from test equipment prior to being fired at Patrick AFB, FL in August 1958. (National Air and Space Museum, Smithsonian Institution) demonstrated on June 7, 1960, when a helium tank in a nuclear-armed BOMARC A exploded at McGuire AFB, NJ. The resulting fire melted the nuclear warhead, spilling radioactive plutonium. The fire was quickly controlled and the radioactively contaminated areas were encased under asphalt and concrete. Remediation has only just recently been completed.

The Air Force was developing solid fuels for their ICBM programs; these, and other improvements, were incorporated into the BOMARC system during 1959–60, resulting in the IM-99B. The solid-fueled BOMARC B had a longer range – 440 nautical miles – and could be launched in 30 seconds. A new streamlined launch facility, the Model IV with underground mechanical and electrical services, was deployed with the new missile.

In June 1961, the first BOMARC B site became operational at Kincheloe AFB, MI; followed by sites at Duluth, MN; Niagara Falls, NY (46 missiles); and the two Canadian sites at North Bay, Ontario and La Macaza, Quebec. BOMARC B missiles replaced the BOMARC A missiles at Langley AFB, McGuire AFB, and Otis AFB. The Suffolk County and Dow AFB sites were not upgraded to B. Once these deployments were completed in the fall of 1964, it was realized that BOMARC (as well as Nike-Hercules) could not be used effectively in an ABM role. The Air Force began to shut down some of the Niagara launchers; all operations had ended there by late 1969. In 1972, as the Army was closing its Nike-Hercules sites, the Air Force closed down its BOMARC sites, the final one being the McGuire AFB site in late 1972.

Other ground-based air defense missile systems

HAWK (MIM-23A/B): In 1954, the Army began research and development on a smaller, low-to-medium altitude missile system that would be deployed in a supporting role to Nike-Hercules. Designated the HAWK (Homing All-the-Way Killer), the system featured a 16ft.-long solid-fueled missile with a range of 22 miles at Mach 2.5. All radars and missile launchers were trailer-mounted for mobility. HAWK became operational in 1959, with the Army deploying 13 battalions, primarily as forward frontier area coverage. ARADCOM actually performed site surveys for its proposed HAWK units, but deployment under ARADCOM was limited to two battalions emplaced in Homestead-Miami and Key West, FL, in response to the Cuban Missile Crisis. These units passed to US Army Forces Command following ARADCOM's demise in 1974, and were inactivated in 1979. The MIM-23B Improved HAWK continues in service with several foreign nations.



A HAWK battery in the Panama Canal Zone (above), and HAWK missiles on a launcher (below). (Office of History, US Army Aviation and Missile Command, Redstone Arsenal)

Ground-Based TERRIER (RIM-2): During the mid 1950s, the Army participated in the development of the Navy's TERRIER shipboard air defense missile system, to the extent of ordering 25 for test purposes. In 1952, ARADCOM proposed the deployment of two battalions of ground-based TERRIERs as a defense for the Hanford Atomic Works. However, the commanding general of ARADCOM had had second thoughts about TERRIER and in April 1953 declared that the system would not be acquired by the Army.

Air Force TALOS (RIM-8): In 1955, the Air Force was assigned responsibility for the evaluation of the Navy's TALOS shipboard air defense missile system for possible use as a land-based SAM. The intent was to provide Strategic Air Command bomber bases and

Atomic Energy Commission installations with a capable point-defense system. The Air Force, concerned with the idea of relying on Nike-Ajax for the protection of its installations, decided to proceed with the ground-based variant of TALOS. In 1956, the service requested funding for site surveys and actually had the survey teams ready to go; instead, the Department of Defense ordered the program transferred to the Army. After a period of testing, the Army decided to proceed with its Nike-Hercules program, and the ground-based TALOS program came to an end. The missile served successfully with the Navy through 1979 on several guided missile cruisers.

US Army antiballistic missile systems: Nike-Zeus A/B (XLIM-49A) and Spartan (LIM-49A)/Sprint (Sentinel/Safeguard systems)

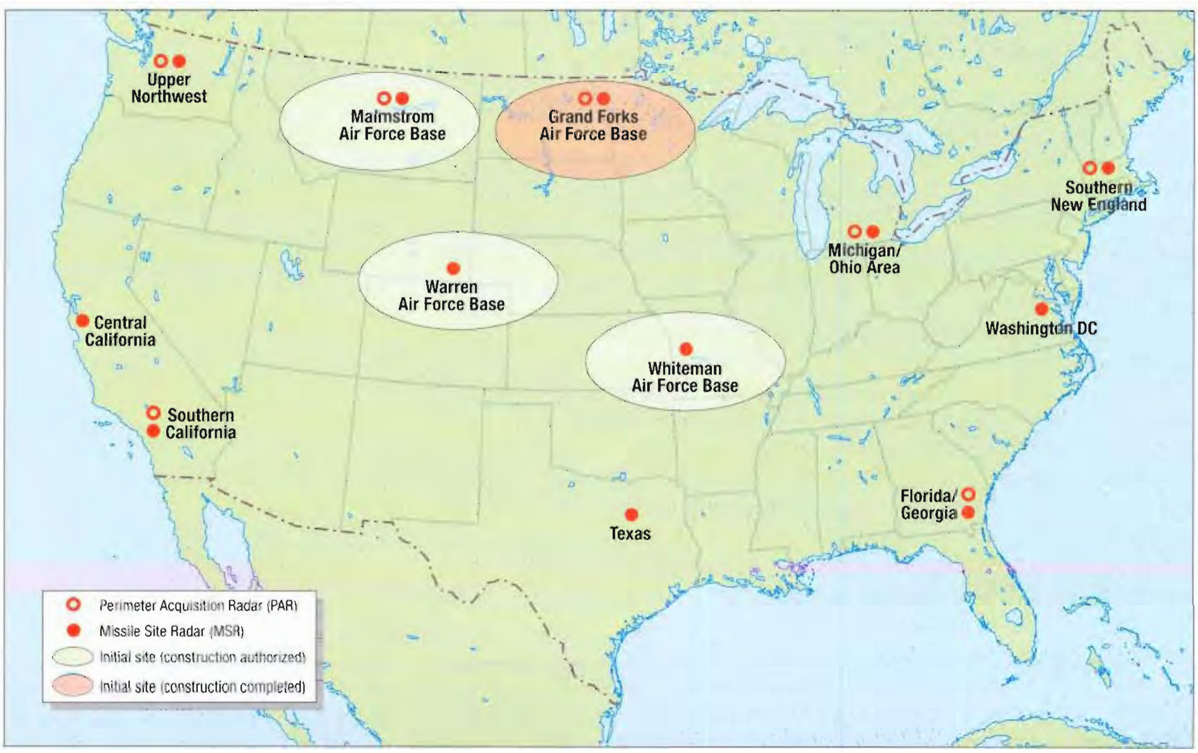
The genesis of the US ABM programs had its beginnings in 1945 as the War Department began to look for ways to defend against rocket attack like that of the German V-2 on Great Britain. A May 1946 report recommended a defense by "guided interceptor missiles dispatched in accordance with electronically computed data obtained from radar detection stations." As the Cold War participants turned to the development of ICBMs in the mid 1950s, the Defense Department began looking for measures to defend against such attacks.

The Air Force had been studying the problem since the end of the war with Project Wizard and other R&D programs. The Air Force argued that the Army's Nike systems were unfit to guard the nation against such a threat. The Army countered that they could improve on the already existing technology of the Nike program and modify it for use in an ABM role.

In February 1955, Bell Labs and the Douglas Aircraft Company contracted with the Army to study a follow on to the Nike-Hercules, nicknamed Nike II. The Army system was expected to counter the projected threats of the next decade – including postulated advanced air breather weapons and Soviet ICBMs.

In 1958 the Secretary of Defense assigned the Army the lead role in ABM development based on the progress they had made with Nike II. Bell and

Planned Safeguard deployment, 1969.



Western Electric were assigned responsibility for full-system development of the Nike II as a functional ABM system. The new system, named Nike-Zeus, was designed to go higher, faster, and carry a bigger nuclear warhead than its Nike-Hercules sibling.

The initial design, the DM-15 (Douglas Missile) Nike-Zeus A, was a scaled-up, two-stage version of the Hercules. The second design, DM-15S (Nike-Zeus B), was a three-stage rocket system released in the spring of 1960. Like Hercules, it featured solid-fueled boosters – a unique tandem design in this case – capable of generating 450,000 lb. of thrust, and a sustainer for a maximum range of over 250 miles at 200 miles of altitude. Nike-Zeus B carried a five-megaton W-50 warhead, powered by its own third-stage motor.

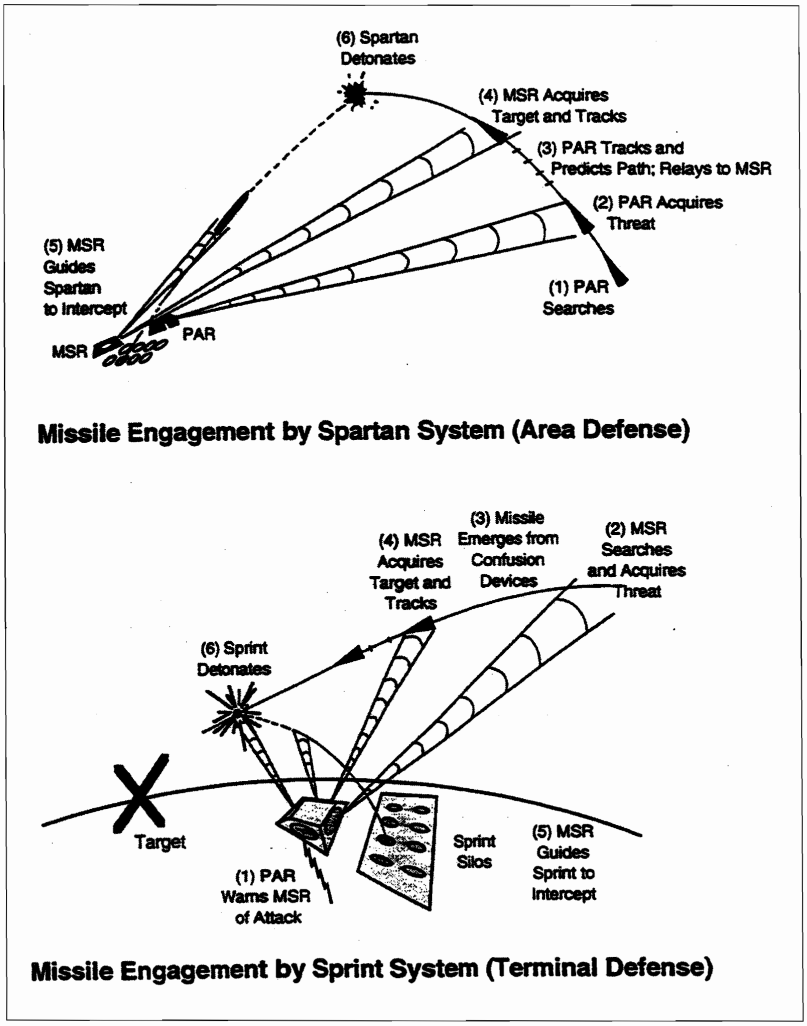
Guidance was by the command method using four radars: the Missile-Tracking (MTR) and Target-Tracking (TTR) radars, both of which were designed to be effective at suborbital ranges. Added to the electronics suite were the Zeus Acquisition Radar (ZAR), which could detect objects as they came over the horizon, and a Discrimination Radar (DR) for separating actual warheads from decoys and booster debris. The first successful launch of the XLIM-49 Nike-Zeus occurred at White Sands Missile Range in October 1959. On December 14, 1961, the Army fired a Nike-Zeus from its newly dedicated test facility on Kwajalein Atoll out in the Southwest Pacific.

However, the outgoing Eisenhower Administration made the decision not to deploy the missile for technological reasons. The ZAR had difficulty distinguishing multiple targets, partly due to its mechanical beam steering. On May 24, 1963 a Zeus test vehicle successfully intercepted an incoming Atlas RV. Further testing indicated the system would in fact work as advertised and had a demonstrated antisatellite (ASAT) capability.

Spartan missile on display in Langdon, ND, city park 2001. (Ron Plante)

Despite the string of successes, the Cabinet members of the new Kennedy Administration did not believe the Nike-Zeus system could defend against an attack by Soviet ICBMs. Secretary of Defense Robert S. McNamara thought the system could be overwhelmed and could not discriminate between real and decoy warheads. The system was maintained on Kwajalein through the end of the year for ASAT test purposes. Notably, following the cancellation of deployment, the ZAR successfully steered 10 Nike-Zeus intercepts out of 14 attempts during its final months. Rather than cancel the ABM program, McNamara directed the Army to field a more advanced ABM system. To replace Zeus, a new higher acceleration missile system was substituted. The new system was announced on January 30, 1964, under the temporary designation of "Nike X."

The new system was to be a layered system with the first layer being a reconfigured Zeus missile that would intercept incoming warheads at an



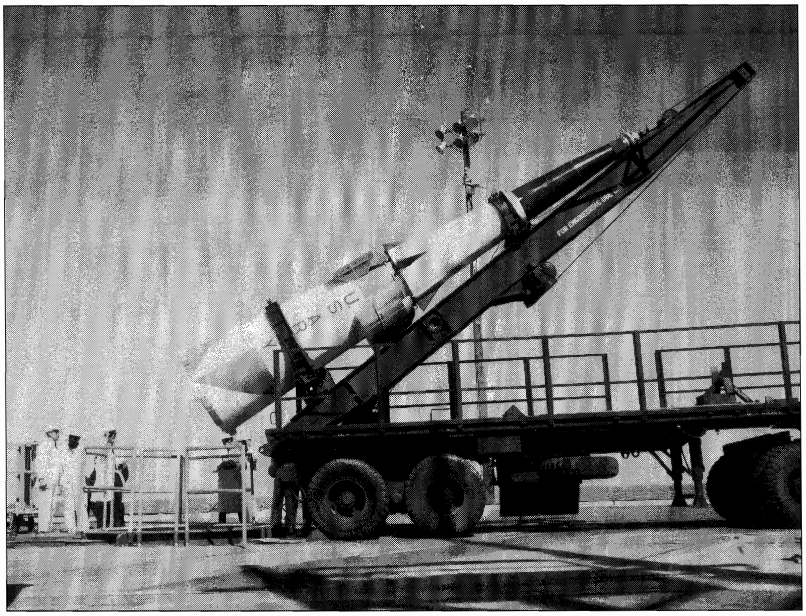
Safeguard antiballistic missile defense engagement.

altitude of 70 to 100 miles. The second layer would be a new short-range high-speed missile that would intercept the warheads missed at an altitude of 20 to 30 miles. The key difference over the old Zeus system was the use of phased-array radars pioneered under the Defense Department's Advanced Research Projects Agency (ARPA). The phased-array radars could track several targets and direct several missile intercepts simultaneously, unlike the single target and missile engagement of the previous Nike programs. The improved radars, computers, and missiles were designed to be a complete antibomber, antifighter and antimissile system. With the completion of full system design in October 1965, the Army presented a program that incorporated two nuclear-tipped missiles, the XLIM-49A Spartan and Sprint, the phased-array Perimeter Acquisition Radar (PAR), and the Multi-Function Array Radar (MAR).

The McDonnell Douglas Astronautics Spartan was the long-range interceptor missile, measuring just over 55ft. in length. The missile had three solid-fuel stages good for about 465 miles at over 300 miles in altitude. Once launched, Spartan would fly to the target at approximately Mach 9 and then detonate its five-megaton W-71 warhead via computer command like the earlier Nike systems. To handle "leakers" that got past Spartan, the system relied on the short – 27ft. – extremely high speed Sprint missile, which never gained a military designator. Developed by Martin Marietta/Orlando, Sprint was designed to accelerate to reportedly Mach 17 and hit targets at about 25 miles within a few seconds of launch. The warhead was a one-kiloton W-66.

As for the radars, both employed electronically steered beams, overcoming the major shortcoming of the predecessor Zeus Acquisition Radar. The PAR was designed for housing in a re-inforced concrete operations building approximately 130ft. tall. Once the PAR detected incoming warheads, at approximately 1,000 miles (or greater), it passed the data to the Raytheon Missile Site Radar (MSR, which had replaced the MAR) which then tracked the incoming targets while guiding in the Spartans and Sprints. As with the PAR, the majority of the supporting equipment for the MSR was underground. Tying everything together was the Data Processing System, or DPS, which handled all digital data processing, controlled the weapons systems, and powered the tactical displays at the Ballistic Missile Defense Center (BMDC) and Fire Coordination Center (FCC).

In 1968, the Johnson Administration announced plans to deploy the revamped Nike X system as the Sentinel ABM program. This was put on hold by the new Nixon Administration, then reconfigured as the Safeguard ABM program in 1969. Construction began at two ICBM sites: Malmstrom, MT and Grand Forks, ND. On March 14, 1969 Sentinel was renamed Safeguard and formally given the task of protecting America's land-based nuclear deterrent forces. Eroding political and public support resulted in a smaller than planned deployment pattern at 12 locations, with an initial deployment at two locations near the Minuteman II/III ICBM fields at Grand Forks AFB, ND; and Malmstrom AFB, MT. In 1970 funding was approved for the development of two more Safeguard sites to defend the ICBMs stationed near Whiteman AFB, MO; and Francis E. Warren AFB, WY. Construction started at both Grand Forks and Malmstrom, although, due to the design requirements for the Safeguard system, the actual ABM and radar sites were many miles removed from their respective air force bases. Initial site surveys commenced at the same time near Whiteman and Francis E. Warren AFBs.

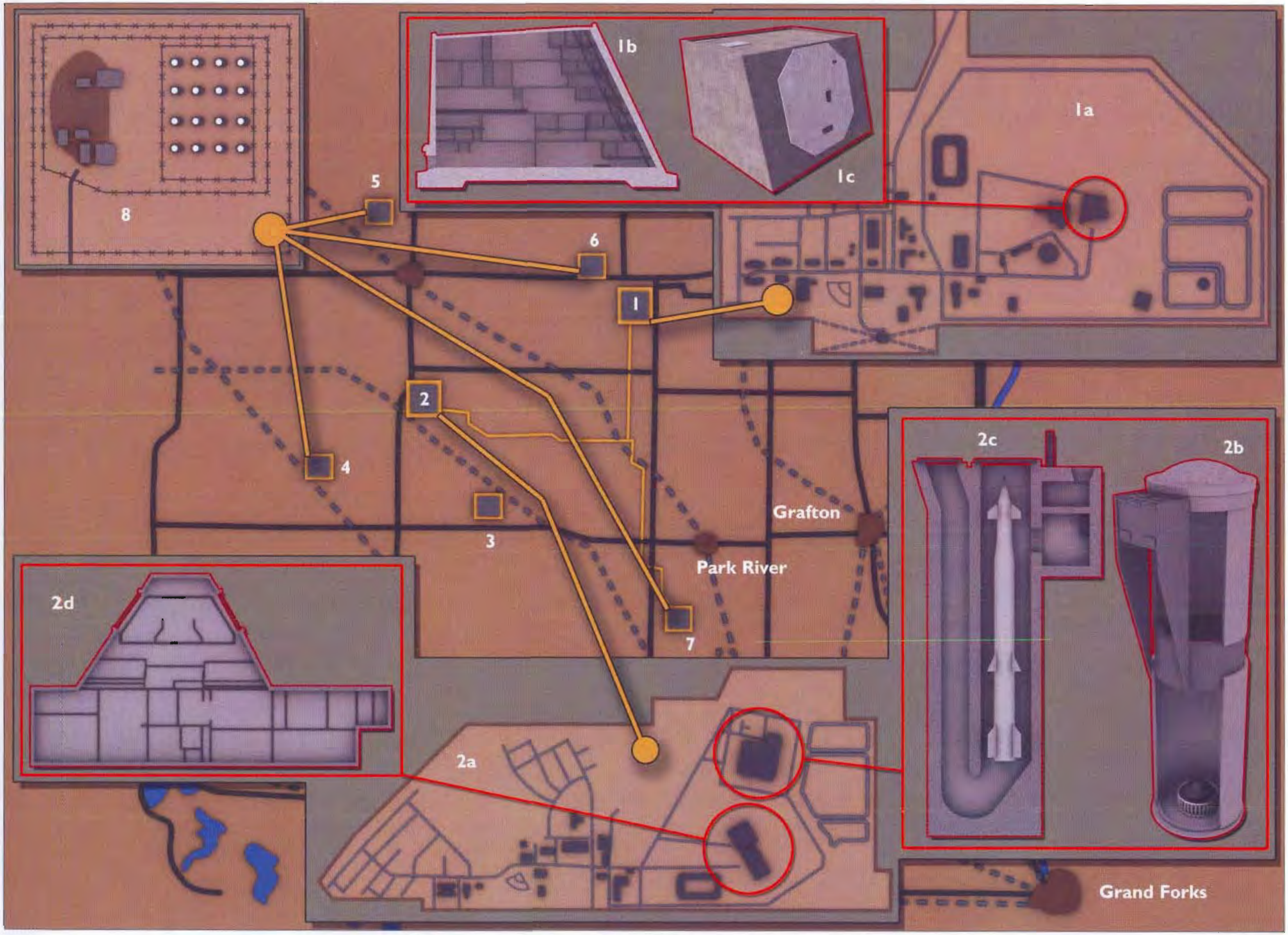


A Sprint missile being loaded into a launch cell. (National Air and Space Museum, Smithsonian Institution)

In 1972, the United States and the Soviet Union signed the Antiballistic Missile Treaty at the Moscow Summit meeting. The treaty permitted the United States and the Soviet Union to retain two ABM facilities – one near each nation's capital and one protecting an ICBM field. The nearly complete Grand Forks site near Langdon, ND was retained as the single US ABM defense location. The construction programs at Malmstrom AFB (which was then only 10 percent complete and hampered by labor problems), Whiteman AFB, and Francis E. Warren AFB were halted; the ABM site for Washington, DC was never started. In 1974 Congress decided to cancel the entire Safeguard program while allowing the work on the Grand Forks site to continue.

The Grand Forks ABM site was composed of six parcels of land. The 400-acre MSR site, located next to Nekoma, ND, consisted of: the missile site control building (MSRB) – the largest structure on the site, which housed the radar and the computer elements of the site and served as the command and control center; an underground power plant adjacent to the missile site control building; a missile launch field containing both Spartan and Sprint missiles; a missile handling building; and a warhead handling building. The major portion of the MSRB

Aerial view of the main missile launch site for the Grand Forks Safeguard site. The Sprint/Spartan launch cells are located in the foreground, the pyramidal Missile Site Radar Building (MSRB) is in the upper center of the photograph. (US Army Space and Strategic Defense Command History Office, Huntsville, AL)


1b
1c
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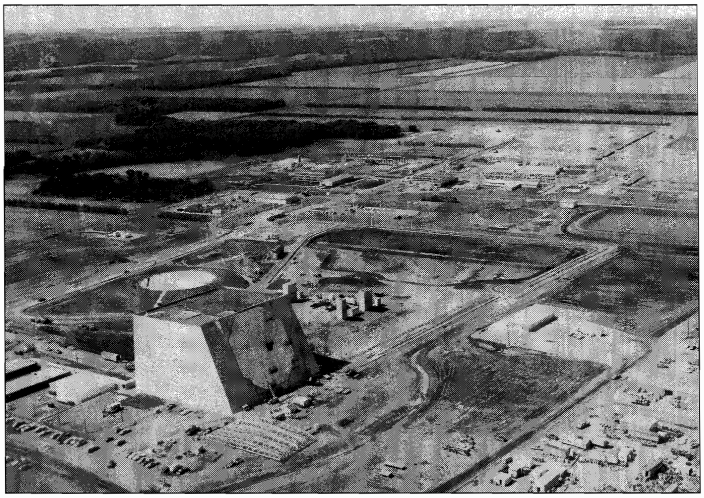
Grafton
Park River
2c
2b
2d
2a
Grand Forks

structure was underground, with only the radar faces and necessary electronic equipment above ground, resulting in an exposed concrete pyramid at a height of approximately 77ft. The MSR was to have four radar faces to facilitate 360° coverage, but only two faces were actually installed. The only visible portion of the underground power plant was a series of exhaust stacks and air intake structures, which served as the breathers for the power generation units. The units operated on diesel fuel or natural gas, or a combination of both. Within the missile field, both Spartan and Sprint were stored in underground cells from which they were to be launched.



Aerial view of the Perimeter Acquisition Radar (PAR) site near Grand Forks under construction in 1971. (US Army Space and Strategic Defense Command History Office, Huntsville, AL)

The 250-acre PAR site, near Concrete, ND, was located some distance from the MSR site and consisted of a PAR building (PARB) housing the radar, data processing, command, and control elements, with an underground power plant similar to the one at the MSR site. The radar was housed in a concrete building approximately 130ft. in height (10 stories) and 200ft. on each side with a thickness averaging 5–7in. of steel reinforced concrete. Beam steering was accomplished electronically and allowed large volumes of space to be searched in short periods of real time. This facilitated simultaneous tracking of multiple objects. In addition to locating and tracking incoming objects, it could predict the point of impact through its data processor. The PAR then relayed its data through a processor to the MSR.

The non-tactical support facilities included an administrative building, an industrial building, a community center, chapel, dispensary, and quarters. Family housing areas of 2-, 3-, and 4-bedroom duplexes were to be provided in sufficient numbers to accommodate married military personnel and essential civilians. Both the MSR and PAR sites had these facilities.

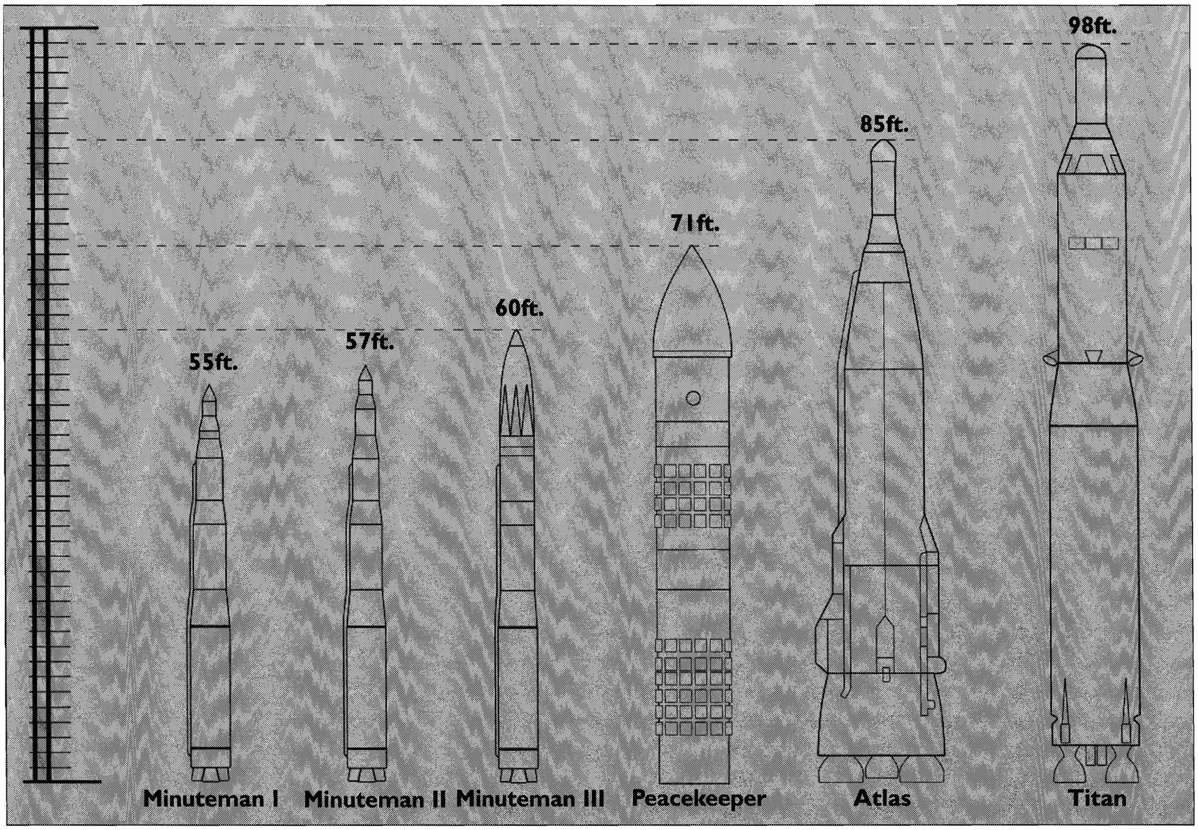
The four remote Sprint launch (RSL) sites contained 12–16 Sprint missiles installed in underground cells next to a remote launch operations building. The Grand Forks sites were located north of Langdon, northeast of Olga, northeast of Hampden, and west of Adams, each totaling about 50 acres. Support facilities were not built at these sites.

Construction was completed on August 21, 1972; the MSR facility was completed and formally turned over to the US Army Safeguard Systems Command (SAFSCOM) Site Activation Team, followed by the PAR facility on January 3, 1973. SAFSCOM acquired the fourth and final remote Sprint site on November 5, 1972. The complex was named the Stanley R. Mickelson

Stanley R. Mickleson Safeguard site, Grand Forks, North Dakota

The base map shows the layout of the Stanley R. Mickleson Safeguard site; key areas are highlighted in the insets.

- **1** The Perimeter Acquisition Radar (PAR) site, shown in further detail in the inset **1a–1c**. The site is spread over some 280 acres.
- **1b** A cross-section view of the 121ft.-high, 213ft.-wide PAR, a five-level, multi-roomed structure.
- **1c** A 3D view of the PAR structure.
- **2** The 470-acre Missile Site Radar (MSR) facility, shown in further detail in the insets **2a–2d.**
- **2b** A cutaway drawing of the launch and test equipment of the MSR.
- **2c** A Spartan missile launch station, with the exhaust duct to the left.
- **2d** A section view of the 123ft.-high Missile Site Control Building (MSCB) of the MSR, arranged on two underground and two above-ground floors. This houses radar and communications equipment.
- **3** Well Field.
- **4** Remote Site Launcher 1.
- **5** Remote Site Launcher 2.
- **6** Remote Site Launcher 3.
- **7** Remote Site Launcher 4.
- **8** A plan view of the Remote Site Launcher areas.



The sizes of ICBM missiles compared. (Chris Taylor)

Safeguard Complex (SRMSC) on June 21, 1974. General Mickelson had commanded ARADCOM during the late 1950s, and his command's early efforts towards ballistic missile defense had started during his tour. The entire complex was turned over to US Army Safeguard Command (SAFECOM), a separate organization from ARADCOM, on September 3, 1974. The Spartan and Sprint missiles were emplaced in their hardened vertical launch structures the following spring, leading to a declaration of Initial Operating Capability (IOC) for the complex. Finally, SAFECOM formally declared the Mickelson complex fully operational on October 1, 1975.

The Congressional decision to terminate the operation of the SRMSC complex came on October 2, 1975, the day after the site had become fully operational. The Missile Site Radar was permanently turned off in February, 1976, and the MSR complex was placed in a mothball status. All electronics and mission specific equipment were placed in secure storage, while the Spartan and Sprint warheads were sent to Sierra Army Depot in Northern California for storage. Later, the interior of the MSRB was salvaged for scrap. The Perimeter Acquisition Radar, later re-designated PARCS (Perimeter Acquisition Radar and Characterization System) was loaned to the Air Force in October 1977 for missile early-warning purposes. Designated Cavalier Air Station, the site remains in operation, the only surviving operational component of Safeguard.

Ground-based strategic (ICBM) missile systems 1950–93

Atlas (SM 65D/E/F)

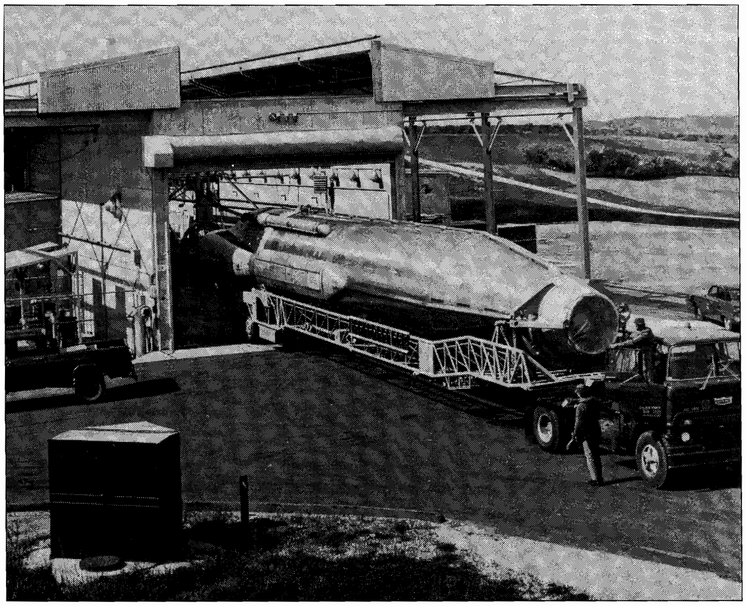
Atlas development can be traced back to 1945 when the Army Air Forces began working on a long-range "strategic" missile patterned after the German V-2 rocket. In April 1946 the Consolidated Vultee Aircraft Corporation (Convair) was awarded project MX-744, resulting in a prototype missile which featured a gimbaled nozzle, an internally pressurized frame, and separable nosecone. The project was officially cancelled in 1947 as the Air Force concentrated its efforts on the air breather missile program. Convair, however, continued its research efforts on its own, test firing some of the prototype rockets and developing new design concepts.

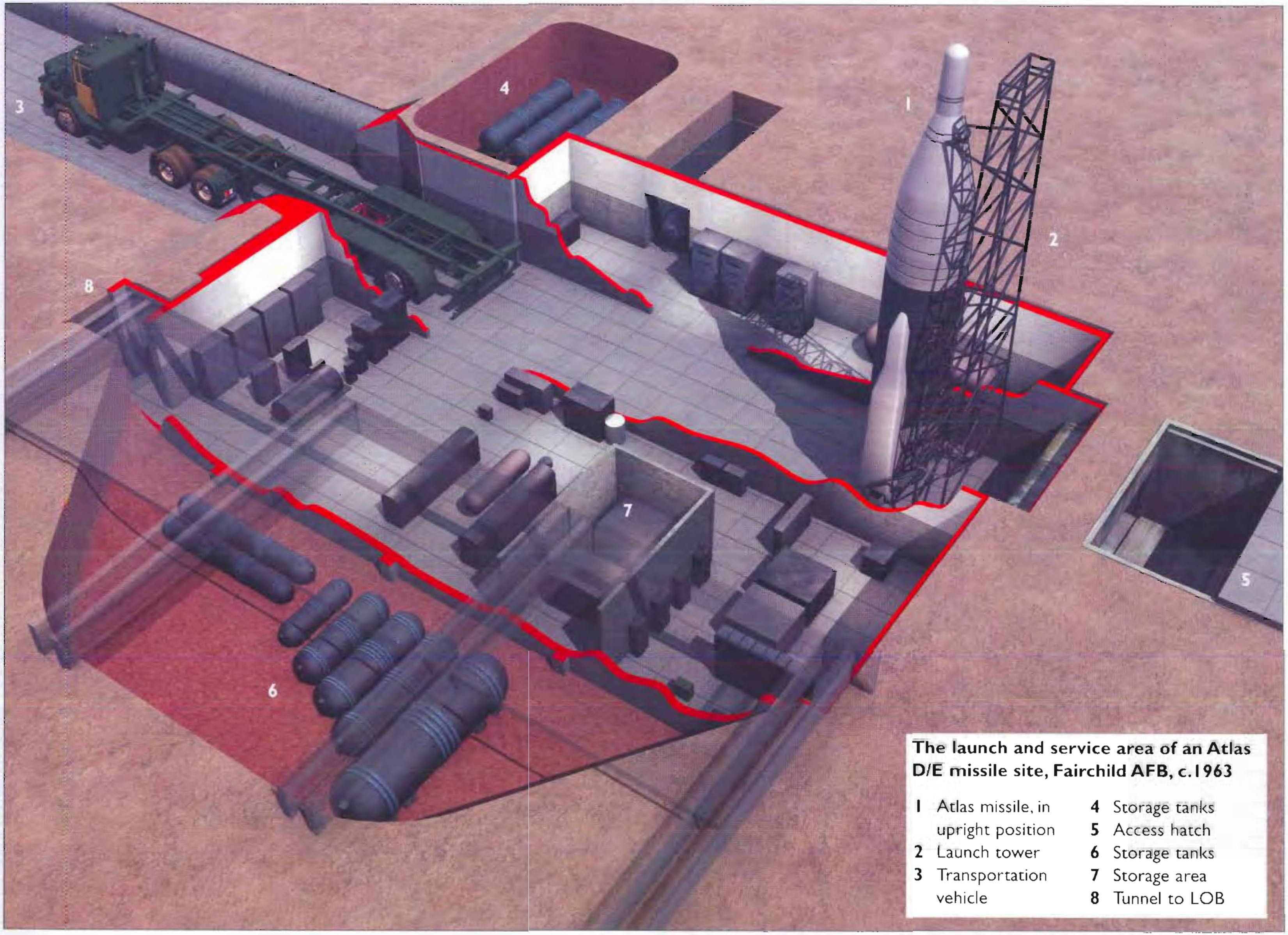
The Air Force renewed its support for the ballistic missile program in January 1951 with funding brought in by the beginning of the Korean War. Convair was directed to design a 6,000 mile-range missile capable of delivering an 8,000 lb. warhead to within 1,000ft. of its target. The resulting design was the 160ft.-tall, 12ft.-diameter "stage and a half" Atlas ballistic missile. Five rocket engines would produce up to 60,000 lb. of thrust. The newer nuclear weapons would be lighter than anticipated, so the range would be increased. The Air Force dithered on assigning priority to this program, and low funding slowed the work on the program until the 1954 Teapot Committee Report recommended putting the ballistic missile program into a high priority. After 1954 the Air Force placed the ballistic missile program into the highest priority and work moved at a quick pace on a revised liquid-fueled, three-rocket engine design that would develop 240,000 lb. of thrust and deliver a 1,500 lb. payload.

Flight testing for Atlas A began in June 1954, with six out of eight test flights blowing up on or near the launch pad, and two missiles having successful flights of 600 miles. The Atlas B series was a more sophisticated missile with a sustainer engine and separable nosecone. In November 1958 an Atlas B flew 6,000 miles. Atlas C was a semi-operational version successfully launched in December 1958. The first deployed version of Atlas was the mixed radio-inertially guided Atlas D; three were placed on operational alert at Vandenberg AFB in late 1959. Atlas E was the first all-inertially guided missile with an improved MA-3 propulsion system, first flown in February 1961. The final variant Atlas F had an improved fuel loading system that allowed faster fueling in the vertically stored rocket.

The Atlas featured a unique "stage and a half" booster system and had pressurized integral fuel tanks built of thin sheets of stainless steel. When

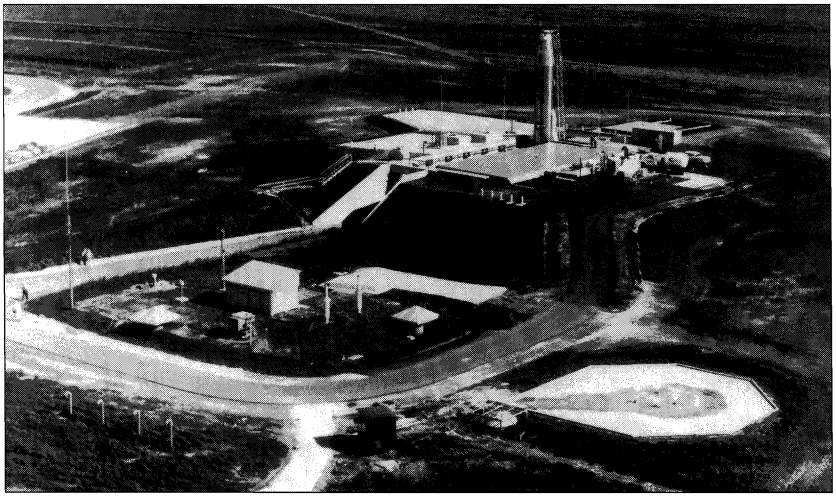
An Atlas D being removed from its above-ground launcher in October 1964. (National Archives Still Pictures Branch)





The launch and service area of an Atlas D/E missile site, Fairchild AFB, c.1963

1. Atlas missile, in upright position
2. Launch tower
3. Transportation vehicle
4. Storage tanks
5. Access hatch
6. Storage tanks
7. Storage area
8. Tunnel to LOB



An Atlas E is ready to launch above its underground launch facility. The location of the underground launch operations building is in the foreground marked by two square metal ventilators. (National Archives Still Pictures Branch)

empty the tanks were filled with nitrogen gas to maintain a positive internal force. Filling the tanks with the liquid fuels was a time consuming and potentially dangerous task. During the launch sequence the two boosters and the sustainer engine were ignited at launch with the two small vernier engines igniting 2.5 seconds later. The missile was accelerated in a gentle arc towards the target. Once in flight the booster burned for 140 seconds. After receiving a staging signal from the ground station, the booster engine and turbo pumps were jettisoned. The sustainer burned for another 130 seconds. Final course and velocity corrections were made by the vernier engines. At the apogee of its elliptical flight path the missile reached an altitude of 763 miles at a speed of approximately 16,000 miles per hour; the flight time for a range of 6,800 miles was 43 minutes. During the powered flight the D model received course corrections from a ground-based computer, the E and F models had an all inertial guidance system that was capable of performing mid-flight corrections independently.

The hallmark of Atlas deployment was a sense of urgency; escalating tensions with the Soviet Union had the military scrambling to deploy the new missiles as rapidly as possible. The number of 10-missile squadrons grew from a planned 4 in 1957 to 9 and later 13 squadrons. Placement of the sites was influenced by the range of the missiles, and the fact that they needed to be inland away from the range of Soviet submarine-based IRBMs; they also needed to be in close proximity to Air Force base support facilities, and – as a cost cutting measure – located on existing government property wherever possible.

The Air Force initially deployed Atlas D on open launch pads at Vandenberg AFB. The first full squadrons were deployed beginning in 1960. The individual launch sites consisted of a launch and service building, a power generating plant, communication facilities, a launch operations building, and a guidance operations building. The unfueled missiles were stored horizontally in a 103ft. by 133ft. launch and service building built of re-inforced concrete that was not designed to withstand a bomb explosion. The missile bay had a retractable roof that was pulled back, and the missile was raised to a vertical position to be fueled and fired. The launch operations building was a two-story concrete blockhouse with entrance tunnels, blast-proof doors, and escape tunnels. The guidance operations buildings were one story with full basement. The first Atlas D squadron at Francis E. Warren AFB had six launchers grouped together with two launch operations buildings clustered around a central guidance facility. The two later Atlas D sites (at Francis E. Warren and Offutt AFBs) had three launchers combined with one guidance facility. Three of these complexes constituted a squadron. The launch complexes were spread 20–30 miles apart.

The major enhancement of Atlas E was the new all-inertial system that eliminated the need for ground control facilities. The launchers could be more dispersed, usually about 20 miles apart. The three Atlas E squadrons at Fairchild AFB, Forbes AFB, and Francis E. Warren AFB had nine independent launch sites each. The Atlas E launch and support facility and launch control facility were housed in a "semi-hardened" structure that was partially buried, with the missile stored horizontally. To launch, the heavy roof over the bay was retracted, the missile then raised to a vertical position, fueled, and launched. The launch operations building, with the crew quarters, launch control facilities, and power plant, was 150ft. away and connected by an underground passageway.

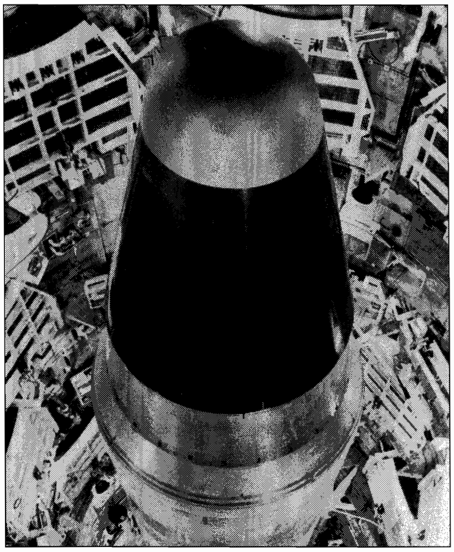
Atlas F was deployed in a "hardened" site, an underground 174ft- deep, 52ft.-diameter, heavily reinforced concrete silo in which the unfueled missile was stored vertically, supported by a steel framework "crib." The launch control center buried adjacent to the launch facility was also built of reinforced concrete, connected by a cylindrical access tunnel to the launch silo. To be launched in this configuration, the missile was fueled, the silo doors opened, the missile lifted by an elevator to the top of the silo and then fired. More costly (and difficult) to build, they offered more protection. The Air Force deployed six squadrons of 12 launch sites each, located about 20–30 miles apart.

The troublesome liquid fuels made the system expensive to man and maintain as well as dangerous. Once the solid-fuel Minuteman missile became operational in 1963, the Atlas system was phased out. By October 1964 the Atlas Ds were gone, followed by the Atlas E/Fs in April 1965. About 350 Atlas missiles of all versions were built with a peak deployment of 129. The Atlas was used as a launch vehicle for some of the Mercury program launches. Descendants of the Atlas program are still in use today as space payload launchers.

Titan (SM-68A and SM-68B/LGM-25C)

As the Atlas program swung into high gear in 1954, the Air Force decided to develop another ballistic missile program as an alternative or back up should the Atlas program fail to deliver. The Ramo-Woolridge Corp was directed to begin the development of this second system eventually involving Lockheed and Martin. A new missile design was developed with an alternate engine design in a two-stage configuration and a rigid fuselage. In April 1955 the Air Force was authorized to proceed with the development of a second ballistic missile system and the Martin Corporation was awarded the contract in October. The program proceeded rapidly and Martin delivered the first Titan I in June 1958. The Army Corps of Engineers began work on the first Titan launch facility at Lowry AFB in April 1958.

A Titan II in its silo. The grates on the wall were folded up to provide access to the missile from the encircling passageways. (National Archives Still Pictures Branch)

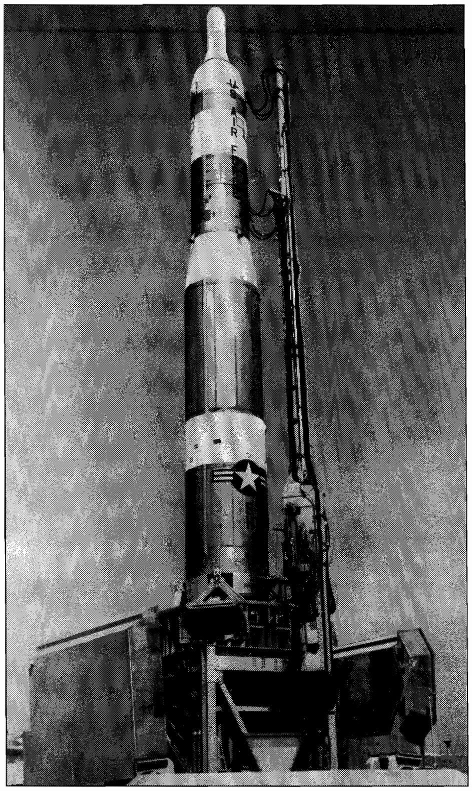


Even as the first Titan Is began to roll off the assembly line, the Air Force was searching for ways to replace liquid oxygen as an oxidizer in the rocket fuels. In 1959, researchers found that with minor modifications the Titan could use a non-cryogenic propellant that could be stored in the missile. This skipped the pre-launch fueling step and allowed for the missile to be launched from within the silo. It simplified maintenance and reduced the risk of accidents. In November 1959, the DOD authorized the development of the modified Titan II to Martin, which developed it in tandem with the Titan I program. Test flights began in December 1961, deployment began soon after, and by December 1963 six Titan II missile squadrons were on operational alert.

Titan was the United States' first true multistage ICBM. Titan I used liquid oxygen as an oxidizer, which was stored in specially refrigerated tanks and pumped aboard the missile prior to launch. Once the 15-minute fueling process was complete, the missile was elevated out of its silo to the surface and fired. The first-stage engine burned for 134 seconds and pushed the rocket up 35 miles. As it expired the first stage dropped away from the missile and the second-stage engine fired, burning for 156 seconds and boosting the missile to an altitude of 150 miles at a velocity of 22,554ft. per second. Once the second stage was complete two small vernier engines fired for an additional 50 seconds making final course corrections to the trajectory. The re-entry vehicle reached its apogee at 541 miles, and the time for a 5,500 mile flight was 33 minutes. Titan II's non-cryogenic oxidizer eliminated the fueling step before launch and allowed for an in-silo launch. The new all-inertial guidance system eliminated dependence on ground-based radars and allowed the missiles to be based in widely dispersed individual silos.

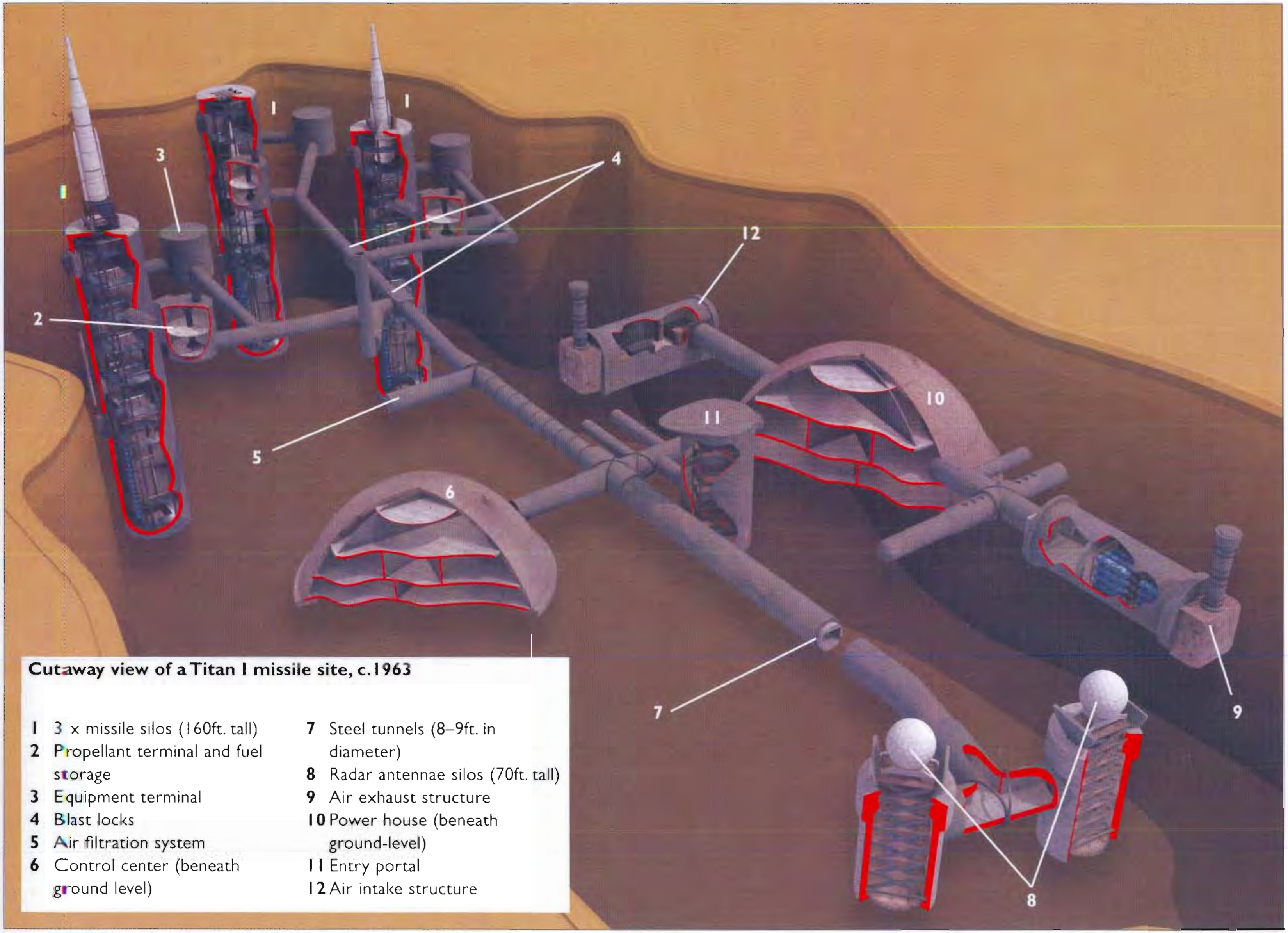
In October 1957 Congress authorized the Air Force to deploy four Titan I squadrons. Later that was increased to six Titan I and six Titan II squadrons. With a range of 6,300 miles, the Titan Is were based in Colorado, Idaho, and Washington State. The 9,000-mile range Titan IIs were based further south in Arizona, Kansas, and Arkansas.

The Titan I missiles were housed in "super-hardened" silos buried deep underground and designed to withstand blast pressure of 100 psi. The launch facilities at Lowry AFB, CO, were begun in 1959. Each squadron consisted of nine missiles divided into clusters of three because they had to remain close to their ground-based guidance facilities. The mammoth underground complexes had their own power and water supplies; all parts were linked by underground passageways. At one end of the complex were the missile silos, each 160ft. deep and 44ft. in diameter, and built of reinforced concrete from 2 to 3ft. thick. Within the silo was a steel frame that housed both the missile and its elevator, and it was capped with 125-ton doors. Adjacent to each silo were the propellant storage tanks and equipment rooms, buried under 17–24ft. of earth. Connected to the silo complexes were the control room and powerhouse. Both were domed structures 10–17ft. below the surface. Between the two was the cylindrical entry portal 72ft. deep and 38ft. in diameter. At the other end of the complex were the two radar antennae that were part of the missile's ground-based guidance system. The antennae were housed in two silos, each 67ft. deep and 38ft. in diameter. The crews raised the antennae above ground as the missiles were being readied for firing. The antennae were approximately 1,300ft. from the furthest silo. More than 2,500ft. of steel-lined tunnels, buried 40ft. down, connected all the structures within the complex.



Raised from its underground silo, a Titan I stands ready for inspection at the Operational System Test Facility at Vandenberg AFB. (National Archives Still Pictures Branch)

Titan II silos were markedly different from the Titan I launch complexes. Each of the nine missiles in the squadron was housed in its own silo located at least seven miles from its nearest neighbor. All the launch facilities were underground. The silo was built of heavily reinforced concrete 147ft. deep and 55ft. in diameter, wider than the Titan I silos. Each silo was fitted with a flame deflector at the base and two exhaust ducts that ran along the side of the silo to the surface. Inside the silo were nine levels of equipment rooms and missile access spaces. The silo was covered with a 740-ton concrete and steel door that could be opened in 20 seconds. The silo was connected to the missile launch control center by a 250ft. access tunnel, which had a heavily reinforced three-room "blast lock." Entrance to the facility was through a 35ft. access tunnel from the surface; each side of the blast lock had a 6,000 lb. steel blast door to protect the crews from a surface nuclear blast or a missile exploding in the silo. The launch control center was a dome-shaped three-level reinforced concrete structure with suspended floors to minimize blast shock. It housed the launch control and communications equipment, and mess and sleeping quarters for the four-person crew.

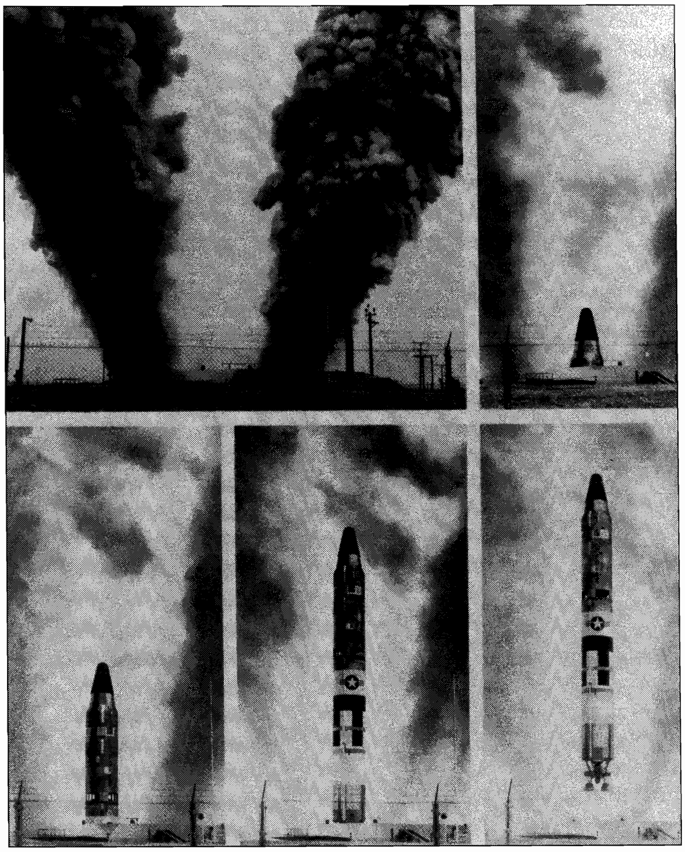


Cutaway view of a Titan I missile site, c.1963

1 3 x missile silos (160ft. tall)
2 Propellant terminal and fuel storage
3 Equipment terminal
4 Blast locks
5 Air filtration system
6 Control center (beneath ground level)
7 Steel tunnels (8–9ft. in diameter)
8 Radar antennae silos (70ft. tall)
9 Air exhaust structure
10 Power house (beneath ground-level)
11 Entry portal
12 Air intake structure

Once the Minuteman and Titan II systems became operational, the obsolete Titan I and the remaining Atlas missiles were phased out as quickly as possible. Between January and April 1965 all 54 deployed Titan Is were retired from service. Total production of Titan I was about 160 missiles, of which more than 60 were used for training. Titan II was by far the most reliable liquid-fueled and the most powerful nuclear-armed missile ever deployed by the United States. The US deployed 54 of these between 1964 and its retirement during the period 1984-87. It remained in service because the huge warheads represented 30 percent of the Air Force's overall ICBM megatonage. In total about 135 Titan IIs were built. Ultimately, the aging missiles became a maintenance liability; several accidents and mishaps brought the Air Force to decide to retire the Titan II missile force in 1984.

The Titan II was a very reliable missile. It was used in the Gemini space program by NASA. The next generation Titan III was used as the main Air Force space launcher, but the retirement of Titan II from the ICBM force has also allowed the Air Force to use refurbished Titan IIs as space launch vehicles.

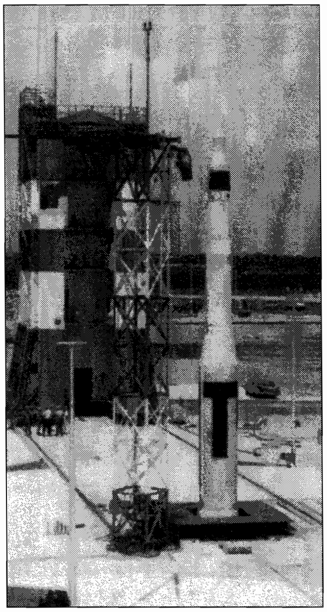


A dramatic series of pictures showing a Titan II launching out of its silo. (USAF Museum, Research Division)

Minuteman (SM80/LGM-30)

The research arm of the Air Force was interested in developing solid-fueled ballistic missiles as early as 1954, but early designs did not produce the power required to boost the heavy payloads involved and were difficult to control. The Air Force continued research efforts in this area because of the problems inherent in the liquid-fuel systems. By the spring of 1957, a solid-fueled missile design was on the board. The Air Force Ballistic Missile Division designed the revolutionary Minuteman ICBM. In contrast to the expensive and delicate liquid-fueled Atlas and Titan I systems, the designers proposed building a smaller three-stage solid-fueled missile system that would be inexpensive to build and maintain, and would be housed in unmanned widely dispersed silos linked electronically to a series of centrally located launch control facilities. The Air Force brass was initially cool to the idea, but when it was proposed that the Navy Polaris missiles be used as an ICBM, the Air Force quickly got on the solid-fuel bandwagon and pushed ahead with the development of the Minuteman in 1958.

The system was rapidly brought to the test stage and in September 1959 a first-stage booster was successfully launched from an underground silo. In February 1961 a complete three-stage missile was launched in a flawless performance from the test center at Cape Canaveral. Based on this test, the Air Force formally accelerated the Minuteman program in March 1961 giving it the same priority as the Atlas and Titan programs. Simultaneously with the missile development program the USACE began building standardized launch facilities at Malmstrom AFB, MT. On October 22, 1962 SAC placed its first flight of 10 Minuteman missiles on operational alert. The deployment of the Minuteman force was accomplished with amazing speed. The launch facilities were much smaller and easier to build than the Atlas or Titan launch facilities. Using prefabricated components and standardized construction techniques, the



A Minuteman I on a launch pad at Cape Canaveral. (National Archives)

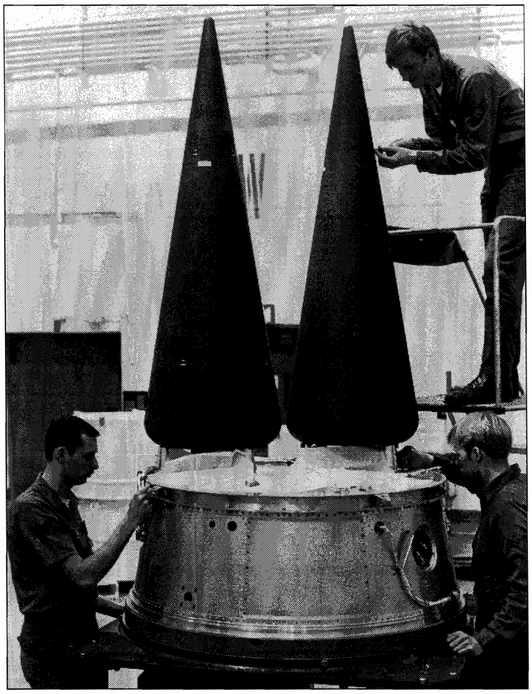
CEBMCO had built 1,000 Minuteman silos by 1966. As the silos were completed, the sites were quickly armed and turned over to SAC crews. By July 1962, 150 Minutemen were operational, 450 by March 1964, 800 by June 1965.

Even as the Minuteman I program accelerated, the Air Force began developing the next generation. The new Minuteman II was a significant improvement over its predecessor with a new second-stage motor, and better thrust vector control increased the missile's range from 6,300 miles to 7,000 miles. The new motors allowed Minuteman to carry a larger 1.2-megaton nuclear warhead. It had an improved guidance system and could store a larger number of preprogrammed targets in its internal memory. Moreover, the Minuteman II also carried penetration aids to camouflage the re-entry vehicle. The contract was awarded in March 1962, and the first test flight occurred in September 1964. The first missile squadrons were operational by May 1966, and by May 1967 the Air Force had 200 Minuteman IIs. The Air Force began to replace some of its Minuteman Is with Minuteman IIs and by May 1969 it had 500 operational Minuteman IIs along with 500 Minuteman Is.

The development of the last in the series began in December 1964. The new Minuteman III had an improved third-stage motor, which increased its range to over 8,000 miles and significantly increased its payload capacity. The Minuteman III was the first American missile to be fitted with MIRVs; each of the three warheads could be programmed to hit a different target. A liquid-fueled post-boost propulsion system allowed the missile to be maneuvered before re-entry, and an improved guidance system with even greater memory capacity improved the system's accuracy. Minuteman III warheads were accurate to within 800ft.

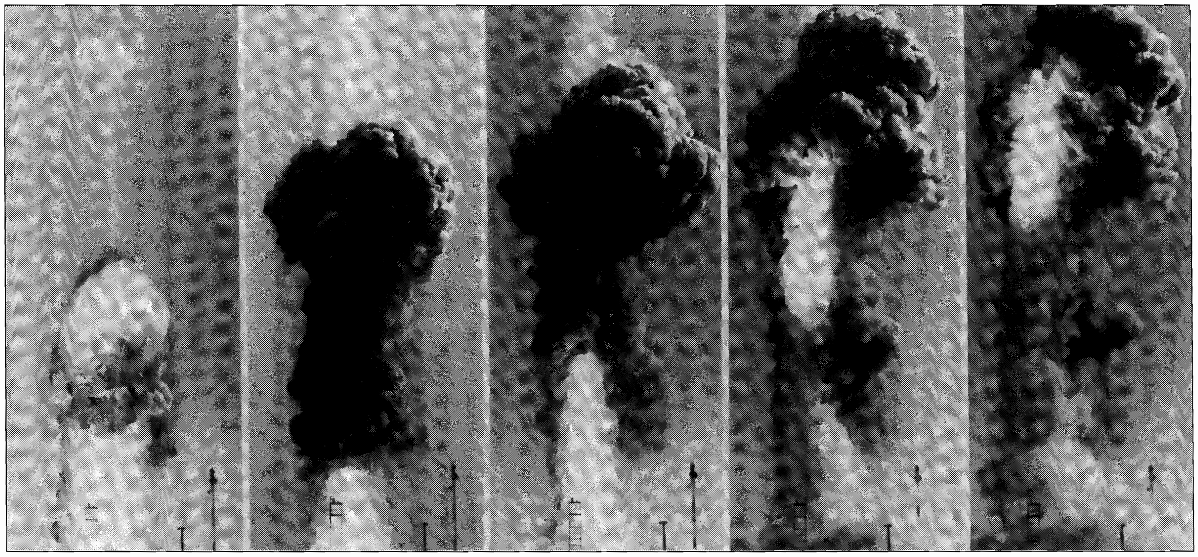
By 1968 successful test fights were underway. In January 1971 the first squadron of Minuteman IIIs became operational at Minot AFB, ND. The Air Force continued to modernize its ICBM force throughout the early 1970s and by July 1975 there were 450 Minuteman IIIs and 550 Minuteman IIs operational. Beginning in 1966 the Air Force instituted a comprehensive long-term maintenance program, which upgraded the Minuteman force throughout the 1990s.

Servicemen at Malmstrom AFB, MT inspect MIRV warheads mounted on a Minuteman III entry bus. Two of the three warheads are shown mounted in this photo. (National Archives Still Pictures Branch)



The Minuteman missile was designed to be stored in its silo in a launch-ready condition. Upon receiving the launch order, the two-man crew in the launch control center would perform a number of checks to confirm the orders and insert their keys into opposite ends of the control room, and simultaneously turn the keys to initiate the automatic launch sequence, resulting in the missile firing 60 seconds later (the system had a number of built in higher-level redundancies all of which had to be activated for a missile launch to occur, this was the final step). Unlike the slow-starting liquid-fueled ICBMs, the Minuteman streaked out of the silo. The first-stage motor separated after 60 seconds, the second-stage after 117 seconds and the third after 181 seconds, by which time the missile had reached an altitude of 118 miles and was traveling at a velocity of 23,000ft. per second. At its apogee the missile was 710 miles above the earth's surface. Minuteman II and III were capable of deploying a number of diversionary measures as it reentered the atmosphere heading towards its target. Minuteman III had a post-boost propulsion system that allowed for additional maneuvering after the diversionary aids were deployed.

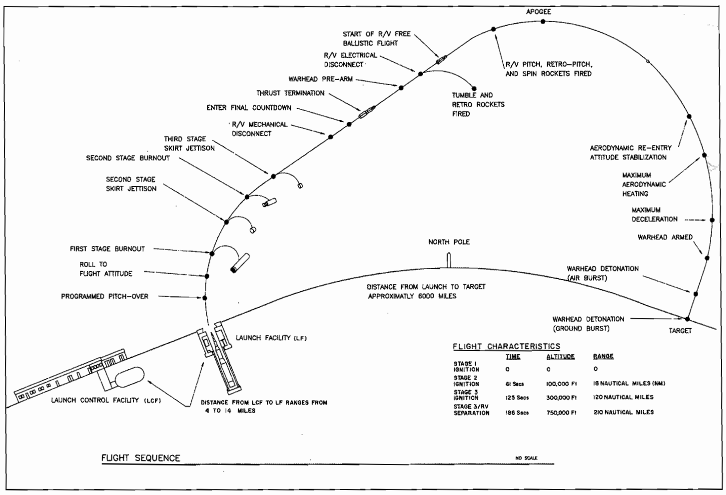
The Air Force deployed the 4,300-mile-range Minuteman IAs in Montana and South Dakota. Longer-ranged Minuteman II and III systems were deployed as far south as Missouri. SAC deployed its Minuteman force into 6 wings,



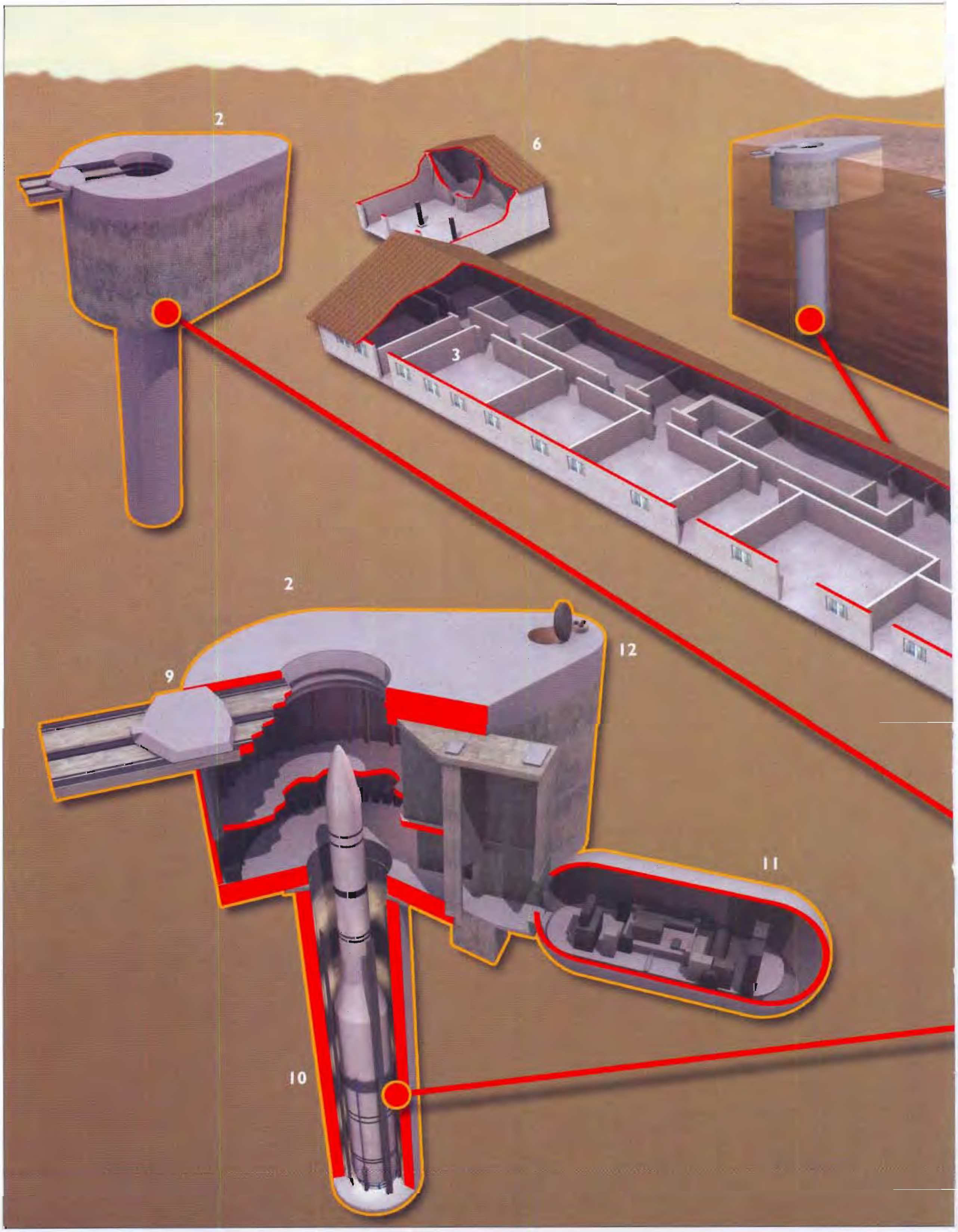
each composed of three or four 50-missile squadrons. Each squadron was divided into five flights of 10 missiles each. A flight was assigned to a launch complex composed of an above ground launch center facility (LCF), an underground launch control Center (LCC), and ten unmanned launch facilities (LFs). The LCF/LCCs were 3 miles from the nearest launch facility and the 10 launchers were similarly dispersed. The 44th Strategic Missile Wing at Ellsworth AFB, SD, had 150 missile launch facilities sprawled over 15,000 square miles. Minuteman's LFC was located on a six-acre fenced property centered around the above-ground launch control facility support building. The building provided living quarters, a security checkpoint, a vehicle garage, and the environmental support equipment. Forty feet beneath the support building was the LCC, with its outer layer built of reinforced concrete lined with steel plate. Entry was gained by climbing down a ladder to a vestibule which was dominated by an 8-ton steel blast door that could only be opened from the inside, leading into the 28ft.-long 12ft.-wide cylindrical LCC. The LCC housed the two-man "Missileer" crew and the equipment to monitor and launch the 10 missiles of the squadron. The six wings had slight variations in the LCF/LCC facilities.

Preceded by a distinctive plume of smoke, a Minuteman I streaks skyward from Cape Canaveral during a test launch in 1961. (National Archives Still Pictures Branch)

The launch facility had three elements: the launch tube, a cylindrical two-level equipment room encircling the top of the launch tube, and an adjacent support building. The launch tube was a prefabricated cylinder of quarter-inch steel 12ft. in diameter and 62ft. long. The lower 52ft. of the cylinder was surrounded by 14in. of reinforced concrete. The missile rested in the tube suspended by a pulley system affixed to shock absorbers on the silo floor. The concrete and steel reinforced equipment room surrounded the upper third of the launch cylinder and housed the electrical generators, surge arresters, electronic equipment, and gas generators; the latter were needed to open the silo's 80-ton reinforced concrete door, and to power and support the missile system guidance equipment and communications equipment. The adjacent support building was



Flight profile of a Minuteman II.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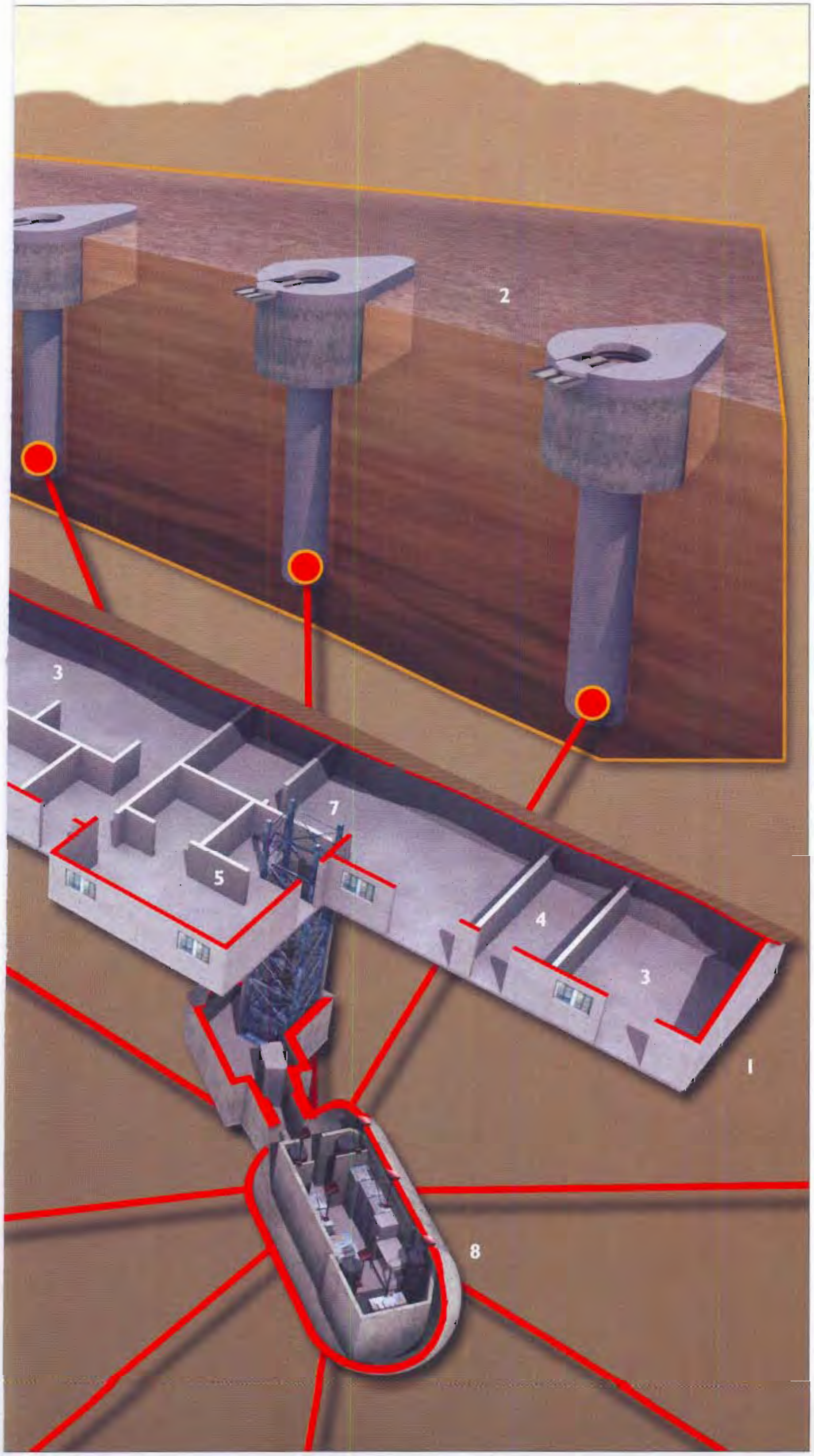


Minuteman II missile system, c.1970
The Minuteman II system comprised 95 manned Launch Control Facilities (LCF, **1**) and some 950 unmanned Launch Facilities (LF, **2**) located anything from 3.5 to 17.5 miles from the LCFs. The LCF and LFs shown are from Ellsworth AFB Launch Control Facility in South Dakota. The above-ground buildings include bedrooms, excercise and day rooms (**3**), generator facilities (**4**), and a Security Control Center (**5**). There is also a vehicle storage room to the rear of the main buildings (**6**). Access to an elevator (**7**), which descends to the Launch Control Center (LCC, **8**), is provided through the Security Control Center. Within the concrete shell of the LCC, a separate missile command capsule is suspended from the walls, to protect it from the shock of a nuclear explosion. The command capsule has its own air and water supply, plus an escape hatch. The LFs (**2**) are a little under 85ft. from top to bottom of the structure, with an aperture some 12ft. wide at the top, which can be sealed with a launcher closure (**9**). Each LF structure comprises a launch tube (**10**) and a launcher equipment room (**11**) containing operational and maintenance machinery. A personnel access hatch (**12**) is located on top of the LF.

11ft. underground and it housed the heating and cooling equipment for the launch facility as well as auxiliary power generators.

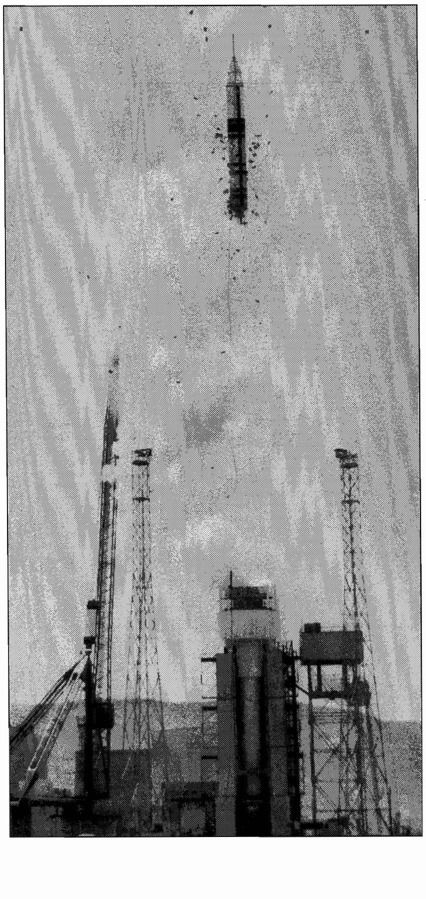
Minuteman production ended in 1978 after more than 2,400 missiles were produced. Many missiles were refurbished by the Air Force by repairing various defects and upgrading some of the missiles' systems. Under the START protocols, the United States has been slowly dismantling its Minuteman force. In 1991 President George Bush ordered all 450 Minuteman IIs immediately taken off operational alert and the silos deactivated. The Air Force imploded the last of the Minuteman II silos in December 1997. The Minuteman IIIs are to remain operational until 2020, though fitted with a single warhead.

Peacekeeper (LGM-118)

The Peacekeeper (originally known as the MX missile) was intended to be the replacement for Minuteman, but it suffered from a long development time and lagging political support as the Cold War slowed down. As early as 1966 the Air Force made plans to develop an advanced ICBM to be deployed in a mobile-based system, but the program was not approved. Research on the new program did not resume until November 1971, and in April 1972 the Air Force announced the new MX ICBM program. Plans were made for all sorts of basing schemes, including air launch from modified transport aircraft. The Air Force intended to employ the MX as a mobile system, but to avoid delays, it decided to design a large solid-fuel missile that could be launched from existing Minuteman launch facilities.

In 1977 the basic design was finalized. The four-stage missile was designed to be "cold-launched" – ejected from the silo by pressurized gas before igniting its first-stage motor. This reduced the damage to the silo, allowing for a quicker rearming effort by fewer men. Congress decided against the idea of using the Minuteman silos and postponed development, allowing the Air Force to develop an acceptable mobile base system. By May 1978 the Air Force gained approval to deploy the mobile protective shelters (MPS) plan in which 200 MX missiles would be shuttled between 4,600 soft shelters; the others would be filled with dummy missiles. The alternate Racetrack plan to base the missiles on huge underground track networks was dropped. Development on the missiles proceeded quickly, but the MPS plan was cancelled in 1980 due to high estimated costs. The missile itself was ready by 1982, but came close to cancellation due to the lack of a basing plan. In 1983 the renamed Peacekeeper system was to be based in reconfigured Minuteman silos (as originally planned) and a small mobile ICBM program was to be developed. This became the Midgetman program, which was eventually cancelled as well. In June 1983 the first full Peacekeeper launch occurred. The first Peacekeepers were operational by December 1986, 50 were in ex-Minuteman silos by December 1988.

Peacekeeper missile launch at Vandenberg AFB, 1980s. The "debris" flying from the missile are the pads that kept the missile in place in the silo, allowing it to be ejected by a pressurized gas ejection before the rocket ignited. (Photo courtesy Michael Binder)



The Peacekeeper has a MIRV payload of 10 Mk.21 re-entry vehicles each carrying a 300-kiloton thermonuclear warhead. The missile is guided by an Inertial Reference Sphere navigation system and is the most accurate ICBM produced by the United States. In 1986 the Peacekeeper Rail Garrison plan was approved for 50 additional Peacekeeper missiles based on 25 special trains with two missile cars, two locomotives, and additional cars for launch control, security, and fuel. The whole plan was cancelled in 1991 after the end of the Cold War.

With the signing of START II in January 1993, the Peacekeeper became a dead program. START II mandates the removal of all MIRV ICBMs and Peacekeeper will be phased out by the end of 2004, leaving Minuteman as the only operational US land-based ICBM. Only about 100 Peacekeeper missiles were produced.

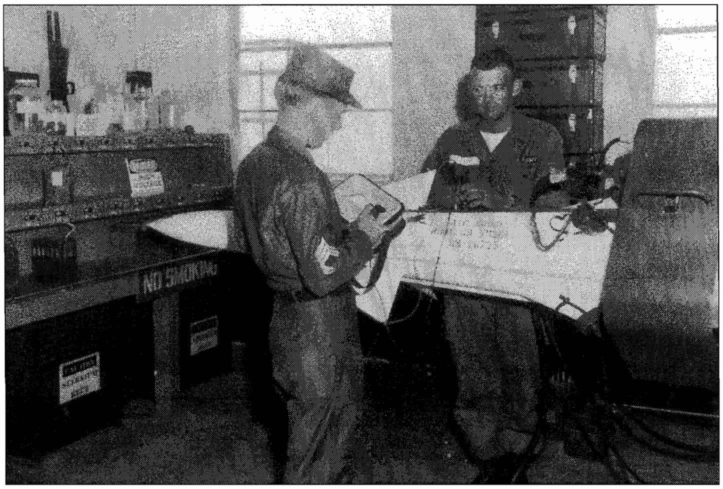
Missile system organization and life at the missile sites

By the mid 1950s the organizational and tactical administration of the United States air defenses had been sorted out. The Army was responsible for the deployment and manning of its ground-based Nike systems under its Air Defense Command (ARADCOM), subject to tactical control under the Air Force Air Defense Commands. The Air Force got a partial deployment of its longer-ranged BOMARC ground-based air defense system as well. The Army won the turf war to deploy the ABM systems. The ground-based strategic missile systems became the sole province of the Air Force.

With the establishment of NORAD in 1957, the construction and deployment of the radar warning systems, and the establishment of the integrated SAGE communication systems in the late 1950s, the tactical command for response to an attack on the United States was firmly invested in the US Air Force. SAGE integrated the ARADCOM missile Army Air Defense Command Posts (AADCP) into the overall response to an attack. Once an incoming force of airplanes was detected by any of the numerous radar systems, NORAD would seek to confirm the identity of the force. Once confirmed as hostile, NORAD, through the SAGE system, would notify its TAC interceptors, its BOMARC missile squadrons and, if needed, SAC bombers and missiles. The Army's ARADCOM Nike-Hercules air defense batteries, with their limited range of under 100 miles, were the last line of defense around American manufacturing cities and SAC bases. If invading bombers made it through the interceptors and were not turned back in response to United States retaliatory attacks, the AACDP was notified of its targets and through the Missile Master/Mentor control systems, individual Nike-Hercules batteries would be targeted and fired to bring down as many bombers as possible.

Army air-defense artillery

ARADCOM was organized into a number of regions, which varied over the years with headquarters at the NORAD command center at Ent AFB in Colorado. Over 30 defense areas were established between 1954 and 1964 with each having from two to over 20 battery sites depending on the size of the area being defended. In general each large area had an Army artillery brigade assigned to it. Each brigade had two or more artillery groups, each of which had two or more artillery battalions. The brigade/group commands operated the AACDP posts. Each battalion usually had four batteries, which were the tactical units that manned and operated the individual Nike missile sites. After a 1958 reorganization the artillery battalions were assigned to numbered artillery regiments that existed as administrative organizations only.



In the Missile Assembly Building, crewmen check batteries on a Nike-Ajax before final assembly at Oat Mountain, Los Angeles defense area June 26, 1959. (US Army Signal Corps)

Casing of the colors of MDARNG 1st Battalion-70th Artillery on September 14 ,1974 at Indiantown Gap Military Reservation, PA. As ARADCOM wound down its activities many Air Defense Artillery units were inactivated. (Courtesy Merle Cole)

Initially, the Nike sites were garrisoned with regular Army artillery battalions, which were "converted" (trained) from AAA gun systems to the new Nike-Ajax systems. As Nike-Ajax was replaced with Nike-Hercules, the regular battalions were "converted" to the new system and Army National Guard units were trained to man the remaining Nike-Ajax sites. This transfer from regular Army battalions to National Guard battalions continued throughout the life span of the deployed Nike system.

Life at a Nike site was generally routine. The sites were continuously manned by a battery detachment with enough personnel to respond to a firing order. These units were on duty 24 hours a day, 365 days a year. Each large defense area had to maintain at least 25 percent of the batteries under its command in a ready status to fire a missile in 15 minutes, 50 percent to be ready to fire a missile in 40 minutes and 25 percent would be in a training and/or maintenance cycle. The men on duty stayed in barracks at the administrative site, which had mess and recreational facilities. The "duty" crews at the control site and launch site had a ready room to spend the tedious hours while waiting out their shifts. During the course of the week there were routine maintenance chores, checking, fixing, and installing new or replacement equipment. The security was handled by a separate military police detachment, who early on incorporated guard dogs. The officers were an elite group. They were generally high achievers and had more time in school and training than other officers. The enlisted men were also generally volunteers and highly trained. The duty tours could be mundane and it was sometimes hard to maintain morale among the enlisted. The situation was worse with the assignment of men back from Vietnam duty waiting out time until their enlistment was up. Attempts to alleviate the tedium, especially at the more remote sites, included bookmobiles, sports, and hobby shops. Families were housed at nearby military installations, but in many cases the men had long commutes to their duty stations.

After missile training at Fort Bliss and assignment to an artillery battery, there were regular training exercises to get everyone functioning smoothly. Regular inspections by higher-ranking officers also occurred. Practice missiles were never fired from the regular sites in the continental United States. Once a year each battery would travel to Fort Bliss and the White Sands firing range for annual service practices. To be sure that each unit was up to snuff, this practice was not scheduled regularly but could be ordered at anytime of the year with a week's notice (short-notice annual practice, or SNAP) to insure unit efficiency. The annual practice was a source of pride for the units; rating scores were posted throughout the Army and units were rewarded for top scores. On-site inspections included the "Blazing Skies" alert, which could either be scheduled or a surprise. A randomly chosen incoming plane was selected as a potential target and the code "Blazing Skies" was given. Batteries had 15/40 minutes to be ready to fire their missiles, depending on their operational status.

In short, there were often long periods of regular routine, sometimes shaken up by inspection or practice. Only a few times did things get "hot," but

US Army Air Defense Artillery color patch.

never was a Nike fired in anger. Accidents were rare, considering the delicacy of the early missile systems. A Nike-Ajax accidentally exploded during a maintenance check, destroying a magazine at a Nike site in New Jersey in 1958 and killing several crewmen.

More information on life with the "scope dopes" and the "pit rats" can be found in John A. Martini and Stephen A. Haller, *What We Have We Will Defend: An Interim History and Preservation Plan for Nike Site SF-88L, Fort Barry, California.*

SAC: strategic missile commands

The Air Force ICBMs were placed under the umbrella of the Strategic Air Command (SAC). As the missile sites achieved operational status they were assigned to Strategic Missile Squadrons (SMSs). With the first generation missiles – Atlas and Titan I – the Air Force assigned the squadrons directly to an existing SAC bombardment or strategic wing, the exception being a stand-alone two-squadron strategic missile wing of Titan Is at Lowry AFB, CO. For Minuteman the Air Force activated strategic missile wings, usually with three squadrons assigned; each squadron operated multiple LCCs using alphabetically designated flights.

Select, highly trained officers and enlisted personnel managed the Air Force ICBM systems. Their lives while on three-day or 24-hour alert tours were intertwined with their equipment and mission. The crews lived and worked at the missile facilities they were assigned to. Each staff member had his/her own responsibilities to support the function of the launch facility. The primary personnel were the missile combat crews who were in charge of the launch controls. The complex maintenance requirements of the liquid-fueled Atlas and Titan I systems had a much larger staffing requirement due to the complex maintenance needs of the liquid-oxygen-fueled missiles. Accidents occurred: five Atlas F missiles exploded in their launch areas during propellant-loading exercises with the warhead removed. The more stable Titan II and the solid-fueled Minuteman greatly decreased the maintenance and staffing requirements.

The Minuteman crews exemplified the SAC ICBM force. The launch control facility (LCF) staff included a facility manager, flight security controllers, security alert team members, and a cook. The wing maintenance crews were based at the nearby AFB and made regular rounds to the sites. The launch facilities were designed to be unmanned in the Minuteman system, but were also visited on a regular basis by the maintenance crews and technical staff. While on duty the flight staff worked, ate, slept, and relaxed at the LCF. Many of the facilities were equipped with basketball hoops, ping pong and pool tables, and weight rooms. Televisions were a required necessity. Each LCF took on the personalities and tastes of its assigned crews. Most were decorated with wall art and murals painted by the crews which reflected their military affiliations. The crews took their jobs very seriously and knew full well the fate of the world was in their hands.

The heart and soul of the missile flight assigned to a launch facility were the officers assigned to missile combat crews. The job required a reliable, stable, intelligent officer who could be counted on to fire missiles in the chaos of nuclear combat, but not before. The "Missileers" completed a rigorous training program at Chanute AFB, IL, before heading to

Many missile sites had distinctive mural art painted by their crews. This "pizza lid" is on the eight-ton blast door protecting the LCC at the Delta-01 launch facility near Ellsworth AFB, SD. (National Park Service)

Participants in the "Olympic Arena" competitions for SAC performance evaluations were famous for their elaborate costumes. Here the 90th Strategic Missile Wing based at Francis E. Warren AFB, WY, celebrate after being named Best Minuteman Maintenance Team. (US Strategic Command, Historical Office)

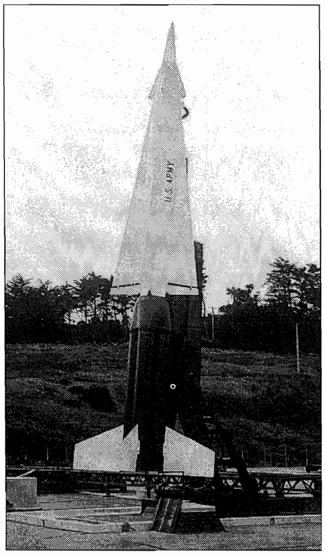
Vandenberg for operational readiness training. Once training was complete, the men (and later women) were assigned to crews at operational bases. Crews underwent training and evaluation once or twice a month to make sure they performed to the strict standards. Periodic competitions were also held as units vied for top squadron honors. These competitions became rather ornate with crews going to town on costumes and presentations.

During the first years of the Minuteman program combat crews worked 40-hour alert tours at the LCF for three days at a time with 8- to 12-hour shifts down in the underground launch control center (LCC). In 1977 the shift was changed to a single 24-hour duty for the two person crew averaging about 8 a month. The most important duty of the crew was constant vigilance to be ready to launch the missiles under their control. Other duties included coordinating maintenance and inspections and monitoring the status of the missiles. Early on the crews were all male; after 1978 women also became missileers, serving initially in all-female crews. But scheduling problems forced the integration of the crews after 1989.

Upon arrival at the LCF, a missile crew was checked in by the flight security controller and then by the on-duty missile crew. Once cleared, the team would ride the elevator down to the LCC. After shouting "clear" by both teams, the on duty team would swing the huge blast door open. Once in the LCC a 10-minute process called changeover occurred during which various security codes and information were exchanged, as well as exchanging padlocks on the metal box that secured the launch keys. Changeover concluded with the handing over of three items to the new duty crew: a box with the day's security code, a key to the locked box with the launch keys, and a .38 caliber revolver. Once the door was closed, the new crew would check the logs and inspect the equipment. The duration of their shift was spent running practice drills or reviewing procedures. If a launch command was received, both crew members would open the box with the authentication codes to confirm. If both crew members agreed on the authenticity, they would open the locked box, remove their keys, and, after a set procedure, insert them into their respective locations and simultaneously turn them as a final step to fire the missiles in their field.

For more detail on the life of the missile crews and staff, see the fine Historic Resource Study edited by Jeffery A. Engel, *The Missile Plains: Frontline of America's Cold War.*

US missile sites today

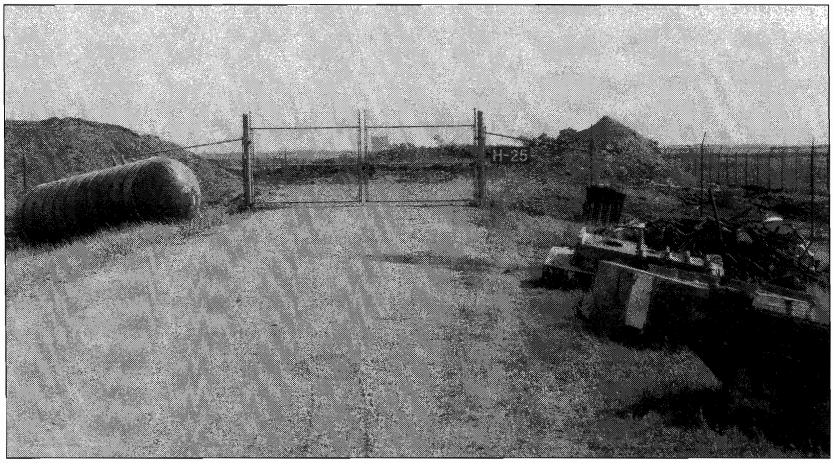


A Nike-Hercules missile in position at Nike site SF-88L. (Mark Berhow, 1996)

As the orders came to inactivate the various systems, the military would remove the missiles and warheads, then remove all important electronic equipment. If the property was not on a large government reserve, it was usually declared excess and the procedure initiated to dispose of the property. Options included transferring the property to another federal, state, or municipal government agency, or selling the property to private ownership. This transfer has been complicated of late with the establishment of the "clean-up fund" to remediate environmental contamination at ex-military sites. Hundreds of old Nike, Atlas, and Titan I sites have been closed down, have been or are in the process of being remediated, and have been transferred or sold. As these sites are typically relatively small parcels of land often containing potentially hazardous underground structures and tunnel systems, many missile sites have been (for all intents and purposes) destroyed – either buried, filled or demolished. Others are in private hands or are being used by other government entities and are not generally open to the interested public visitor. Only a handful of relatively intact Cold War missile sites are open to the public.

Most of the hundreds of Nike sites around the country have been transferred to other public agencies, which often use the buildings and sometimes the underground magazines. A few have been sold to private owners. As time goes by, more and more of the buildings and structures at these sites are being destroyed or buried. As a result there are very few relatively intact Nike sites that can be visited today. These include site SF-88L north of San Francisco, which is described below, site LA-43 in San Pedro, CA, south of Los Angeles, and site SL-40, Hecker, IL west of St. Louis, MO. Site LA-43 is on public lands and work is beginning on site restoration. Site SL-40 is now owned by a local school district, which uses the control/administration site as a vocational school and the launch area as storage facility. Advance arrangements must be made to visit the Hecker site. A few other sites, such as one in the Florida Everglades National Park and a site at the Sandy Hook Unit of Gateway National Recreation Area, may be restored and opened to the public in the near future.

The hundreds of deactivated ICBM sites are also generally inaccessible. Many are still on government lands and have been locked up or buried. Others have been transferred to private owners and are either buried, destroyed, or



Minuteman launch site H-25 near Grand Forks AFB, ND, after being destroyed in 2001. The site was salvaged for scrap metal before being filled and leveled. (Ron Plante)

Nike Battery SF-88L in the Marin Headlands Unit of the Golden Gate National Recreation Area, the only restored Nike battery open to the public. (Mark Berhow, 1994)

being used as storage facilities or in a few cases as a part of private homes. Both the Titan II and Minuteman II sites were deactivated and nearly all have been destroyed as part of the START II Treaty. The inactivated sites were cleared of all salvageable equipment, left open for satellite/photographic inspection for a period of time, then blown up. After removal of scrap metal, the sites were graded over and often returned to private or public ownership. Only three ICBM sites are open to the public: Titan II site 571-7 – the Titan Missile Museum south of Tucson, AZ; the Minuteman II site Delta-01/09 east of Wall, SD (both described below); and the Minuteman II Oscar-01 control site at Whiteman AFB, Sedalia, MO. The Whiteman site is only open a few days of the year and advanced registration must be made to visit the site. A group in North Dakota is attempting to preserve and interpret one of the former Minuteman III complexes outside of Grand Forks AFB.

Numerous display missiles are located around the country; most are located at current or ex-military bases. The Army Ordnance Museum at Aberdeen, MD, the Fort Bliss Air Defense Museum in Texas, and the Air Force Museum at the Wright-Patterson AFB in Dayton, OH all have excellent missile displays. Most of the SAC bases near where the ICBMs were based have missiles on display as well.

Nike site SF-88L (Marin Headlands Unit, Golden Gate National Recreation Area, CA)

In the mid 1970s, as the Nike system was being taken off-line, it was decided to save a single site in the San Francisco defense area. The lands were being transferred to the National Park Service for the newly formed Golden Gate National Recreation Area (GGNRA). The launch site, known as SF-88L, was transferred relatively intact, but without the radar and electronic control equipment. The site languished in neglect for a number of years as the GGNRA was being set up and learning to manage the huge amount of property it inherited from the military. By the mid 1980s, a concerted effort with volunteer help was underway to restore the site. Today, Nike site SF-88L at Fort Barry on the Marin Headlands is the only restored Nike site open to the public. The site is staffed by volunteers and is only open for guided tours Wednesday to Saturday. The site features functioning control equipment, two radars (a LOPAR and a MTR), about 30 dummy Hercules and Ajax missiles, and assorted equipment and displays. One magazine has a functioning magazine elevator and one or two operational missile elevators. On the first Sunday of the month, the site holds an open house, the missiles are brought up and elevated into firing position. Docent volunteers provide talks and answer questions (www.nps.gov/goga/nike).

Titan site 571-7 (The Titan Missile Museum, Sahuarita, AZ)

The Arizona Titan sites were all deactivated by August of 1984. On May 8, 1986 this site, located between Tucson and Green Valley, AZ, was turned over by the Air Force to a non-profit foundation to be used as a museum. A number of modifications were made to the site and a dummy Titan missile was placed in the silo. To meet treaty obligations the silo door was permanently opened half way and a skylight installed over the open half. The museum has been open since the mid 1990s and in 2003 opened its education and research center. The site has a visitor center and conducts regularly scheduled tours to the Titan facility. The museum is open everyday except Thanksgiving and Christmas, and tour reservations are recommended (www.pimaair.org/TitanMM/titanhome.shtml).

Minuteman site Delta 01/09 (Minuteman National Historic Site, Wall, SD)

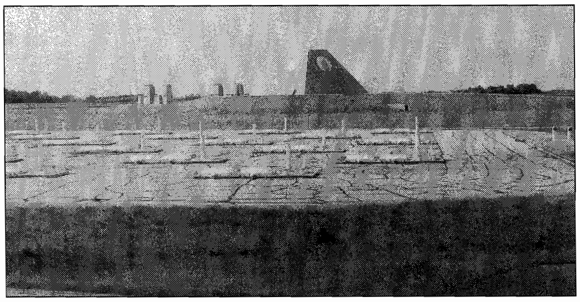
The Air Force began deactivating the Minuteman II sites of the 44th Missile Wing around Ellsworth AFB, SD, in 1992. During the deactivation process, a decision was made to keep one of the Ellsworth sites as part of the historical preservation program. A series of studies was conducted during 1993–96 to provide the historical background and information for nomination as a historical site. Congress created the Minuteman National Historic Site on November 29, 1999, to preserve, protect, and interpret the structure associated with the Minuteman II system. Work began on converting Delta 01, a launch control center, and Delta 09, a missile launch facility, into static displays for visitors and to make it comply with the conditions of START II. An unarmed training missile was procured and placed in the launch silo in June 2001. Construction of a viewing enclosure was begun soon after and a Russian team inspected the site for treaty compliance. The formal transfer of the site from the Air Force to the NPS occurred on September 27, 2002. The site is now open on a limited basis by reservation during the summer months. Small groups of people, six at a time, can be taken through the launch control center, then out to the launch site silo. The site will be fully open to the public following completion of the visitor center anticipated in 2006 (www.nps.gov/mimi).

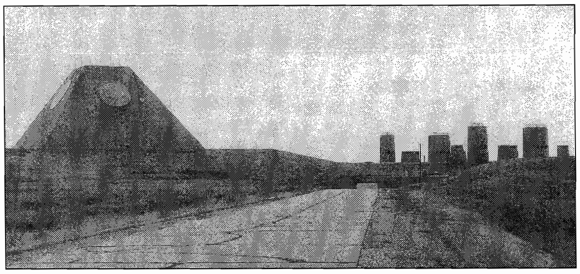
The LCC chamber at the Minuteman National Historic Site. (National Park Service)

Conclusion

The life span of these defensive systems was relatively short when compared to the previous incarnations of the seacoast artillery fortification systems. The life span of the Nike program was 20 years; that of the Minuteman ICBM system will be 40. Many of the other programs were much shorter – in the case of the initial ABM system officially operational only one day! Giant technological advances during the Cold War era quickly outmoded systems even as they were being deployed.

Looking across the Spartan launch field at the Stanley R. Mickleson MSR facility near Nekoma, SD.

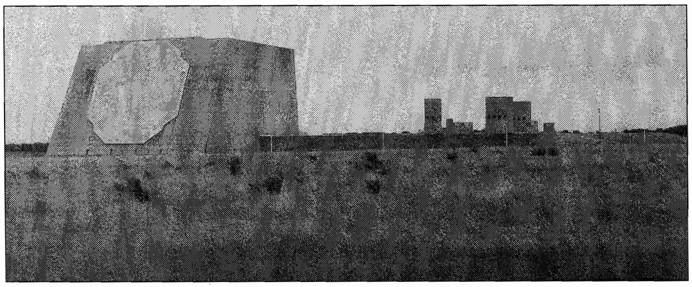




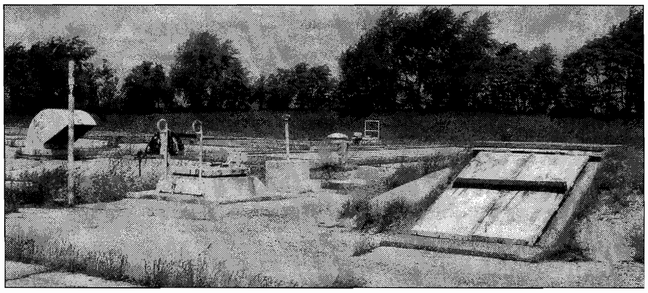
The entrance to the MSR building and power facility at the Stanley R. Mickelson MSR facility near Nekoma, SD, 2001. (Ron Plante)

An excellent assessment of the costs of the US nuclear programs can be found in *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940* edited by Stephen Schwartz. From World War II to the late 1990s, the authors estimate that the United States spent $937 billion on programs for strategic air and missile defense, antisatellite and antisubmarine defense, and civil defense. This figure attempts to estimate both development and deployment costs. Despite this enormous investment, it is felt by some that these defenses would have been ineffective in preventing nuclear destruction if the Soviets had attacked; yet others point out that the very fact the Soviets did not attack more than justified the defensive efforts. The rapid development of offensive countermeasures coupled with very high projected costs and uncertain performance left a trail of uncompleted programs often abandoned before completion. The estimated cost of offensive nuclear delivery systems, both missiles and bombers, by the United States is even more at $3.2 trillion, covering costs to deploy and support the nuclear arsenal. The United States manufactured some 6,135 ICBMs at a cost of $266 billion. At $189 million the Peacekeeper was the most expensive. Minutemans were a mere $34–37 million each, Atlases were $92 million each, Titan Is were $131 million, and Titan IIs were $100 million. These figures do not include the many other expenses – such as building the silos, construction and maintenance of the radar monitoring systems, the cost of the nuclear warheads themselves, and maintaining the missiles – that was factored into the Atomic Audit's total $3.2 trillion price tag.

The PAR building, with the air intake and exhaust vents of the power facility behind, near Cavalier, SD in 2001. (Ron Plante)



The Cold War produced sweeping changes in the United States military establishment, American technological development, and American society at large. For more than 40 years, the United States prepared to defend itself against a massive nuclear attack that never came. The United States reversed its long-standing policy against maintaining a large peacetime military establishment and utilized the nation's industrial might and scientific genius to fashion the ultimate weapons of war and a means to defend against them. High technology became the ultimate arbitrator of military power, culminating in the nation's guided missile programs. Armed with nuclear warheads, the guided missiles became the defining weapons of the Cold War.



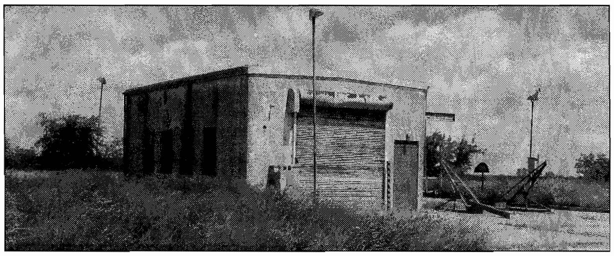
The top of a Nike launch magazine at Nike site SL-40 near Hecker, IL in 2003. (Mark Berhow)

Looking back, the impact of the Cold War missile programs is starkly evident. The Cold War forced changes on the military services molding them into a more integrated system. The missile program, among other modern weapon systems, recast the relationship between the military, the scientific community, and private industry into what President Eisenhower called the "industrial-military complex." The strategic missile technology was the basis for the civilian space program. Atlas and Titan missiles delivered the first Americans into space; their descendants are still boosting payloads into space today. Moreover, the many technologies developed for the various missile programs have an impact on our lives today: computers, miniaturized electronics, inertial guidance systems, high-performance fuels, new metal alloys, and advanced telecommunications among other things. The impact of these programs on the American economy is perhaps somewhat underappreciated. Construction programs brought employment for thousands of workers at the industrial centers, as well as jobs to areas surrounding the military bases. The missile programs brought sudden prosperity to places like White Sands, NM; Huntsville, AL; and Grand Forks, ND.

The US missile defense program in the 21st century

The American missile defense story does not end with the close of the Cold War, however. The SDI was refocused under the elder Bush Administration to a system for Global Protection Against Limited Strikes (GPALS) with three major components: a ground-based National Missile Defense (NMD), a ground-based Theater Missile Defense (TMD), and a space-based global defense. This plan remained in development under the Clinton Administration, but deployment was deferred at the end of Clinton's term of office.

On December 17, 2002, President George W. Bush announced the deployment of a new flexible-deployment missile defense system. The initial capabilities include 20 ground-based mid-course defense (GMD) interceptor missiles (16 at Fort Greely, AK, and 4 at Vandenberg AFB, CA) for destroying ICBMs; 20 sea-based interceptors based on Aegis ships to intercept short- and medium-range ballistic missiles in mid flight; deployment of air-transportable Patriot Advance Capacity-3 (PAC-3) systems to intercept short- and medium-range ballistic missiles; and a series of land-, sea- and space-based sensors – including early warning satellites, upgraded land-based radar at Shemya Island, AK, and a new sea-based X-band radar system. The initial deployment was targeted for completion at the end of 2005. Additional systems would be added and upgraded as new developments were made and with changing threats. The United States Department of Defense plans to develop and deploy missile defenses capable of protecting not only the United States and its deployed forces, but also its friends and allies. The missile defense will be structured in a manner that encourages industrial cooperation by friends and allies and is consistent with overall US national security. The deployment of the new missile defense system is "an essential element of the United States overall national security policy to transform US defense and deterrence capabilities to meet emerging and evolving threats."



The missile assembly building at Nike site SL-40 near Hecker, IL in 2003. (Mark Berhow)

Abbreviations

AAA	antiaircraft artillery
AAAMBn	antiaircraft missile battalion
AADCP	Army Air Defense Command Post
AAF	Army Air Forces
ABAR	alternate battery radar
ABM	antiballistic missile
ABMA	Army Ballistic Missile Agency
ACQR	acquisition radar
ADA	Air Defense Artillery
ADC	Air Defense Command
ADCOM	Aerospace Defense Command
AEC	Atomic Energy Commission
AFB	Air Force Base
AFS	Air Force Station
AMSC	Army Missile Support Command
AN	Army/Navy (equipment designation)
ARAACOM	Army Anti-Aircraft Command
ARADCOM	Army Air Defense Command
ARDC	Air Research and Development Command
ARGMA	Army Guided Missile Agency
ARPA	Advanced Research Projects Agency
ASP	annual service practice
BIRDIE	Battery Integration and Radar Display Equipment
BMDC	Ballistic Missile Defense Center
BMEWS	Ballistic Missile Early Warning System
BOMARC	missile developed by Boeing and the University of Michigan's Aeronautical Research Center
CC	combat center
CEBMCO	Corps of Engineers Ballistic Missile Construction Office
CONAC	Continental Air Command
CONAD	Continental Air Defense Command
CONUS	continental United States
DAR	defense acquisition radar
DC	defense center
DEW	Distant Early Warning system
DOD	Department of Defense
DPS	data processing system
DR	discrimination radar
FCC	Fire Coordination Center
GAPA	ground-to-air pilot-less aircraft
GSA	General Services Administration
FOC	fire coordination center
GPALS	Global Protection Against Limited Strikes
HE	high explosive
HIPAR	High-Powered Acquisition Radar
ICBM	intercontinental ballistic missile
IFC	integrated fire control
IRBM	Intermediate Range Ballistic Missile
LOPAR	Low-Power Acquisition Radar
MAB	missile assembly building
MAR	multi-function array radar
MICOM	Army Missile Command
MIRV	Multiple Independently-targeted Re-entry Vehicle
MSR	missile site radar
MTR	missile-tracking radar
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NG	National Guard
NMD	National Missile Defense
NORAD	North American Aerospace Defense Command
NSA	National Security Agency
NSC	National Security Council
PAR	perimeter acquisition radar
R&D	research and development
RRIS	remote radar integration station
RSL	remote Sprint launch (site)
SAC	Strategic Air Command
SAFSCOM	Safeguard Systems Command
SAGE	Semi-Automatic Ground Environment
SALT	Strategic Arms Limitation Talks
SAM	surface-to-air missile
SDI	Strategic Defense Initiative
SDS	Strategic Defense System
SENSCOM	US Sentinel Systems Command
SLBM	Submarine-Launched Ballistic Missile
SMFU	secondary master fire unit
SMS	Strategic Missile Squadron
SMW	Strategic Missile Wing
SNAP	short-notice annual practice
SRMSC	Stanley R. Mickleson Safeguard Complex
START	Strategic Arms Reduction Talks
TAC	Tactical Air Command
TRR	Target-Ranging Radar
TTR	Target-Tracking radar
USACE	US Army Corps of Engineers
USAF	US Air Force
USASDC	US Army Strategic Defense Command
ZAR	Zeus Acquisition Radar

Internet resource sites

The US Army Redstone Arsenal History site	http://www.redstone.army.mil/history
Redstone Nike history web site	http://www.redstone.army.mil/history/nikesite/welcome.html
Ed Thelen's Nike web site	http://ed-thelen.org
Donald Bender's Nike web site	http://alpha.fdu.edu/~bender/nike.html
The Stanley R. Mickleson Safeguard Complex web site	http://www.srmsc.org
Nuclear ABMs of the USA	http://www.paineless.id.au/missiles/index.html
The FAS United States nuclear forces guide websites has a number of documents on Cold War missile programs	http://www.fas.org/nuke/guide/usa/
The Environmental Analysis Branch ACC/CEVP site provides a number of historical studies in downloadable PDF format under Cultural Resources, Cold War Related Studies	http://www.cevp.com
Andreas Parsch's Directory of US Military Rockets and Missiles	http://www.designation-systems.net/dusrm/index.html
Minuteman ICBM website	http://www.geocities.com/minuteman_missile/index.html
Strategic Air Command Missile Pages	http://www.strategic-air-command.com/missiles/00-missile-home.htm

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Appendix

US defensive and strategic missile data

Source: Andreas Parsch's *Directory of US Military Rockets and Missiles* (http://www.designation-systems.net/dusrm/index.html)

Missile:	Nike-Ajax	Nike-Hercules	BOMARC A	BOMARC B
Length	21ft. (6.4m)	26ft. 10in (8.18m)	46ft. 9in. (14.2m)	45ft. 1in. (13.7m)
Booster length	13ft. 10in (4.21m)	14ft. 3in. (4.34m)		
Wingspan	4ft. 10in. (1.37m)	6ft. 2in. (1.88m)	18ft. 2in. (5.54m)	18ft. 2in. (5.54m)
Booster wingspan	11ft. 6in. (3.5m)	–	–	–
Diameter	12in. (0.3m)	21in. (0.53m)	35in. (0.89m)	35in. (0.89m)
Booster diameter	31.5in. (0.8m)	–	–	–
Weight	100 lb. (450kg)	5,530 lb. (2,505kg)	15,500 lb. (7020kg)	16,000 lb. (7,250kg)
Booster weight	1460 lb. (660kg)	5,180 lb. (2,345kg)	–	–
Speed	Mach 2.3	Mach 3.65	Mach 2.8	Mach 3
Ceiling	70,000ft. (21,300m)	150,000ft. (45,700m)	65,000ft. (20,000m)	100,000ft. (30,000m)
Range	30 miles (48km)	88+ miles (140+km)	250 miles (400km)	440 mile (710km)
Propulsion booster	Allegany Ballistics Lab solid-fueled rocket (55,000 lb./246 kN)	Hercules M42 solid-fueled rocket 210,000 total thrust	Aerojet General LR59-AJ-13 liquid-fueled rocket (35,000 lb./156 kN)	Thiokol M51 solid-fueled rocket (50,000 lb./222 kN)
Propulsion sustainer	Bell liquid-fueled rocket (2,600 lb./11.6 kN)	Thiokol M30 solid-fueled rocket (10,000 lb./44.4 kN)	2 x Marquardt RJ43-MA-3 ramjet (11,500 lb./51 kN each)	2 x Marquardt RJ43-MA-7 ramjet (12,000 lb./53 kN each)
Guidance warhead	Ground-based radar. Three HE frag WH. 12 lb., 179 lb., 122 lb. (5.44kg, 81.2kg, 55.3kg)	Ground-based radar. M17 blast-frag or W-31 nuclear 20 kT	Ground-based radio/radar. W-40 nuclear fission 7–10 kT, or conventional HE	Ground-based radio/radar. W-40 nuclear fission 7–10 kT

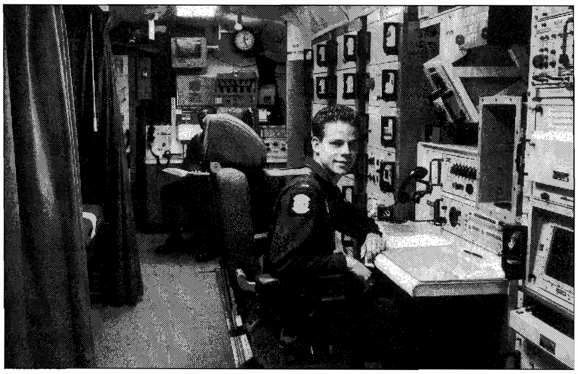
Missile:	HAWK A	HAWK B	Nike-Zeus A	Nike-Zeus B
Length	16ft. 8in. (5.08m)	16ft. 6in. (5.03m)	44ft. 3in. (13.5m)	48ft. 4in. (14.7m)
Wingspan	3ft. 11in. (1.19m)	3ft. 11in. (1.19m)	117.6in. (2.98m)	96in. (2.44m)
Diameter	14.5in. (37cm)	14.5in. (37cm)	36in. (91cm)	36in. (91cm)
Weight	1290 lb. (584kg)	1400 lb. (635kg)	11,000 lb. (4,980kg)	22,800 lb. (10,300kg)
Speed	Mach 2.5	Mach 2.5	> Mach 4	>Mach 4
Ceiling	45,000ft. (13,700m)	58,000ft. (17,700m)	–	–
Range	15 miles (25km)	25 miles (40km)	200 miles (320km)	250 miles (740km)
Propulsion	Aerojet M22E8 dual-thrust solid-fueled rocket	Aerojet M112 dual-thrust solid-fueled rocket	1st Stage: Thiokol TX-135 solid fuel 400,000 lb. (1800 kN). 2nd Stage: ?	1st Stage: Thiokol TX-135 solid fuel 400,000 lb. (1800 kN). 2nd Stage: Thiokol TX-238 solid fuel. 3rd stage: Thiokol TX-239 solid fuel
Guidance	Ground-based radar	Ground-based radar	Ground-based radar	Ground-based radar
Warhead	HE blast-frag, 119 lb. (54kg)	HE blast-frag, 163 lb. (74kg)	W-31 thermonuclear, 20 kT	W-50 thermonuclear, 400 kT

Missile:	Spartan	Sprint
Length	55ft. 2in. (16.8m)	26ft. 11in. (8.2m)
Wingspan	117.6in. (2.98m)	–
Diameter	43.1in. (1.09m)	4ft. 5in. (1.35m)
Weight	29,000 lb. (13,100kg)	7,700 lb. (3,500kg)
Speed	> Mach 4	Mach 10 plus
Range	460 miles (740km)	25 miles (40km)
Propulsion	1st stage: Thiokol TX-500 solid fuel 500,000 lb. (2200 kN). 2nd stage: Thiokol TX-454 solid fuel. 3rd stage: Thiokol TX-239 solid fuel.	1st stage: Hercules X-265 solid-fuel 650,000 lb. (2,900 kN). 2nd stage: Hercules X-271 solid fuel.
Guidance	Ground-based radio	Ground-based radio
Warhead	W-71 thermonuclear 5 mT	W-66 thermonuclear 1 kT

Missile:	Snark	Atlas D/E	Atlas F	Titan I	Titan II
Length	68ft. 8in. (20.93m)	75ft. (22.9m)	82ft. 6in. (25.1m)	98ft. (29.9m)	103ft. (31.4m)
Wingspan	42ft. 2in. (12.86m)	–	–	–	–
Diameter	–	10ft. (3.05m)	10ft. (3.05m)	8ft. (2.44m)	10ft. (3.05m)
Weight	49,600 lb. (22,500kg)	260,000 lb.	260,000 lb.	220,000 lb.	330,000 lb.
Booster weight	11,365 lb. (5,150kg)	(118,000kg)	(118,000kg)	(99,700kg)	(149,500kg)
Speed	Mach 0.94	15,500 mph (25,000 kph)	15,500 mph (25,000 kph)	15,000 mph (24,100 kph)	15,000 mph (24,100 kph)
Ceiling	60,000ft. (18,300m)	500 miles (800km)	500 miles (800km)	500+miles (800km)	600 miles (960km)
Range	6,000 miles (9,650km)	5,500 miles(10,200km)	5,500 miles (10,200km)	6,300 miles (10,100km)	9,300 miles (15,000km)
Propulsion booster	2 x Allegany Ballistics solid-fueled rockets, 130,000 lb. (580 kN) each	2 x Rocketdyne XLR89-NA-5, 150,000 lb. (666 kN) each	2 x Rocketdyne LR-89-NA-5, 165,000 lb. (733 kN) each	2 x Aerojet LR87-AJ-1, 150,000 lb. (666 kN) each	2 x Aerojet LR87-AJ-5, 215,000 lb. (955 kN) each
Propulsion sustainer	Pratt & Whitney J57-P-17 turbojet, 11,500 lb. (51.1 kN)	Rocketdyne XLR105-NA-5, 60,000 lb. (267 kN)	Rocketdyne LR105-NA-5, 57,000 lb. (253 kN)	Aerojet LR91-AJ-1, 80,000 (356 kN)	Aerojet LR91-AJ-5, 100,000 (444 kN)
Propulsion vernier		2 x Rocketdyne LR101-NA-7 1,000 lb. (4.5 kN) each	2 x Rocketdyne LR101-NA-7, 1,000 lb. (4.5 kN) each		
Guidance	Radio-inertial General Electric	Radio-inertial/all-inertial General Electric	All-inertial American Bosch-Arma	Radio-inertial General Electric	All-inertial AC Spark Plug
Warhead	W-39 thermonuclear 4 MT	W-49 thermonuclear 1.45 mT in Mk.2 or Mk.3 RV	W-38 thermonuclear 4.5 MT in Mk.4 RV	W38 Thermonuclear 4.5 MT in Mk.4 RV	W-53 thermonuclear 9 MT in Mk.6 RV

Missile:	Minuteman I	Minuteman II	Minuteman III	Peacekeeper
Length	53ft. 8in. (16.4m)	55ft. 11in. (17m)	59ft. 9.5in. (18.2m)	71ft. (21.6m)
Diameter	5ft. 6in. (1.7m)	5ft. 6in. (1.7m)	5ft. 6in. (1.7m)	7ft. 8in. (2.34m)
Weight	65,000 lb. (29,400kg)	65,000 lb. (29,400kg)	78,000 lb. (35,300kg)	195,000 lb. (88,300kg)
Speed	15,000 mph (24,100 kph)	15,000 mph (24,100 kph)	15,000 mph (24,100 kph)	15,000 mph (24,100 kph)
Range	6,300 miles (10,100km)	6,000 miles (9,600km)	8,100 miles (13,000km)	6,800 + miles (10,900+ km)
Ceiling	–	–	–	500 miles (800km)
Propulsion booster	Thiokol M55 solid fuel rocket 210,000 lb. (933 kN)	Thiokol M55 solid fuel rocket 210,000 lb. (933 kN)	Thiokol M55 solid fuel rocket 210,000 lb. (933 kN)	Thiokol solid fuel rocket 500,000 (2200 kN)
Propulsion 2nd stage	Aerojet General M56 solid-fueled, 60,000 lb. (267 kN)	Aerojet General M56 solid-fueled, 60,000 lb. (267 kN)	Aerojet General SR19-AJ-1 solid-fueled, 60,300 lb. (268 kN)	Aerojet solid-fueled
Propulsion 3rd stage	Hercules M57 solid fuel, 35,000 lb. (156 kN)	Hercules M57 solid fuel, 35,000 lb. (156 kN)	Aerojet/Thiokol SR73-AJ/TC-1 solid fuel, 34,400 lb. (153 kN)	Hercules solid fuel
Propulsion post boost	–	–	Rocketdyne RS-14 liquid fuel, 315 lb. (1.4 kN)	Rocketdyne restartable liquid fuel
Guidance	All-inertial Autonetics/Rockwell	All-inertial Autonetics/Rockwell	All-inertial Autonetics/Rockwell	All-inertial
Warhead	W-59 thermonuclear 1.2 MT in Mk.5 RV	W-56 thermonuclear 2 MT in Mk.11 RV 3x	W-62 thermo 170 kT in 3x Mk.12 MIRV or 3x W-78 thermo 340 kT in 3 x Mk.12A MIRV	10x W-87-0 thermo 300 kT in 10x Mk.21 MIRV

A Minuteman silo under construction near Ellsworth AFB, SD in June 1962. The launch support facility is to the left of the silo. (National Archives, Washington National Records Center, Suitland)



From the underground Delta 01 Launch Control Center, the on-duty crew kept watch over ten Minuteman II missiles near Ellsworth AFB, SD. (National Park Service)

United States missile deployment

Army air-defense areas

Defense Area	Ajax batteries	Hercules batteries	HAWK batteries	Operational dates
Anchorage, AK*	–	3	–	1959–79
Baltimore, MD	7	4	–	1956–74
Barksdale AFB, LA	–	2	–	1962–66
Bergstrom AFB, TX	–	2	–	1960–66
Boston, MA	11	4	–	1956–74
Bridgeport, CT	6	1	–	1956–70
Buffalo, NY	4	1	–	1956–70
Chicago, IL	22	9	–	1956–74
Cincinnati–Dayton, OH	–	4	–	1966–71
Cleveland, OH	8	3		1956–71
Columbus AFB, MS**	–	(2)	–	–
Dallas–Fort Worth, TX	–	4	–	1964–69
Detroit, MI	15	6	–	1956–74
Dyess AFB, TX	–	2	–	1960–66
Ellsworth AFB, SD	4	1	–	1957–61
Fairbanks, AK*	–	5	–	1959–71
Fairchild AFB, WA	4	1	–	1956–66
Hanford, WA	4	1	–	1955–60
Hartford, CT	6	2	–	1956–71
Homestead–Miami, FL	–	4	4	1962–79
Kansas City, MO	–	4	–	1959–69
Key West, FL, FL	–	–	5	1962–79
Lincoln AFB, NE	–	2	–	1960–66
Little Rock, AR**	–	(2)	–	–
Loring AFB, ME	4	2	–	1957–66
Los Angeles, CA	16	9	–	1956–74
Malmstrom AFB, MT**	–	(2)	–	–
Milwaukee, WI	8	3	–	1956–71
Minneapolis– St. Paul, MN	–	4	–	1959–71
Mountain Home AFB, ID**	–	(2)	–	–
New York, NY	19	10	–	1956–74
Niagara Falls, NY	4	2	–	1955–70
Norfolk, VA	9	3	–	1958–74
Oahu, HI*	–	4	–	1961–70
Offutt AFB, NB	–	2	–	1960–66
Philadelphia, PA	12	5	–	1956–74
Pittsburgh, PA	12	6	–	1956–74
Providence, RI	7	2	–	1956–74
Robins AFB, GA	–	2	–	1960–66
St Louis, MO	–	4	–	1960–66
San Francisco, CA	12	5	–	1955–74
Schilling AFB, KS***	–	2	–	–
Seattle, WA	11	3	–	1956–74
Sheppard AFB, TX**	–	(2)	–	–
Thule AB (Greenland)*	–	4	–	1958–65
Travis AFB, CA	4	2	–	1957–71
Turner AFB, AL	–	2	–	1958–65
Walker AFB, NM***	–	2	–	–
Washington, DC	13	5	–	1954–74

Notes
* The Alaska, Hawaii and Greenland sites were not under ARADCOM control, they operated under a different command structure.
** The site surveys for these locations were conducted, but the construction of the Nike batteries was not authorized.
*** Nike battery sites were constructed at Schilling and Walker AFBs, but were not operational.
Note that each battery had two or three magazines. For more details on Nike site locations, equipment, and unit assignments see Morgan, Mark L. and Mark A. Berhow, *Rings of Supersonic Steel: Air Defenses of the United States Army 1950–1979.*

USAF BOMARC deployment

Squadron	Location	Missiles	Service dates
46th ADMS	McGuire AFB, NJ	28 IM-99A/56 IM-99B	1959–72
6th ADMS	Suffolk County AFB, NY	56 IM-99A	1959–64
26th ADMS	Otis AFB, MA	28 IM-99A/28 IM-99B	1960–72
30th ADMS	Dow AFB, ME	28 IM-99A	1960–64
22nd ADMS	Langley AFB, VA	28 IM-99A/28 IM-99B	1960–72
37th ADMS	Kinross/ Kincheloe AFB, MI	28 IM-99B	1961–72
74th ADMS	Duluth AB, MN	28 IM-99B	1960–72
35th ADMS	Niagara Falls AP, NY	56 IM-99B	1961–69
446 SAM Sqdn	North Bay, ONT	28 IM-99B (RCAF – CBP)	1962–72
447 SAM Sqdn	La Macaza, QUE	28 IM-99B (RCAF – CBP)	1962–72
28th ADMS	Paine AFB, WA	28 IM-99B	cancelled
	Adair AFS, OR	28 IM-99B	cancelled
	Travis AFB, CA	28 IM-99B	cancelled
	Vandenberg AFB, CA	28 IM-99B	cancelled
	Malmstrom AFB, MT	28 IM-99B	cancelled
	Glasgow AFB, MT	28 IM-99B	cancelled
	Minot AFB, ND	28 IM-99B	cancelled
	Charleston AFB, SC	28 IM-99B	cancelled
4751st ADMS(M)	Hurlburt Field, FL	Operational test/training	1958–79

Notes
There were 18 original sites, but only ten were active. The data was compiled by Mark Morgan.

USAF Atlas ICBM deployment

SM squad	Location	Storage	Operational dates	Launch configuration	Missile series
576	Vandenberg AFB, CA*	Above/Vert	1959	3 x 1	D
		Above/Horz	1960–65	3 x 1	D
		Above/Horz	1961–65	1 x 1	E
		Silo-lift	1961–65	1 x 1	F
		Silo-lift	1962–65	1 x 1	F
564	F.E. Warren AFB, WY	Above/Horz	1960–64	3 x 2	D
565	F.E. Warren AFB, WY	Above/Horz	1961–64	3 x 2	D
566	Offutt AFB, NB	Above/Horz	1961–64	3 x 3	D
567	Fairchild AFB, WA	Below/Horz	1961–65	1 x 9	E
548	Forbes AFB, KS	Below/Horz	1961–65	1 x 9	E
549	F.E. Warren AFB, WY	Below/Horz	1961–65	1 x 9	E
550	Schilling AFB, KS	Silo-lift	1962–65	x 12	F
551	Lincoln AFB, NB	Silo-lift	1962–65	1 x 12	F
577	Altus AFB, OK	Silo-lift	1962–65	1 x 12	F
578	Dyess AFB, TX	Silo-lift	1962–65	1 x 12	F
579	Walker AFB, NM	Silo-lift	1962–65	1 x 12	F
556	Plattsburg AFB, NY	Silo-lift	1962–65	1 x 12	F

Notes

*Vandenberg AFB also deployed Titan and Minuteman ICBMs in various launch configurations. This is not noted in the tables that follow.

USAF Minuteman deployment

SM wing	Location	Squad	Operational dates	Missiles deployed in silos MMI	MMII	MMIII	PK
341	Malmstrom AFB, MT	10*	1961–	(50)§	(50)#	50	–
		12*	1962–	(50)§	(50)#	50	–
		490*	1962–	(50)§	(50)#	50	–
		564*	1966–	–	(50)#	50	–
44	Ellsworth AFB, SD	66	1962–93	(50)§	(50)	–	–
		67	1962–92	(50)§	(50)	–	–
		68	1962–94	(50)§	(50)	–	–
91 (455)	Minot AFB, ND	740*	1962–	(50)#	–	50	–
		741*	1962–	(50)#	–	50	–
		742*	1963–	(50)#	–	50	–
351	Whiteman AFB, MO	508	1963–95	–	(50)	–	–
		509	1963–95	–	(50)	–	–
		510	1963–95	–	(50)	–	–
90	F.E. Warren AFB, WY	319*	1964–	(50)#	–	50	–
		320*	1963–	(50)#	–	50	–
		321*	1963–	(50)#	–	50	–
		400*	1964–	(50)#	–	(50)**	50
321	Grand Forks AFB, ND	446	1965–98	–	(50)#	(50)	–
		447	1965–98	–	(50)#	(50)	–
		448	1965–98	–	(50)#	(50)	–

Notes

* active unit, 2004
§ converted to Minuteman II 1968–70
\# converted to Minuteman III 1971–74
** converted to Peacekeeper 1988

USAF Titan deployment

SM squad	Location	Basing mode	Operational dates	Launch configuration	Missile series
724	Lowry AFB, CO	Silo-lift	1962–65	3 x 3	I
725	Lowry AFB, CO	Silo-lift	1962–65	3 x 3	I
569	Mountain Home, ID	Silo-lift	1962–65	3 x 3	I
851	Beale AFB, CA	Silo-lift	1962–65	3 x 3	I
568	Larson AFB, WA	Silo-lift	1962–65	3 x 3	I
850	Ellsworth AFB, SD	Silo-lift	1962–65	3 x 3	I
570	Davis-Monthan AFB, AZ	Silo	1963–84	1 x 9	II
571	Davis-Monthan AFB, AZ	Silo	1963–83	1 x 9	II
533	McConnell AFB, KS	Silo	1963–85	1 x 9	II
532	McConnell AFB, KS	Silo	1963–86	1 x 9	II
373	Little Rock AFB, AK	Silo	1963–87	1 x 9	II
374	Little Rock AFB, AK	Silo	1963–86	1 x 9	II

ABOVE: Work on the main tunnel of Titan I complex at Vandenberg AFB nears completion in 1960. Located 40ft. underground, the tunnel connected the launch center to the missile launch silos. (National Air and Space Museum, Smithsonian Institution)

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Figures in **bold** refer to illustrations

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