On Alert
On Alert


David N. Spires

Air Force Space Command
United States Air Force
Colorado Springs, Colorado
The reader is reminded that this survey of Air Force ICBM history is based largely on open source materials. For more comprehensive treatments of the topics examined here, the interested reader is encouraged to consult studies listed in the bibliography and, if possible, the classified document record. Although the Strategic Air Command and other command and government histories remain classified, the material from those sources cited in this study is unclassified.

Library of Congress Cataloging-in-Publication Data

Spires, David N.
p. cm.
Includes bibliographical references and index.
UG1312.I2S72 2012
358.1'.7540973--dc23
2012020370
To the men and women who made Air Force ballistic missile history and to those who recorded their achievements.
Contents

Foreword xi
Preface xiii

1. The Air Force Enters the Missile Age, 1945–1955 1
   The Air Force Shuns Ballistic Missiles 2
   Ballistic Missiles Receive New Life 9
   Eisenhower Faces the Threat of Surprise Attack 14
   Trevor Gardner Energizes the Missile Program 15

   Establishing Force Levels 28
   Developing and Testing the Atlas and Titan 30
   The Development of Vandenberg (Cooke) Air Force Base 34
   Atlas Operational Deployment—F. E. Warren Air Force Base Leads the Way 38
   Titan I Operational Deployment—Lowry Air Force Base Leads the Way 42
   Building the Missile Bases 42
   Training the Operational Force 48
   The Operational Force and the Reliability Issue 50
   Phase-out of the Atlas and Titan I ICBMs 55
   The Balance Sheet—Looking Ahead 56

   From Titan I to Titan II 60
   The Titan II Takes Flight 66
   Deploying the Titan II 68
   Building the Davis-Monthan Missile Complex 71
   Into an Uncertain Future, 1964–1969 74
   The Titan Combat Crew Experience 78
   Addressing Crewmember Morale 80
   Bringing Women into the Titan Force 84
   Deactivating the Titan II 86

4. The “Ace in the Hole” Minuteman, 1945–1991 95
   Colonel Edward N. Hall Envisions a Revolutionary ICBM, 1945-1959 96
   The Minuteman I Takes Flight 107
   Deploying the Minuteman I 110
The Minuteman Combat Crew Experience 120
SAC’s Minuteman Education Program Initiative 126
Women Join Minuteman Crews 128


An MX Advanced ICBM Project Takes Shape 136
The Carter Administration Commits to a Basing Strategy 138
The Reagan Administration Pursues Another MX Basing Strategy 141
The Scowcroft Commission Establishes an Agenda 142
The Peacekeeper ICBM Takes Shape 143
The Air Force Selects F. E. Warren Air Force Base, Wyoming, for the Peacekeeper’s Home 147
The Site Activation Task Force Deploys Peacekeeper Missiles in Minuteman Silos 150
The Peacekeeper Becomes Operational 151
The Air Force Adopts Peacekeeper Rail Garrison Mobility 154
Arms Control Agreements Set the Course for Peacekeeper 158
The Peacekeeper Combat Crew Experience 159
Momentum Builds for Peacekeeper Deactivation 163
The Air Force Deactivates the Peacekeeper 165


Arms Control Agreements Compel Minuteman Force Structure Changes in the 1990s 169
U.S. Leaders Decide to Extend the Service Life of the Minuteman III 172
The Air Force Implements Minuteman III Flight System Modifications 174
Guidance Replacement Program (PRP) 174
Propulsion Replacement Program (GRP) 175
Propulsion System Rocket Engine (PSRE) Life Extension Program (LEP) 176
Safety Enhanced Reentry Vehicle (SERV) Program 176
The Minuteman III Receives Ground System Modifications 178
REACT Service Life Extension Program (SLEP) 178
Environmental Control System (ECS) Service Life Extension Program (SLEP) 178
Minuteman Minimum Essential Emergency Communications Network (MEECN) Program (MMP) 179
ICBM Security Modernization Program 180
ICBM Cryptology Update 181
The Bush Administration Assesses the Minuteman III 182
The Air Force Inactivates the 564th Missile Squadron 184
The Obama Administration Addresses the Minuteman III’s Future 187
<table>
<thead>
<tr>
<th>Contents</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Minuteman III Combat Crew Experience in the New Century</td>
<td>189</td>
</tr>
<tr>
<td>An Uncertain Future</td>
<td>196</td>
</tr>
<tr>
<td>Appendices</td>
<td>199</td>
</tr>
<tr>
<td>Notes</td>
<td>239</td>
</tr>
<tr>
<td>Glossary</td>
<td>306</td>
</tr>
<tr>
<td>Bibliography</td>
<td>309</td>
</tr>
<tr>
<td>Index</td>
<td>337</td>
</tr>
</tbody>
</table>
D r. David Spires provides an important contribution to the storied history of the ICBM force in his book, *On Alert: An Operational History of the United States Air Force Intercontinental Ballistic Missile Program, 1945-2011*. In today’s world, it is difficult to fully grasp and appreciate the cultural and geopolitical climate that existed after the Allied victory in World War II. The rise of the Soviet Union, the lack of insight into actual military capabilities held by the Soviets, and the threat of nuclear annihilation were existential concerns for the United States leadership. Ensuring the nation’s survival in this environment—particularly in the face of the war-weary mindset of the people—required tremendous wisdom and technical foresight.

Developing a credible means to deliver a nuclear weapon to intercontinental distances on very short notice provided a powerful deterrent against aggression toward the United States. The men and women who eventually built these intercontinental-range rockets, as well as the ones who transformed nuclear weapons to be capable of launching on these rockets, deserve a key place in our nation’s history. Dr. Spires’s book describes their struggles, both on the technical front and on the political front, as they pursued game-changing capabilities.

From the early Atlas and Titan missiles to the Minuteman and Peacekeeper families of missiles, the prowess of our engineers and scientists was evident. And it’s again important to remember the era Dr. Spires is referencing: the rudimentary computing power available dictated that most design calculations were done by slide rule. And yet, they succeeded in spectacular fashion, as clearly demonstrated in Dr. Spires’s book.
The value of the government-industry-academia partnership cannot be overstated in those development programs. Dr. Spires cites many key leaders in these various camps who ensured the success of the projects and who provided the drive to completion. He has carefully documented their contributions to give credit where it is clearly due. General Benny Schriever and his team at the Western Development Division in Inglewood, California, literally changed the course of history by designing and building the rockets needed for ICBM performance, and they also paved the way for the United States space program. Dr. Spires captures the intrigue and difficulties which faced that team.

Later chapters in the book capture the challenges of operating the ICBMs and keeping them viable in the modern era, to include describing the modification and sustainment projects that keep the ICBM weapon systems viable for the current era. The development of the Peacekeeper missile and the various basing modes considered are important insights into the history of deterrence debates in this country.

*On Alert* is a fascinating look at a period in our nation's history that is too often overlooked. The vital role the ICBM played in keeping the peace in the Cold War era is increasingly less understood by our populace. Dr. Spires's careful documentation of the past and present contribution of the ICBM force to global deterrence will ensure the lessons of this period are not forgotten.

WILLIAM L. SHELTON
General, USAF
Commander
Air Force Space Command
On Alert: An Operational History of the United States Air Force Intercontinental Ballistic Missile Program, 1945–2011 is a study of both the nation’s land-based strategic missile force and the men and women who operated and supported it. For more than half a century, Air Force intercontinental ballistic missiles (ICBMs), from Atlas and Titan to Peacekeeper and Minuteman, have been on alert twenty-four hours a day fulfilling their role in the U.S. Triad of strategic defensive forces. The venerable Minuteman III ICBM continues this important deterrent mission in the post-Cold War world of the 21st century.

Alert meets the need of a single-volume overview of the Air Force ICBM story, serving as a guide and introduction to interested readers. It both reviews the era described in Jacob Neufeld’s impressive study, The Development of Ballistic Missiles in the United States Air Force, 1945–1960, and continues the narrative through the remainder of the Cold War and into the second decade of the new century. Throughout, the focus is on the operational aspect of the missiles and on the missileers.

Chapter 1 describes the efforts of the Air Force and its fellow service competitors to develop ballistic missiles in the aftermath of World War II. The chapter examines the policy, organizational, and funding constraints, based largely on inter- and intra-service rivalries, that Air Force missile advocates had to overcome in order to establish an effective enterprise. President Dwight D. Eisenhower’s determination to protect the nation from surprise attack provided the momentum needed by the fledging ICBM program and its supporters. Along with the other services, the Air Force pursued missile—and satellite—development by establishing the Western Development Divi-
sion and giving its commander, Brigadier General Bernard A. Schriever, wide-ranging responsibilities to produce an operational ICBM by the end of the decade. By 1955, Schriever and his team had established an unprecedented crash program to develop both the Atlas ICBM and its more sophisticated backup, the Titan.

Chapter 2 focuses on the challenges overcome by the Air Force, the Army Corps of Engineers, and the industrial community in creating the nation’s first-generation ICBM force to confront the “missile gap” with the Soviet Union. Under the “concurrency” management concept, General Schriever pursued simultaneous completion of missile development and testing, base construction, deployment, and training. Although the Air Force-led team fielded an operational fleet of Atlas D, E, F, and Titan I missiles on schedule, these liquid-propellant ICBMs were beset by safety, survivability, and reliability problems that required extensive modifications to keep the majority of them operational before their deactivation in 1965. Already considered obsolete when placed on alert, this initial short-lived ICBM force, nevertheless, provided an effective Cold War land-based nuclear deterrent and established the groundwork for development and deployment of the more capable Titan II and Minuteman ICBMs to follow.

Chapter 3 discusses the second-generation Titan II, the most powerful ICBM in the nation’s Triad of strategic defense forces throughout its operational lifespan. Making up less than 6 percent of the ICBM inventory, the Titan II fleet represented fully one-third of the total ICBM megatonnage. Its revolutionary design and operational characteristics overcame its predecessors’ weaknesses and enabled Titan crewmembers to launch the missile rapidly, directly from its silo. Unlike its Minuteman and Peacekeeper solid-propellant counterparts, the Titan II required each four-person crew to adopt a “hands-on” approach to missile operations and maintenance from their underground launch control center located in close proximity to the missile silo. The Titan crew also became the nation’s first to integrate women into its ranks, both as crewmembers and as maintenance specialists. Although modifications kept the Titan force operational into the 1980s, the missile’s age and several tragic accidents precipitated substantial public criticism. The Titan II became a casualty of arms control restrictions and of a new administration’s strategic modernization agenda that favored replacing it with the far more sophisticated Peacekeeper ICBM.

Chapter 4 examines the “ace in the hole” Minuteman that served as the bedrock of America’s land-based nuclear deterrent for more than twenty-five years. From the beginning, Minuteman planners conceived of a large force of extremely efficient, reliable, and survivable solid-propellant ICBMs, capable of launching rapidly and effectively against all types of Soviet targets. By 1967, the Air Force had deployed the programmed force of 1,000 Minuteman ICBMs in six locations; by 1975 the Minuteman I had been retired, leaving a force that consisted of the Minuteman II and the MIRV-capable Minuteman III. In contrast to their Titan II counterparts, Minuteman crewmembers operated in launch control centers considerably separated from their missile silos; generally encountered more serious morale problems; and underwent a far more contentious experience when women joined the two-person combat crews.
in the mid-1980s. Modifications and improvements would continue to keep the missiles operational far beyond their predicted design and service life spans. Although the Minuteman II succumbed to age and policy changes at the close of the Cold War, as of 2011, 450 Minuteman IIIs remained fully operational, and upgrades promised to keep the Minuteman the nation’s ace in the hole well into the 21st century.

Chapter 5 centers on the Peacekeeper ICBM, which represented the most powerful, most technically sophisticated, and most accurate ballistic missile in the U.S. strategic nuclear arsenal from 1986 to 2005. Capable of delivering its ten MIRV-warheads with more than twice the accuracy of the Minuteman III, the fifty deployed Peacekeepers provided the central threat to Soviet and Russian hardened strategic targets throughout its nineteen-year operational lifespan. Despite its superior accuracy, payload, and launch capability, however, it became the focal point in a divisive debate over the nation’s strategic direction and arms control priorities that centered on how best to base the Peacekeeper force to ensure its survivability against increasingly capable Soviet ICBMs. Ultimately, planners compromised by deploying the Peacekeeper force in Minuteman silos, but they also proposed a mobile “rail garrison” alternative. Arms control agreements in the early 1990s gave the missile its “death sentence” and put the Peacekeeper on the road to elimination. Although it continued its role as a bargaining chip and underwent only modest system improvements, it remained the nation’s ultimate deterrent weapon system until its deactivation early in the new century.

Chapter 6 discusses the viability of the Minuteman III as the nation’s current and future land-based strategic missile in the post-Cold War era. Two loosely defined schools of thought on the Minuteman’s future emerged within the greater Air Force ICBM community. One favored incremental upgrades to extend the Minuteman’s service life indefinitely, while the other preferred development of a new, more capable replacement for the Minuteman III. Proponents of both had to contend with a diminishing industrial base and critics who questioned the very role of the ICBM in the post-Cold War strategic environment. With arms control agreements prescribing reduced nuclear forces and regional conflict and the global war on terror demanding priority attention, the Air Force chose to reduce, reorganize, and decentralize its nuclear “enterprise.” Nuclear incidents in 2006 and 2007, however, compelled the service to implement a “reinvigoration of the Air Force nuclear enterprise” to provide renewed appreciation for the nuclear deterrent mission, more effective stewardship of nuclear weapons, and greater career opportunities for missileers. For defense planners in 2011, the question surrounding the remaining 450 Minuteman IIIIs continued to center on whether to sustain the aging deterrent—first to 2020, then 2030, and even 2040 and beyond—or to initiate development of an entirely new and considerably more sophisticated ICBM to support the ICBM leg of the strategic Triad.

In preparing this study I received help from many able people. Above all, I must acknowledge the generous assistance I received from my friends and colleagues in the Air Force Space Command’s History Office: Command Historian Mr. George W.
“Skip” Bradley, Deputy Command Historian Dr. Rick W. Sturdevant, Historian and Editor Dr. Richard “Rick” Eckert, and historian Mr. Jerome V. Schroeder. All four read the entire manuscript critically and offered important suggestions. Mr. Bradley directed the project superbly, provided full use of the command’s excellent historical archives, and facilitated my access to archival collections at other institutions. I benefited greatly from my many discussions of policy and technical issues with Dr. Sturdevant, whose comprehensive knowledge and encouragement invariably kept me on the right track. Dr. Sturdevant and historian Dr. Herbert M. Zolot wrote the biographies of missile pioneers included in this study. Dr. Eckert also deserves special thanks for agreeing to serve as editor once again, this time following his retirement from the Air Force history program. His final editing, including design and page layout, ensured the project’s success. Mr. Schroeder tracked down many documents and worked tirelessly to have classified material downgraded and made available for my use. Thanks also to historian Ms. Margaret Ball who located and provided the pioneer biographies, to artist Mr. Jay Ashurst for use of his pioneer portrait images, and to Mr. Bradley and historian Mr. John M. Lacomia for completing the myriad printing arrangements.

I am indebted to my friend, Dr. Elliott V. Converse III, who generously agreed to take time from his OSD projects to read and comment on the draft for accuracy and clarity. I also wish to thank former missileer Mr. James C. Mesco, Space Innovation & Development Center historian, for providing insightful comments on the Minuteman and Peacekeeper chapters. Two former senior officers with broad missile experience, General Lance W. Lord and Major General Thomas F. Deppe, reviewed the manuscript, while retired Lieutenant General Harry E. Goldsworthy provided a first hand account of his experience as Site Activation Task Force commander for the initial Minuteman deployment at Malmstrom Air Force Base, Montana.

Many other government historians and museum officials deserve my thanks for their help. Mr. Michael R. Byrd, 90th Missile Wing historian, provided a base of operations at F. E. Warren Air Force Base for my numerous visits, introduced me to former missileers, and provided me with a wealth of material from his archive. Dr. Harry N. Waldron, Chief of the Space and Missile Systems Center History Office, generously allowed me full use of the Center’s extensive archival holdings, while Center historian Mr. Robert Mulcahy supplied me with an important collection of missile system and personnel images. Likewise, Dr. John C. Lonnquest, Chief, Office of History, U.S. Army Corps of Engineers, put his collection of Corps ICBM construction documents at my disposal, while his colleague, historian Mr. Michael Brodhead, efficiently guided me through the histories and correspondence. I also wish to thank Dr. Mary D. “Dixie” Dysart, Chief of the Research Division, Air Force Historical Research Agency, for responding to my many questions, Mr. Jeffrey Geiger, 30th Space Wing historian, for supplying material on early MX/Peacekeeper development, and Mr. Michael Hosking, Cultural Resource Specialist at the Minuteman Missile National Historical Site, for arranging a visit to the site archives and a tour of the Delta-01
missile alert facility and the Delta-09 launch facility. Two individuals associated with
the Titan II missile deserve recognition for their assistance: Mr. Chuck Penson, Titan
Missile Museum Historian and Archivist, for introducing me to the Titan II and
making his archive available, and to David K. Stumpf, Titan II author, for reading and
commenting on the Titan II chapter. Two museum curators also merit strong praise
for their help procuring photographs and documents. On numerous occasions, Ms.
Paula B. Taylor, Director of the Warren ICBM & Heritage Museum, supplied me with
documents and photographs, and gave me access to Warren’s impressive collection
of Minuteman and Peacekeeper equipment. Mr. Curtis Shannon, Curator of the
Malmstrom Air Force Base Heritage Center, also came to my aid by furnishing an
extensive set of photographs depicting Minuteman deployments. Others who as-
sisted me include Mr. Bruce S. Stewart, Air Force Global Strike Command historian,
Dr. Jerome Martin, US Strategic Command historian, and former 45th Space Wing
historian, Mr. Mark C. Cleary.

Additionally, I owe a debt of gratitude to many active duty and retired missileers
who helped make me more knowledgeable and this study more accurate and realistic.
Three missileers merit special mention. Colonel Linda S. Aldrich both provided
an insightful description of her pathbreaking experience as one of the initial cadre
of women entering Minuteman and introduced me to many of her past and present
colleagues in the missile field. Among the latter, I am most grateful to retired Colonel
Norman B. “Blaine” McAlpin, who currently serves as Twentieth Air Force Technical
Director, for repeatedly offering expert commentary on the missile career field in
general and drawing on his wealth of experience to answer my numerous technical
questions on missile operations and maintenance. The third missileer to single out
is retired Colonel Charles G. Simpson, the indefatigable executive director of the
Air Force Association of Missileers, who recounted his own missile experience and
furnished me both a listing of missileers to contact and an extensive digital archive of
documents and photographs.

Among active duty missileers, I am grateful to the following for their insights on
various aspects of the missile career field: Colonels Jeffrey E. Frankhouser and Robert
M. Walker, Lieutenant Colonels Anita Feugate Opperman, Paul L. Johnson, David D.
Kelley, Jonathan E. Lowe, and Larry D. Opperman, Jr., Majors Polly S. Brown and Ja-
son D. Smith, and Captains Jannel A. Emery, Nicole S. Holmstrom, Alina V. Matson,
and Diane E. Percy.

Many retired missileers also contributed to this study. I especially wish to acknowl-
edge the help of Colonel Rodney L. Holder for his insightful comments on his Titan
II, Minuteman, and Peacekeeper experience. Others who deserve thanks are Col-
nels Arthur T. Beiser, Ronald V. Bouchert, Albert R. “Rich” Greene, Jr., Patricia M.
Forbes, Barry D. Kistler, Joseph C. Friedman, Edmund L. Robert, Robert E. Servant,
and David H. Teigen, Lieutenant Colonel Michael J. Precella, Major Gerard “Rod”
Reidy, Captain Melissa Reidy, Chief Master Sergeant William D. “Dave” Clark, Senior
Master Sergeant Rex C. Ellis, and Mr. Rulon Booth.
Also deserving praise is Ms. Regina L. Carlyon and her colleagues in the University of Colorado’s Interlibrary Loan department for their tenacious efforts to fulfill my every request. Finally, my special appreciation to MM, FL, and above all, my wonderful TASita.
Chapter I

The Air Force Enters the Missile Age, 1945–1955

In the aftermath of World War II Air Force leaders laid the foundation for future operations in the missile arena by establishing a clear research and development focus for the new service. Commanding General of the Army Air Forces Henry H. "Hap" Arnold and his eminent scientific advisor Theodore von Kármán set the course through their policy statements, organizational decisions, and comprehensive analysis of Air Force scientific requirements for a technological future. Their legacy appeared endangered in the late 1940s when tight budgets and higher priorities confined long-range missile development primarily to low-level studies. Air Force leaders seemed intent on establishing Air Force responsibility for long-range ballistic missiles, but remained unwilling to promote their development.

By the early 1950s, however, change was in the air. New concerns about Soviet political and military activity and technological progress compelled leaders to reexamine the country's defense posture. In doing so, intercontinental ballistic missiles (ICBMs) received new attention. Larger defense budget outlays and successful testing of thermonuclear devices and the prospect that they could be reduced in size and weight offered the promise of a feasible long-range ballistic missile. A number of government officials and Air Force officers who shared Arnold's legacy acted as catalysts for change by creating new organizational structures for missile development and promoting greater awareness of the ICBM. Although they faced strong opposition every step of the way, their considerable efforts helped set the Air Force and the nation on the path to an operational ICBM by the end of the decade.
The Air Force Shuns Ballistic Missiles

In a postwar America, with armed forces undergoing demobilization and the reassertion of domestic priorities, Arnold and other Air Force innovators quickly realized that it was one thing to advocate an imaginative, liberally-funded research and development program for the Army Air Forces (AAF) and quite another to have it put into practice by a conservative military establishment. In the years after World War II, missiles drew only modest attention from the administration of President Harry S. Truman and the defense establishment. Initial postwar interest in long-range guided missiles soon succumbed to an Air Force policy that relied on strategic bombers, interservice conflicts over roles and missions, and administration-imposed budget ceilings that compelled Air Force planners to focus on present rather than future service needs.1

General Arnold was not the only military leader impressed by the German v-2 achievements during the war. In the flush of victory, all the services sought to build on the wartime experience by conducting rocket and guided-missile experiments based either on aerodynamic, jet-propelled “cruise” missile principles, or the German v-2 short-range liquid-propellant ballistic rocket technology. Operation Paperclip brought nearly 130 leading German rocket scientists, a vast array of data, and approximately one hundred dismantled v-2s to White Sands Proving Ground, New Mexico. There, under Project Hermes, the Army Ordnance Department conducted upper atmospheric research into airborne telemetry, flight control, and two-stage rocket capability with representatives from the Air Force, the Air Force Cambridge Research Center, the General Electric Company, the Naval Research Laboratory, and a number of other scientific institutions, universities, and government agencies. From 1946 to 1951, participants received valuable data from sixty-six v-2 launches that first carried various scientific instruments, then, primates.2

Back in early 1949 the Army, which viewed rockets as extensions of artillery, had successfully used a v-2 as the launch vehicle for the Jet Propulsion Laboratory’s wac Corporal second-stage rocket to an altitude of 250 miles. As Frank Malina, the missile’s project director, noted, “The wac Corporal thus became the first man-made object to enter extra-terrestrial space.” These early v-2-based Bumper-wac Corporal experiments set the stage for the Army’s future missile and space program involving the Redstone, Jupiter, and Juno boosters developed by the von Braun team under Army supervision after it moved in 1950 from Fort Bliss, Texas, to the Redstone Arsenal at Huntsville, Alabama. Postwar Naval rocket research led by the Applied Physics Laboratory of Johns Hopkins University and the Naval Research Laboratory in Washington, D.C., produced two reliable and effective sounding rockets: the fin-stabilized Aerobee, a larger version of the wac Corporal modified for production as a sounding rocket, which achieved a height of 80 miles; and the more sophisticated Viking, which would reach an altitude of 158 miles in May 1954.3

Despite General Arnold’s interest in developing long-range missiles of the v-2 type, the Air Force followed the path charted by Theodore von Kármán, which stayed
within the atmosphere, then the Air Force’s only operating environment. Short-range jet-propulsion weapons seemed to offer faster development and better payload capabilities. They also directly complemented the strategic bomber fleet, the nation’s intercontinental strike force of the day. In October 1945 the Army Air Forces Air Technical Services Command solicited proposals from seventeen aircraft companies for a ten-year research and development program for pilotless aircraft, and the fiscal year 1946 budget included an impressive twenty-six different projects. Yet only two involved missiles in the 5,000-mile range, and one of these consisted of a Northrop Aircraft supersonic turbojet vehicle. The other, Project MX-774, a supersonic ballistic rocket design from the Consolidated Vultee Aircraft Corporation (Convair), would serve as the precursor of the future Atlas ICBM.4

If the Army Air Forces seemed devoted to shorter-range air-breathing missiles, it could not abandon long-range missile development to the Army or Navy. All three services jealously guarded their prerogatives and jockeyed fiercely with their rivals over roles and missions in the postwar world. As it looked to a future as an independent service, the Army Air Forces proved particularly sensitive to new, unproven weapon fields such as rockets and missiles. While Major General Curtis E. LeMay, the recently appointed deputy chief of air staff for research and development, in early 1946 staked out the AAF’s claim to any prospective satellite mission, he also became embroiled with Army and Navy representatives over which service should be responsible for what types of missiles. Above all, the Army Air Forces took special interest in missiles it considered strategic.

Confusion and friction about missile development and operational control had emerged earlier, during the war, in the competition within and among the services. The AAF sought primary responsibility for all missile programs, and a number of Army Air Forces offices asserted their “special” interests, while attempting to ward off the Army Ordnance Department and various other elements in the War Department. A directive issued by Lieutenant General Joseph T. McNarney, deputy chief of staff of the Army, on 2 October 1944, attempted to clarify the situation by assigning the AAF responsibility for “all guided or homing missiles launched from the ground which depend for sustenance primarily on the lift of aerodynamic forces.” Although this ruling appeared to award the Army Ordnance Department (an organizational element of the Army Service Forces) the ballistic missile mission, the AAF continued to complain of Army encroachment into the cruise missile field.5

Conflict persisted into the postwar era as each of the services pursued its own guided missile program while keeping a wary eye on its competitors. In a revealing memorandum in September 1946 to AAF chief General Carl A. Spaatz, Arnold’s successor, General LeMay expressed his concerns about the Air Force maintaining its rightful “strategic role.” Admitting that the “long-range future of the AAF lies in the field of guided missiles,” he cautioned that the Army justified its control of guided missiles as their being extensions of artillery, and might use the same argument to acquire responsibility for close air support and strategic aircraft. After all, he noted, the
“stated opinion” of the Army Ground Forces is that guided missiles are extensions of artillery. LeMay saw the possibility of the Army Air Forces losing control of a weapon system that might replace manned aircraft in the future. Yet control of the weapon did not necessarily mean that it should be developed, at least at the present time. Meanwhile, the Navy entered the contest for preeminence. Given AAF aspirations and its strategic mission, Naval leaders joined their Army counterparts in arguing that each service should have the freedom to develop missiles in response to its particular needs.6

On 7 October 1946 the War Department’s assistant secretary of war for air, W. Stuart Symington, attempted to settle the dispute between the Army Ground Forces and the Army Air Forces by awarding the latter responsibility for research and development activities pertaining to all guided missiles. The directive remained silent, however, on the important question of ultimate operational assignment. The issue between the two services lay dormant until after September 1947, when the establishment of an independent Air Force reopened the competition. A year later the National Military Establishment (redesignated the Department of Defense in April 1949) achieved a modicum of peace when the Air Force relinquished its responsibility for conducting missile research and development work for the Army. In return, the Air Force received authority to develop strategic missiles, while the Army became responsible for tactical missiles. Meanwhile, the Air Force continued its path breaking ballistic missile defense studies, Projects Wizard and Thumper. Although the latter was cancelled in March 1948, Project Wizard continued until early 1958, when then-Secretary of Defense Neil H. McElroy reacted to persistent feuding over ballistic missile defense responsibilities by awarding the Army the mission of strategic defense and merging Wizard with the Army’s Nike Zeus anti-ballistic missile system.7

The problem of interservice rivalry over missiles received little help from the defense committees most responsible for providing direction. With passage of the National Security Act of 1947, the Research and Development Board replaced the Joint Research and Development Board. Dr. Vannevar Bush continued as chairman until his retirement in October 1948. Neither he nor those active on subordinate committees, like the Committee on Guided Missiles, possessed the authority needed to provide firm direction. Too often they allowed the complex committee system to work to their disadvantage and avoid decisive action.

Throughout the conflict over roles and missions, the Air Force demonstrated more interest in gaining and preserving its prerogatives than moving ahead with a strong missile research and development program. Paradoxically, as the Air Force’s commitment to develop an ICBM diminished, its determination to be designated sole authority responsible for long-range missiles increased. Even with long-range cruise missiles, for which Air Force leaders sought exclusive control based on the service’s strategic mission, it normally chose not to implement programs leading to operational missiles. Efforts to garner exclusive control of missiles would continue. In September 1948, for example, the National Military Establishment awarded the Air Force
operational control of strategic, surface-to-surface cruise missiles such as the Snark and Navaho. Eighteen months later, in a very important March 1950 decision, the Air Force received official responsibility for developing long-range strategic missiles and short-range tactical missiles that related to the service’s air interdiction and close air support missions. Later, near the end of the Truman administration, the Air Force successfully defeated the Army’s bid to develop the Redstone rocket’s range beyond two hundred miles. The strategic mission would remain with the Air Force.8

Already in the late 1940s Air Force leaders had signaled their attitude about research and development when forced to respond to the Truman administration’s drastic economy drive that began in late 1946. Compelled to choose between supporting the forces of the present and those of the future, the Air Staff ignored the admonitions of General Arnold and Dr. von Kármán by focusing on manned aircraft to the detriment of guided missiles. As a result, Air Force research and development programs for missiles suffered severely in the late 1940s.

Budget figures help tell the story of decline. Air Force leaders needed to show a firm commitment to research in terms of policy advocacy and budget allocation. As expressed by Lieutenant General Benjamin W. Chidlaw, commander of Air Materiel Command, “Many people have given lip-service to the magic phrase ‘Research and Development.’ Very few of us have really fought for it—and made sacrifices for it.”9 Without such a commitment, the Truman economy drive was bound to seriously erode research and development funding and projects. The fiscal year 1946 Army Air Forces budget allocated $28.8 million for research and development, with half earmarked to support the twenty-six guided missile programs sponsored in 1946. The initial fiscal year 1947 budget reflected the importance of research with a grant of $75.7 million, $29 million of which was dedicated to guided missiles research. Then the budget ax fell. Under pressure from the War Department, in December 1946 the Army Air Forces cut the missile budget by $5 million and eleven missile projects. Additional funding cuts in May led planners to eliminate five more programs.10

Faced with drastic reductions in the guided missile program, the Air Materiel Command (AMC) decided to protect those programs promising the earliest operational availability, and in June 1947 General Hoyt S. Vandenberg, the AAF’s deputy commanding general, approved the AMC recommendations. This criterion effectively eliminated the only long-range ballistic missile project, Convair’s MX-774, and the AAF terminated the contract on 1 July. That same month the Air Staff established development priorities for managing the smaller budgets they expected in the future. The subsonic bomber and air-to-air and air-to-surface missiles received top priority. In the belief that long-range surface-to-surface missiles would be prohibitively expensive and require ten years to develop, build and launch, long-range ballistic missiles stood at fourth priority.11

By 1947 the pressure to downgrade the development priority of long-range ballistic missiles proved overwhelming. In the growing Cold War the administration increasingly looked to strategic bombers and the atomic bomb as the country’s main line of
retaliatory defense. Moreover, manned aircraft remained the heart of the Air Force, and advocates of a new, if potentially revolutionary, weapon and “push-button” warfare found themselves outmatched in competition for funding. An Air Force culture wedded to pilots in the cockpit would long feel threatened by pilotless ballistic and cruise missiles. Critics focused on the technological challenges of missile development. The budget slashers argued that putting scarce funds into a research program that might not be realized for a decade or possibly never could not be justified in light of current priorities. Therefore, one must continue with a cautious step-by-step approach to any long-range missile program. Missile advocates found themselves victims of a circular argument: missiles seemed too challenging technologically, but no funds could be spent on solving the technological dilemmas; so the problems would go unresolved and the missile would remain “impossible.” To questions about the logic of budgeting for missile programs, the answer always seemed to be the dogmatic response: “the time is not right” for an expanded program.

The Air Force’s devotion to aerodynamic missiles like the intercontinental MX-770 Navaho, with its combination ramjet-booster rocket propulsion, and the subsonic MX-775 Snark and MX-771 Matador missiles must be seriously questioned. Planners consistently offered the rationale that aerodynamic research benefited ballistic missile research. This proved correct to a point, as later shown by the transfer of the Navaho Rocketdyne engines for use in the Redstone and Atlas systems. Yet cruise missile guidance systems offered little commonality, while aerodynamic vehicles could provide no help with the ICBM’s high-speed reentry from space into the upper atmosphere. Unfortunately, Air Force scientists never reexamined the assumptions so forcefully established in the 1945 von Kármán reports. Although the Air Staff reassessed guided missile priorities in 1948 and 1949, it elected not to change them. Fortunately, Convair decided to use its own funds to continue its long-range missile project, MX-774, under imaginative structural engineer Karel J. “Charlie” Bossart.

Back in April 1946, the Army Air Forces had awarded Convair a $1.4 million contract (increased to $1.893 million two months later) to evaluate two missile proposals, one for a subsonic, aerodynamic missile and the other for a rocket-powered ballistic missile. Both were to be capable of delivering a 5,000-pound warhead anywhere from 1,500 to 5,000 miles to within 5,000 feet of designated targets. Following budget cuts at the end of the year that included Convair’s subsonic missile design, the company would concentrate on the intercontinental ballistic missile (Project MX-774). The V-2 represented the point of comparison and departure for Bossart and his team. From the start, they focused on reducing the weight of the missile with innovative concepts and experiments involving internal fuel storage and tank design, swiveling engines, and various methods of separating the nose-cone warhead as a solution to the formidable reentry problem. A separating nose cone meant that it rather than the entire missile would endure the excessive heat upon reentering the atmosphere. This would result in a major weight reduction, an increase in the missile’s range, and elimination of the need to design engines and fuel tanks able to withstand the heat.
Mr. Karel J. “Charlie” Bossart was involved in the early development of rocket technology with Convair Corporation and is known as the “father of Atlas.” Mr. Bossart was largely responsible for conceiving in 1946 the design of the propellant tanks, which served as the primary structure for the Atlas launch vehicle. The tanks were a unique design consisting of pressure-stabilized, thin steel, a monocoque structure with a common inter-tank bulkhead—a “steel balloon.” One writer described Bossart’s design “one of those brilliant, innovative, and yet simple ideas, that have withstood the test of time as a major contribution to the advancement of astronautics.”

Born in 1904 and a native of Belgium, Mr. Bossart graduated from the University of Brussels in 1925 with a degree in mining engineering. He won a scholarship to the Massachusetts Institute of Technology from the Belgian-American Education Foundation. At MIT he studied aeronautics, specializing in structures. He remained in America working on several airplane projects. By 1945 he was Chief of Structures at Consolidated-Vultee Aircraft in California (Convair, later General Dynamics). As Chief of Structures, he worked on a proposal for Project MX-774, the first U.S. study of the V-2 and long-range missiles. Intrigued by the potential for such vehicles to do things airplanes could not, he was challenged by the skepticism about their feasibility. Mr. Bossart emerged as the driving force who successfully transformed the MX-774 from a study to a vehicle test program. When the Air Force requested that Convair develop a rocket with an 8,200-kilometer range, Mr. Bossart was placed in charge of development. The Air Force agreed to the construction of ten MX-774 vehicles, with three different developmental stages. Stage A, the Teetotaler, was a sub-sonic, self-navigational jet plane. Old Fashioned, Stage B, was a test missile to try out the design work for the final stage. Stage C, the Manhattan, was to be the end result—a rocket with a range of 8200 kilometers. The MX-774 was cancelled in 1947 due to budget restrictions. Bossart, however, convinced the Air Force to fund the completion of the three vehicles allowing Convair Corporation to launch three MX-774S with less than satisfactory results. The tests, which concluded in December 1948, however, successfully demonstrated several design concepts including Bossart’s pressurized, monocoque tanks.

In 1949, in response to the Soviet Union’s detonation of its first atomic bomb, interest in the MX-774 project was rekindled. Bossart again led efforts to revive the program in 1951 as the Project MX-1593. Because of its familiarity with the MX-774, Convair was awarded the contract. Karel Bossart again headed the team who renamed the system “Atlas,” in honor of the mythological being who bore the weight of the world on his shoulders. In addition to the integral, pressurized, monocoque tanks, Mr. Bossart is credited with conceiving gimbaling of entire rocket engines. He also experimented with various means of separating the nose-cone warhead as a solution to the reentry problem. All of these experiments would prove important in designing the Atlas. The Atlas finally went into production in 1955 and has remained as one of the most weight efficient designs ever developed.

A member of his team at Convair described Bossart as “a one-man System Requirements and Functional Analysis Group. … and much more effective. He could quickly understand all the requirements of a subsystem and then conceptualize a design that would perform all the critical functions most efficiently.” He recognized that for the Atlas liquid propellant tanks to be efficient they had to serve as both the primary vehicle structures as well as the propellant containers.

Karel Bossart retired from General Dynamics in 1967. He died on 3 August 1975. Among the awards he received which recognized his contributions to engineering and the Atlas program were the U.S. Exceptional Civilian Service Award in 1958 and the 1959 Collier Trophy from the U.S. Air Force and General Dynamics.
of reentry. Bossart’s key innovation, representing another weight savings measure, was to replace the double-walled V-2 fuel tank structure with single-walled pressure-stabilized propellant tanks made of aluminum no thicker than a dime. Serving as part of the missile structure itself, the dime-thin aluminum “balloon” required pressure either from bottled-nitrogen in storage or from propellants loaded for operational use to avoid collapsing. Additionally, the introduction of swiveling engines represented a significant improvement over the V-2’s use of movable graphite vanes in the exhaust system, which had reduced its thrust by as much as 17 percent. Responding to commands from a gyro-stabilized autopilot guidance system, the swiveling engines of the MX-774 provided directional thrust and much improved control of the missile. Built by Reaction Motors, Incorporated, each of the four clustered engines produced a thrust of 2,000 pounds and burned a mixture of alcohol and liquid oxygen supplied by a hydrogen-peroxide, pressure-fed turbo pump. Measuring 31 feet in length and 2.5 feet in diameter, the missile weighed 1,200 pounds without propellants.15

Meanwhile, in the late 1940s the outlook for the long-range guided missile project appeared bleak. As noted earlier, in July 1947, shortly before Convair had completed the first test vehicle, the Truman administration and Congress compelled the AAF to accept funding cuts for either its bomber fleet or some of its future weapons proposals. Not surprisingly, the service elected to protect its present air fleet, and continue with the aerodynamic Navaho and Snark cruise missiles they considered easier to develop and having better range and payload capabilities than the ICBM. Consequently, the Air Staff cancelled the MX-774 because, as one official asserted, ballistic missiles offered no prospect of “any tangible results in the next 8 to 10 years.” The same official also argued that the ballistic missile program would prove too costly, with estimates for research and development as much as $50 million, let alone the $500,000 estimated for each missile produced. Critics also pointed to the major technical roadblocks to achieving a highly accurate missile guidance system, reducing the weight of atomic warheads, and developing a heat shield capable of protecting the nose cone.16

Convair, however, had unspent contract funds available, and the AAF authorized the company to continue its research on guidance systems and nose-cone reentry and to complete and launch three test vehicles at the White Sands Proving Ground. Following several months of static tests at Point Loma, California, near San Diego, the first launch occurred on 13 July 1948. The missile reached an altitude of one hundred miles before the nose cone was jettisoned, and then floated back to earth under its 40-foot parachute. Unfortunately, after a flawless ascent to 6,200 feet in 12.6 seconds, the engine quit abruptly, and, when a crewmember failed to deploy the parachute by remote control, the missile exploded when it fell to the ground. Investigators recovered most of the wreckage, including the on-board camera with instrumentation film intact, and chose to record the flight as partly successful. The remaining two flights ended prematurely as well, but lasted longer, with the second aloft for forty-eight and the third for fifty-two seconds. Although the flight tests achieved only modest success, they validated Bossart’s designs and provided Convair a wealth of information
that would prove beneficial when the Air Force decided to pursue the Atlas program seriously in 1951. Meanwhile, Convair elected to use company funds to keep the MX-774 project afloat as a low priority item.¹⁷

Ballistic Missiles Receive New Life

The first signs of a significant change in attitude toward research and development in general and guided missiles in particular appeared in 1949. Faced with growing criticism that the Air Force was paying insufficient attention to research and development, General Vandenberg requested the Scientific Advisory Board to examine the state of the service’s research and development. It appointed a special committee chaired by widely respected Louis N. Ridenour, a physicist and dean of the graduate college at the University of Illinois. Throughout the summer of 1949 he and his committee examined the Air Force’s research and development programs, then on 21 September submitted a highly critical report. The committee determined that “existing organizations, personnel policies, and budgetary practices do not allow the Air Force to secure the full and effective use of the scientific and technical resources of the nation.” Its major recommendations included ensuring better assignment and promotion opportunities for technical officers and reorienting budget priorities because “if war is not imminent, then the Air Force of the future is far more important than the force-in-being and should, if necessary, be supported at its expense.” The Ridenour Report is best remembered, however, for its organizational recommendations: the creation of a deputy chief of staff for research and development on the Air Staff, and a new major Air Force command for research and development.¹⁸ Elevation of the organizational status of research and development in the Air Force was von Kármán’s wish, too.

Because of expected opposition within the Air Force to a “civilian” report that called for radical change, sympathetic officers like Major General Donald L. Putt, the director of research and development in the Office of the Deputy Chief of Staff for Materiel, helped create a parallel, senior-level military group that would undertake a review similar to the Ridenour study and thereby promote broader acceptance for its recommendations. Their efforts produced the Anderson committee, named for its chairman, Air University’s commander, Major General Orvil A. Anderson, which conducted extensive interviews throughout the Air Force before issuing its report on 18 November 1949. The Anderson Report strongly supported the Ridenour committee’s findings, using the argument that failing to implement the recommendations might easily lead the Army and Navy to “take over responsibilities abdicated by the USAF.”¹⁹

These powerful arguments for change convinced General Vandenberg to implement the organizational recommendations promptly. On 23 January 1950, the Air Force created the Office of the Deputy Chief of Staff, Development, and the Research and Development Command (redesignated the Air Research and Development Command, or ARDC, in April) with headquarters at the Sun Building in Baltimore, Maryland. Yet it would take the “personal salesmanship” of retired Lieutenant Gen-
eral James H. “Jimmy” Doolittle, acting as special assistant to General Vandenberg a year later in the spring of 1951, to end Air Materiel Command’s foot-dragging. In late March General Vandenberg ordered the immediate transfer of AMC’s Engineering Division and other designated responsibilities and functions to the new command, and reassignment of ARDC directly to Air Force headquarters rather than AMC. If the new arrangement divided responsibility for weapons acquisition between the two commands, it nevertheless highlighted the importance of the research and development function in contrast to the heretofore production-oriented emphasis in Air Materiel Command. Significantly, the Air Staff assigned the guided missiles program to the new command.  

While the Air Force made organizational changes in the early 1950s, events on the international scene contributed to major reassessments of the country’s defensive posture. News that the Soviet Union had successfully detonated an atomic device in August 1949, communism’s triumph in China, and alarming reports of Soviet progress in missile development led to calls for increased military preparedness both in and outside the administration. In January 1950, President Truman authorized immediate development of the hydrogen or thermonuclear bomb and directed a comprehensive review of national security policy. In April, the result of that review, National Security Council paper 68 (NSC 68), called for sharp increases in U.S. military spending, not immediately approved by Truman who was concerned about such a program’s cost. The outbreak of the Korean War in June 1950 heightened the growing sense of national weakness. Congress authorized a seventy-group Air Force and nearly doubled the administration’s defense budget request from $14.4 to $25 billion. After the Chinese entered the Korean War in November, the president approved the force objectives established by NSC 68 and advanced the original target date for completing them from 1954 to mid-1952.

The deteriorating security environment and the Truman administration’s decision to rearm enhanced the importance of guided missile programs. In the summer of 1950, for example, Under Secretary of the Air Force John A. McCone submitted reports on America’s vulnerability to Soviet attack to Secretary of the Air Force Thomas K. Finletter, advocating a “Manhattan-type” program for missiles under the “most capable man who can be drafted.” In late August 1950 President Truman responded to calls for action by appointing K. T. Keller, chairman of the Chrysler Corporation, “Director of Guided Missiles.” Keller approached his job as missile “czar” on a part-time basis, and focused on getting missiles most likely to become operational rapidly, such as cruise missiles and the Army’s tactical Redstone ballistic missile. As a result, Convair’s MX-774 ballistic missile project held a much lower priority.

At the same time, the Air Force had received a number of reports on the progress of ICBM research from RAND, its think-tank established in 1946, initially to determine the feasibility of artificial earth satellites. In 1949 RAND’s comparison of air-breathing and ballistic missiles clearly favored the latter, while its report of December 1950 argued that technical progress with engines, guidance systems, and reentry vehicles
had made the long-range ballistic missile viable. It could point to North American Aviation’s development of liquid-propellant engines for the Navaho, which resulted by 1950 in the XLR43-NA-1, the first large American designed and produced liquid-fuel engine. Its more powerful successor, the XL43-NA-3, would later power the Atlas. Air Force interest in guidance technology centered on Dr. Charles S. “Stark” Draper’s work on all-inertial guidance systems at the Massachusetts Institute of Technology. By 1951 bombers using his system had proven accurate to within two miles over the course of a 3,000-mile flight. At the same time, the aerodynamic heating experiments of Ames Research Laboratory scientist H. Julian Allen showed that a blunt body was more efficient in dissipating heat than the sharply pointed nose cone used on the MX-774.23

Armed with a larger budget and clear evidence of ballistic missile technical progress, the Air Force reconsidered Convair’s long-range rocket proposal. The company’s presentations helped lead to a contract on 23 January 1951 from the Air Force for project MX-1593, which directed Convair to examine—once again—both the ballistic technique and the “glide” method, by which vehicles would use rocket power to reach the outer atmosphere then use their wings to glide through the atmosphere to their targets. The boost-glide approach reflected continued Air Force interest in the post-war “x”-series of high-altitude rocket-powered aircraft.24

The Air Force’s criteria called for both types of missiles to be able to launch 8,000-pound warheads 5,000 nautical miles and achieve a circular error probability (CEP) of 1,500 feet, later modified to one mile when smaller and lighter warheads became available.25 Convair’s six-month contract to conduct a “study and test program” for the two types of missile propulsion hardly represented a ringing endorsement of the ICBM concept. Nevertheless, by July Convair had produced an eight-volume assessment of air breathing and ballistic missiles, and included designs for both systems. On 1 September 1951, Convair engineers and the ARDC decided to drop the winged missile in favor of the ballistic-type rocket, largely because it represented a weapon considered unstoppable for the foreseeable future, while they believed the formidable technical problems could be mastered by the early 1960s. Convair had named the ballistic version Atlas, and its specifications clearly envisioned a mighty vehicle, with five or seven large clustered engines to power a missile 160 feet long and 12 feet in diameter.26

Over the next two years, Charlie Bossart continued to wrestle with the engine ignition reliability problems that had affected his test vehicles. Impressed by North American’s Navaho booster engine, Convair contracted for a modified version for the Atlas using a combination of kerosene and liquid oxygen. A major challenge, however, remained the ability to achieve smooth combustion and consistently ignite a second-stage engine at altitude. Because the few tests of “staging” that were conducted produced uneven results, Bossart elected to forego a genuine two-stage missile in favor of a more reliable “stage-and-a-half” design. The latter meant that the four
booster engines and single sustainer engine would be started together on the ground using propellants from the same pressure-stabilized tanks. Shortly after liftoff, the booster engines would be jettisoned, and the missile would rely on the sustainer engine for the remainder of the powered flight, to the point of nose cone separation. Although the Atlas would be powering empty propellant tanks during the sustainer phase, thus increasing the vehicle's weight and mass, Bossart reasoned that the extra weight penalty could be offset by the lightweight balloon structure. The Bossart team also addressed the problem of sustainer engine cutoff, electing to include two small vernier engines that would provide final course correction to the point of nose cone separation.27

Despite the Air Force decision to proceed with the ballistic missile, the road ahead proved anything but smooth. ARDC, which had responsibility for the guided missiles program, agreed that the missile deserved greater support. Convincing Air Force headquarters to award it sufficient funding and project priority, however, proved next to impossible. In the fall of 1951, the Air Staff’s Research and Development Directorate rejected ARDC’s request for increased funding and directed a slowed-down five-year test program before considering further commitments. Convair continued to lobby for more Air Force support in late 1951 and early 1952, while ARDC’s vice commander, General Putt, in a letter to his former office on the Air Staff, argued that the ballistic missile project should be approved immediately because of its total “invulnerability to all presently known countermeasures and because of the relative simplicity of the entire weapons system.” Putt also warned that the Soviets appeared to be pursuing development of such a weapon. In the spring of 1952 Air Force headquarters referred the ARDC request to the Guided Missiles Committee of the Defense Department’s Research and Development Board. The committee, however, authorized only continued studies and component testing, rather than full-scale development of the Atlas system.28

In spite of growing evidence to the contrary, skeptics on the Air Staff and in the Office of the Secretary of Defense (OSD) continued to view the intercontinental ballistic missile as a weapon system too complex and never likely to reach the operational stage. Much of the criticism focused on the old issue of warhead weight. Yet by 1950 the Atomic Energy Commission affirmed the existence of a sufficient number of atomic warheads small enough to be carried in guided missiles. Moreover, President Truman noted in his memoirs that in early 1950 his military service chiefs proceeded with elaborate plans to use the H-bomb on the assumption that the tests he had just authorized would be successful. In November 1952, test results at Eniwetok, involving a sixty-five-ton device with five hundred times the explosive power of the Nagasaki atomic bomb, demonstrated the feasibility of thermonuclear technology and confirmed their optimism. Believing that a smaller, lighter thermonuclear weapon could be developed in the near future, ARDC petitioned the Air Staff to reassess the overly restrictive weight and accuracy parameters for the Atlas. In submitting Project Atlas performance requirements, ARDC called for a warhead reduced in weight from 8,000
to 3,000 pounds. In response, a Scientific Advisory Board ad hoc committee chaired by Dr. Clark Millikan, head of the Guggenheim Aeronautical Laboratory at the California Institute of Technology (Caltech), reviewed the technical issues and issued a report in December. Although the Millikan committee supported the Atlas project and concluded that anticipated warhead yields called for reducing missile accuracy and guidance requirements, it saw no need to accelerate the program. Rather, it favored the Air Staff’s cautious approach and recommended a “step-wise” project, based on a lengthy program of testing Atlas components on Viking and Navaho vehicles, that would guarantee “a review of the project at appropriate intervals.”

In early 1953, Air Research and Development Command convinced the Scientific Advisory Board that a three Atlas test vehicle development program could lead to an operational missile in ten years at a cost of $378 million, considerably less than the Millikan committee proposal's figure. Millikan's committee then reconvened in late March and, while approving the ARDC plan, reaffirmed its step-wise approach of sequential component development that forecast research completed in 1956, development in 1961, and prototype testing in 1963. The ARDC plan that the Air Staff approved in October 1953 reflected the Millikan committee's cautious approach and a “slowed down” budget plan that saw the earlier figure of $378 million reduced to $269 million.

Air Research and Development Command designated the Atlas, Weapon System (WS)-107A. Measuring 110 feet in length, or 50 feet less than Convair’s 1951 version, 12 feet in diameter, and with a total weight of 440,000 pounds when fueled with gasoline-liquid oxygen propellants, this “1953 Atlas” was a huge vehicle. The stage-and-a-half missile was to generate 656,100 pounds of thrust from its four booster and sustainer engines, delivering its 3,000-pound warhead a distance of 5,500 nautical miles. Still relying on a fission warhead, its low yield of from twenty to thirty kilotons meant that it needed to impact within 1,500 feet of the target. A ground station and an inertial autopilot transponder-receiver aboard the missile would provide guidance.

After lift off, the flight plan called for the rocket to ascend to an altitude of 15,000 feet before making a turn toward the target on a ballistic trajectory. Two minutes into the flight the booster engines would cut off and be jettisoned, and the sustainer engine would then continue to power the rocket for an additional two minutes and twenty-six seconds. When the sustainer engine shut down, two small vernier engines, each providing 1,000 pounds of thrust, would make final flight corrections during the last thirty seconds of powered flight. At that point, nearly five minutes after launch, the verniers would shut down, and the nose cone with armed warhead would make an elliptical free-fall descent toward the target.

Looking back over the course of missile development in the late 1940s and early 1950s, the ICBM clearly fell victim to skepticism about its practical military use, technological challenges, and to fiscal retrenchment that grew unabated through the 1940s. Strategic bombers represented the key element in the nation's offensive arsenal, while the ICBM project moved painfully forward as a cautious, low-funded, phased
study and test program that reflected the traditional skepticism of the Air Staff. By the advent of the Eisenhower administration, however, heightened security concerns and further technological progress offered the prospect of breaking with the past and accelerating both missile and emerging satellite programs. Although still a formidable challenge, the 1953 Atlas clearly represented a major improvement over the earlier configurations and convinced missile advocates that the ICBM was feasible. The issue now became convincing the Air Staff and Strategic Air Command (SAC) bomber pilots to accept the viability of the ballistic missile and accelerate its development.

**Eisenhower Faces the Threat of Surprise Attack**

President Dwight D. Eisenhower took office in January 1953 determined to implement a “New Look” defense policy that stressed strategic nuclear striking power at the expense of conventional forces. In order to do this and roll back the Truman administration’s Korean War budget from nearly $45 billion to $35 billion, he charged his Defense Department to end waste and duplication throughout the services. Missile programs could be expected to absorb their share of Defense Department cutbacks. Indeed, in early 1953 the administration expressed no particular interest in accelerating the ICBM program. Yet in the space of just four years, President Eisenhower would come to preside over a costly expansion of a variety of military ballistic missile programs, as well as the birth of the American space program. These events have left their mark on the nation ever since.

Early in the administration, three developments galvanized the nation’s ICBM effort. One involved the president’s determination to take all possible measures to forestall another “Pearl Harbor.” A second concerned the technological “thermonuclear breakthrough” that solved much of the ICBM payload weight dilemma. Finally, several determined government officials streamlined and energized the decision-making process. Throughout this period, the Air Force community remained divided between reform-minded individuals, represented by ARDC and its supporters who favored accelerated missile development, and more conservative leaders, found primarily on the Air Staff and in the Strategic Air Command, who preferred a cautious, step-by-step approach leading to commitment well into the future. In a long, hard fought effort, the reform group ultimately proved victorious, bypassing traditional Air Force bureaucratic structure and procedures to accelerate the ballistic missile program.

Like General Arnold, General Eisenhower could never forget Pearl Harbor. As president, his scientific advisor, James R. Killian, Jr., remarked that Eisenhower remained “haunted…throughout his presidency” by the threat of surprise nuclear attack on the United States. To avoid this horror, intelligence data on Soviet military capabilities became essential. Yet, neither news of Soviet advances in long-range bombers like the TU-4 nor reports on Soviet long-range missile progress could be verified. At the same time, the development of a thermonuclear device and its testing in both the United States and the Soviet Union raised alarms about a potentially
devastating surprise attack. A number of RAND studies in 1952 and 1953 heightened awareness by describing the vulnerability of strategic air bases to attack. The RAND assessments complemented the Central Intelligence Agency’s (CIA) national intelligence estimates that forecasted imminent increases in Soviet atomic weapons production and improved delivery capabilities.36

But reports remained confusing or contradictory, and the administration quickly realized that current intelligence methods could not provide meaningful data. Pre-hostilities intelligence information became increasingly essential, and all parties realized that aerial reconnaissance offered the most effective means to solve the dilemma. The near-term answer became the U-2 high-altitude reconnaissance plane, while the long-term solution would prove to be the military reconnaissance satellite. Meanwhile, the major defense effort would be devoted to developing medium and long range ballistic missiles rapidly for the New Look doctrine of “massive retaliation,” considered the best means of deterring surprise nuclear attack.

Trevor Gardner Energizes the Missile Program
While President Eisenhower and his advisors worried about intelligence data, Trevor Gardner, the “technologically evangelical” special assistant to the secretary of the Air Force for research and development, made it his mission in public life to convince the government that the nation must pursue a crash program to develop an operational Air Force ICBM or face nuclear disaster. Ironically, he assumed his office with the mandate to implement the expected economy agenda in the Defense Department by ending waste and duplication in the Air Force missile program. Trevor Gardner was to have a profound influence on the nation’s missile program.37

In April 1953 Gardner called for review of all Air Force missile programs. He instinctively rebelled against what he regarded as Air Research and Development Command’s too cautious approach and SAC’s and the Air Staff’s persistent delaying tactics. To him, the Air Staff’s reasoning, in particular, reflected the dilemma of the self-fulfilling prophecy: missiles represented too costly an investment for an “impossible” system. But no development money meant that the problems would continue unsolved and the missile would remain “impossible.” Gardner, who had heard reports of the “thermonuclear breakthrough,” knew that, now, accuracy and guidance performance requirements could be relaxed and the missile no longer need be considered “impossible.”38

Fortunately, Gardner found willing allies to accelerate missile development among middle-echelon ARDC and Air Staff officers, the Convair group promoting Atlas, and from long-time proponent General Putt, who became commander of ARDC in June 1953. At the same time, the Joint Chiefs of Staff, as part of its military posture review for the incoming administration, called for a broad-based reexamination of the entire Defense Department missile picture. Gardner received the assignment to review the country’s missile programs based on Secretary of Defense Charles E. Wilson’s drive to eliminate waste and duplication among the services.
Trevor Gardner

The Honorable Trevor Gardner was born in Cardiff, Wales, on 24 August 1915. He came to the United States in 1928 and became a naturalized citizen in 1937. He received a Bachelor of Science degree in engineering from the University of Southern California in 1937. He returned to the University of Southern California to teach freshman mathematics while obtaining his masters degree in business administration which he was awarded in 1939.

During World War II Gardner’s work at the California Institute of Technology focused on rocket and atomic bomb projects for the Office of Scientific Research and Development. With the end of World War II, Gardner became associated with General Tire and Rubber Company of California as general manager and executive vice president. Three years later he left to found Hycon Manufacturing Co., an electronics manufacturer. He was president of Hycon until February 1953 when he became the Secretary of the Air Force’s Special Assistant for Research and Development.

President Eisenhower began his first term by initiating a defense policy that sought to significantly reduce spending. Gardner was asked to lead a committee and implement an economy program to reduce missile development activities. Its final report recommended that promising missile projects should be continued. The Atlas, under development since 1951, was America’s best hope, however its development had been constrained by the Air Force due to the belief that missiles required too great an investment in systems that seemed “impossible.” Impatient, Gardner requested a scientific review of all Air Force missile programs in April 1953. The impetus came from two directions. First, he was concerned over the growing Soviet threat and, in August 1953, they exploded a hydrogen bomb. The other trend was the development of lighter nuclear weapons. The “impossible” ICBM was now much more possible. In October 1953 Gardner established a second committee to review the Air Force’s strategic missiles—the Snark, Navaho, and Atlas. He directed the committee to find ways to accelerate the development of the Atlas. The committee issued its report on 10 February 1954. Its thrust called for a “radical reorganization of the . . . [Atlas] project considerably transcending the Convair framework.” Gardner developed a five-year plan to accelerate the Atlas which would yield a “preliminary capability” by June 1958.

In early 1955 most of the Eisenhower administration assumed that America had a strong lead over the Soviet Union in strategic technology and felt no particular urgency for the ICBM programs. The Killian report indicated that America was becoming vulnerable and that the ICBM should be given the “highest priority.” While an Air Force priority, he believed that ICBMs must also be a national priority. He indicated that the U. S. could have a rudimentary ICBM by mid-1958 if the program was conducted on a crash basis. Eisenhower requested a briefing and, on 28 July 1955, Gardner, John von Neumann, and Brigadier General Bernard A. Schriever made a presentation to the President and the National Security Council. As a result the National Security Council recommended the ICBM be designated a “research program of the highest priority” which the President approved on 13 September 1955. Gardner had achieved his goal.

In January 1955 the Scientific Advisory Committee urged the Air Force to develop a tactical ballistic missile. All three services developed plans and the interservice rivalry led to a compromise with the Air Force building the Thor and the Army and Navy in charge of the Jupiter. Gardner viewed this approach as dangerous since the IRBM could drain resources from the ICBM and threaten its early delivery. His fears were realized when President Eisenhower assigned the ICBM and the IRBM “joint” highest national priority. The ICBM program no longer had a unique status. Trevor Gardner felt betrayed and resigned his position in protest on 10 February 1956.

After the election in 1960 Gardner again became active in public life. He served on the President’s Space Task Force Commission to review the nation’s space program and also chaired the U. S. Air Force Space Task Force. He also became involved in preventing the use of weapons in space. Gardner played a major role in establishing the U. S. Arms Control and Disarmament Agency and was named to its General Advisory Commission on 1 March 1962. Trevor Gardner died on 28 September 1963.
At this point Gardner decided to bypass the Air Force bureaucracy and appoint a full-time group of experts on whom he would rely for advice. Late in the fall of 1953 he convened the Strategic Missiles Evaluation Committee under the chairmanship of renowned Princeton Institute for Advanced Study mathematician and activist John von Neumann. The von Neumann committee, popularly known as the “Teapot” committee, comprised an impressive assemblage of scientists and engineers, all of whom had been handpicked by Gardner for their “progressive” views on ICBM requirements as well as their technical brilliance. Gardner also engaged the newly formed Ramo-Wooldridge Corporation to provide technical support on questions involving missile propulsion, guidance, and warhead reentry. Specifically, Gardner charged von Neumann’s committee to determine the measures necessary to accelerate development of the Atlas missile.39

While von Neumann committee members deliberated, a RAND Corporation group directed by engineer Bruno W. Augenstein neared completion of a similar study on mounting thermonuclear weapons atop ICBMS, entitled “A Revised Program for Ballistic Missiles of Intercontinental Range.” Responding to Air Force direction to investigate aerodynamic systems, RAND analysts had produced a number of reports on missiles in the early 1950s that favored ramjets and boost-glide rockets over ballistic missiles. When nuclear weapons were made smaller, RAND concluded that the ICBM represented the optimum surprise-attack weapon. RAND evaluators worked closely with the von Neumann team, and Augenstein briefed von Neumann committee members personally in December 1953 on his findings. The RAND analysis concluded that an Atlas initial operational capability (IOC) could be achieved by the early 1960s, if the project received increased funding, became a national priority, and had its demanding performance requirements relaxed.40

The von Neumann report confirmed the RAND study by calling for a drastic revision of the Atlas ICBM program in light of Soviet missile progress and newly available thermonuclear technology. Referring to the recent Operation Castle tests in the spring of 1953 and the findings of a nuclear weapons panel he had chaired that fall, von Neumann predicted the advent of thermonuclear warheads weighing only 1,500 pounds with a yield of one megaton. This amounted to fifty times the yield of the much heavier Atlas warhead proposed by Convair and meant that the size, weight, and accuracy requirements of the Atlas could be reduced, making its development more feasible within the state of the art. On 1 March 1954, von Neumann’s prediction received further credence when additional Castle results involving the first “drop-pable” thermonuclear bomb confirmed the viability of a lightweight, higher-yield weapon with extensive radioactive fallout coverage.41

Critical of Convair’s management practices and design, which continued to envision an enormous five-engine rocket to boost the earlier, heavier warhead, the von Neumann committee recommended conducting a thorough technical study of various alternate design approaches and the establishment of a new development-management agency in the Air Force authorized to provide overall technical direction.
John von Neumann

Dr. John von Neumann was born 28 December 1903 in Budapest, Hungary. He entered college and graduated from the Swiss Federal Institute of Technology with a degree in chemical engineering in 1925. The following year he earned a doctorate in mathematics from the University of Budapest. He subsequently taught at the University of Berlin until 1930, when Princeton University invited him to lecture on mathematical physics. While at Princeton, the founders of the newly created Institute for Advanced Study asked him to accept a chair in mathematics, which he did in 1933. John von Neumann became a United States citizen in 1937. In 1943 von Neumann began working on the Manhattan Project, where he tackled the immense calculations and formulas required for construction of an atomic bomb. Faced with that daunting task, he became interested in using machines for complicated numerical calculations and resolution of specific mathematical problems. During and after the war Dr. von Neumann's interest in computers grew, and he contributed extensively to the construction of the first modern computers.

In 1953 Trevor Gardner asked him to chair a series of Air Force advisory groups in the fields of missile technology and nuclear physics. In June the panel met in Los Alamos, New Mexico, to discuss the plausibility of mounting nuclear weapons on intercontinental ballistic missiles. The panel determined a hydrogen bomb of 3,000 or fewer pounds could retain an explosive power of two-megatons and easily destroy everything within a range of 3.2-4.5 miles. The panel's findings excited military and political officials and provided an impetus for further missile research and development.

Later in 1953 Trevor Gardner created the Air Force Strategic Missiles Evaluation Committee, commonly known as the “Teapot Committee.” Under Dr. von Neumann’s direction the committee evaluated the Snark, Navaho, and Atlas strategic missile programs. The committee made recommendations to improve all three missiles, but preferred the Atlas ICBM to the others, believing the Atlas missile to have the best reliability and least vulnerability of the three. The “Teapot Committee” provided an additional impetus for the Atlas program when they expressed concern about Soviet advances in missile technology. With intelligence received from German scientists released by the Soviets after 1951 and other intelligence sources within the government, the committee members believed the Russians were several years ahead of the United States in missile development. Dr. von Neumann predicted that by the late 1950s the Soviets would have an operational ICBM and improved technology capable of defeating U.S. strategic bombers. At its current rate of development, the Atlas missile program was scheduled for earliest operational duty in the early 1960s. To forestall a “missile gap” and catch up to the Soviet missile program, the committee members decided the Air Force needed an organization of specialists dedicated to overseeing the construction of the Atlas missile. As a direct result of committee recommendations, the Air Force created the Western Development Division under Brigadier General Bernard A. Schriever. The WDD assigned highest priority to Atlas research and worked closely with the Ramo-Wooldridge Corporation to ensure a coordinated, expeditious effort in developing the missile.

To retain “Teapot Committee” expertise Trevor Gardner asked Dr. von Neumann to chair the Atlas (later ICBM) Scientific Advisory Committee in 1954. The new committee acquired the task of monitoring and accelerating Atlas missile development. Over the next few years his committee provided technical advice to all of the military branches and the Office of the Secretary of Defense. Under Dr. von Neumann’s direction the committee also spearheaded significant advancements in the Air Force missile program. They suggested developing a back up ICBM for Atlas that eventually became the Titan ICBM program. In 1955 the committee discussed the possibility of developing an intermediate range ballistic missile and assured the Air Force that IRBM technology could fall out of the new Titan program and Atlas could remain a separate entity. After reviewing the committee’s proposal, the Air Force initiated the Thor IRBM program.

Dr. von Neumann continued his work on projects in both the civilian and military sectors until his death on 8 February 1957.
Committee members considered this agency more important than all the technical guidance, warhead weight, and reentry problems yet to be solved. Finally, panel members urgently recommended the project be given high priority and substantial funding.\textsuperscript{42} To no one’s surprise, the RAND team and the von Neumann committee reached similar conclusions in their final reports, which appeared two days apart in early February 1954. These reports would help convince President Eisenhower later that year to convene the Surprise Attack Panel or, as it was soon renamed, the Technological Capabilities Panel (TCP), chaired by Killian, then president of the Massachusetts Institute of Technology.

Armed with the findings of the RAND and von Neumann committee studies, Gardner set off to win support throughout the Air Force hierarchy to expedite an expanded ballistic missile development effort. After gaining approval from Chief of Staff General Nathan F. Twining and Secretary of the Air Force Harold E. Talbott, Gardner could successfully counter any disapproval from key Air Staff agencies. The traditional Air Force bureaucracy did not favor this civilian-sponsored initiative that proposed creating a separate development-management agency that would bypass established administrative channels. In the end, the Air Staff supported the Gardner-engineered initiative, perhaps because disapproval might result in appointment of a new missile “czar” completely outside the Air Force framework. If not all that the Gardner group desired, the results nevertheless proved “revolutionary.” In April 1954 the Air Staff proceeded to create a new Air Force headquarters position, an assistant chief of staff for guided missiles, with responsibility for coordinating all Air Force guided missile activities. The following month, Air Force leaders took a more significant step by directing ARDC to form a West Coast project office at Inglewood, California. Organized as the Western Development Division (WDD), the latter represented the central von Neumann committee recommendation, and Gardner ensured that the new organization’s chief would be his ally, Brigadier General Bernard A. Schriever. Shortly after the Western Development Division began functioning in August, General Schriever arranged for the Air Force to contract with the Ramo-Wooldridge Corporation as full-time technical consultant to his command.\textsuperscript{43*}

Schriever proved to be a brilliant choice to head a crash ICBM program. A young disciple of Hap Arnold, whom he considered “one of the most farsighted persons” he had ever known, Schriever had joined Trevor Gardner’s reform group in early 1953 while serving on the Air Staff as assistant for development planning in the Office of Deputy Chief of Staff for Development. He used his intelligence, patience, and superb negotiating skills with military and other government and private industry leaders to become an outstanding advocate for missile and space systems. He handpicked his initial group of officers and, given the priority of the missile program, he was able to recruit from among the most capable officers in the Air Force.\textsuperscript{44}

\textsuperscript{* See Appendix I-1.}
General Bernard A. Schriever was born in Bremen, Germany, on 14 September 1910. His family migrated to the United States in 1917 and settled in Texas. He graduated from Texas A&M in 1931, earning a B.S. in architectural engineering. In June 1932 he entered Army Air Corps Flying School which he graduated from in June 1933. He served on active duty from July 1933 until April 1935.

On 1 October 1938 he passed the Air Corps examination for commission as a Regular second lieutenant and took an assignment in the Air Corps as a B-18 instrument-flying instructor with the 7th Bombardment Group at Hamilton Field, California. In June 1942 he earned a Master’s in aeronautical engineering from Stanford University. By the end of World War II, he had advanced to colonel and was commander of the Advanced Headquarters, Far East Air Service Command.

In January 1946 he was assigned to the Pentagon as Chief of the Scientific Liaison Branch in the Office of the Deputy Chief of Staff for Materiel. From July 1950 until May 1954 he served in various development and planning offices. In March 1953 Schriever learned of a scientific breakthrough that appeared to make the ICBM technically feasible much sooner than previously thought possible. At a meeting of the Scientific Advisory Board (SAB), Dr. Edward Teller, who championed the development of hydrogen weapons, reported on the successful test of a hydrogen device in November 1952. The U.S. could now build less powerful missiles because of the lighter warheads and could relax the accuracy of missiles because of the warhead’s greater destructive power.

In early 1954 President Dwight David Eisenhower assigned the nation’s highest priority to the development of an ICBM. Trevor Gardner, Special Assistant Secretary of the Air Force for Research and Development, asked Schriever, now a brigadier general, to manage the ICBM program. Defense Department officials accorded his office extraordinary authority to streamline review and approval procedures, thus eliminating cumbersome red tape. In June 1954 General Schriever became the commander of the Air Research and Development Command’s Western Development Division in Inglewood, California, and the Assistant to the Commander of ARDC. The progression of the Thor Intermediate Range Ballistic Missile, from program approval to the Initial Operational Capability, had taken only three and one-half years. Atlas’s development time was little more than five years, better than the 1954 prediction of six to eight years, which, at the time, was thought to be optimistic. Titan took less than six years to reach operational status. Moreover, even as the first Titan lifted off from Cape Canaveral, the Air Force was developing the more advanced Titan II. The Minuteman, whose development Schriever began, from start to finish took only four years and eight months to deploy. The first ten were combat alert in their underground silos in October 1962.

On the space side, the Air Force launched Discoverer 1 on 28 February 1959, though it tumbled in orbit. However, Discoverer 2, launched 13 April 1959, performed well. On 26 February 1960, Midas 1, an infrared satellite, blew up during stage separation, but in late May 1960, Midas 2 lifted successfully into orbit. Samos 2, a photoreconnaissance satellite, began a fully successful mission on 31 January 1961.

In February 1958 he became Deputy Commander for Ballistic Missiles at Air Research and Development Command (ARDC) for three short months. In April 1959, he became commander of ARDC. When ARDC became Air Force Systems Command (AFSC) in April 1961, he assumed command of AFSC, where he remained until his retirement on 1 August 1966. As commander of AFSC, General Schriever was responsible for the development of all Air Force weapons. In partnership with NASA, he began transforming his missiles into reliable manned launch systems and supported NASA’s manned space programs by providing modified Atlas and Titan boosters and launch services at Cape Canaveral.

After his retirement, Schriever consulted with civilian organizations and frequently served as an advisor to the Air Force and the Department of Defense. General Schriever died on 20 June 2005.
When General Schriever surveyed the state of his command in the spring of 1954, he realized that he faced a major battle within the Air Force to retain control of his project. Despite his relatively independent status under ARDC with responsibility for system planning, technical direction, and budgeting, the Air Materiel Command continued to control the major funding areas of system production and procurement. To do the job assigned, General Schriever believed he needed authority over all aspects of missile acquisition, from design, research and development, through production. The Air Staff, however, refused to compromise on this issue, and AMC maintained its production prerogative by establishing a Special Aircraft Project Office at the Western Development Division to handle ICBM procurement. According to General Schriever, initial friction soon gave way to a reasonable “partnership” arrangement after the general established good rapport with the AMC officers. This far from optimum division of system management responsibilities would continue until the creation of Air Force Systems Command and the dissolution of AMC and ARDC during the organizational reform of 1961.45

Managerial problems with the Air Materiel Command proved only the tip of the iceberg. Even though the Air Force had accorded the Atlas its highest research and development priority, 1-A, and the secretary of defense had declared Atlas of “critical importance” in early 1955, the bureaucratic labyrinth at the Air Staff and the Office of the Secretary of Defense continued to cause bottlenecks and delays because of the multiple program review levels. Once again Trevor Gardner—actively supported by General Schriever—decided to bypass the Air Force bureaucracy by going directly to congressional leaders. Meetings with Senators Clinton P. Anderson and Henry M. “Scoop” Jackson, the two most influential members of the Joint Committee on Atomic Energy, and congressional visits to Schriever’s suburban Los Angeles headquarters, convinced the senators to support streamlined management procedures to eliminate the bureaucratic obstacles. At the same time, additional reports of new Soviet long-range bombers and missile tests picked up by radars in Turkey raised fears that the United States might be falling behind not only in the ICBM contest, but also more generally in the advanced technology race.46 The two senators wrote President Eisenhower in late June 1955 about their concerns and recommended immediate action on the Atlas program to avoid funding delays, overcome interference from major Air Force commands, and bypass the multiple review levels.

Earlier in the year the president had also received the report of the Technological Capabilities Panel, chaired by Killian. Eisenhower had frequently expressed grave concerns about inadequate intelligence to the National Security Council. The president also followed with great interest the work on the country’s strategic missile program undertaken by Trevor Gardner and the civilian scientists serving on the Scientific Advisory Committee in the White House Office of Defense Mobilization (ODM). In late March 1954, in the wake of the RAND and Teapot committee reports, he called to the White House a number of prominent scientists, including ODM Science Advisory Committee chairman Lee A. DuBridge, president of Caltech, and requested their
help on the problem of surprise attack. They responded in August by establishing the Technological Capabilities Panel. After five months of deliberations, in February 1955 it issued a momentous report titled, “Meeting the Threat of Surprise Attack.”

The Killian panel projected changes in the relative postures of American and Soviet strategic forces. Confirming the vital need for pre-hostilities strategic intelligence on Soviet military capabilities, the panel supported development of the Lockheed u-2 high-altitude reconnaissance plane, either a land or sea-based intermediate range ballistic missile (the latter became the solid-fueled Polaris), and more rapid construction of the Distant Early Warning (DEW) line across northern Canada. Most importantly, the report advocated an accelerated ICBM program, and rapid development of intermediate range ballistic missiles as a stopgap security measure until the ICBM force became operational. On 8 September 1955, President Eisenhower responded to the findings and recommendations of the TCP and congressional leaders by assigning the Atlas program “the highest priority above all others,” and “not…[tolerating]…any of the delays which may attend normal development or procurement programs.”

Although the Atlas ICBM had now been designated the “highest national priority” weapon system, administrative procedures remained cumbersome, prompting Trevor Gardner again to seize the initiative by directing Hyde Gillette, Air Force deputy for budget and program management, to form a committee and recommend measures to make the decision-making process for the missile program more effective. In October 1955 the Gillette committee’s recommendations led to the establishment of two ballistic missiles committees, one at OSD and one in the Office of the Secretary of the Air Force to function as the sole reviewing authorities for Western Development Division programs. Gone were the various separate offices that Schriever had to consult individually. Now he submitted a yearly development plan to a single committee, made up of representatives from the offices concerned with the ICBM program. Although not entirely able to overcome all Air Staff skeptics and Air Materiel Command opponents, the Gillette procedures removed many bureaucratic bottlenecks, and the ICBM program moved ahead rapidly.

In order to produce an operational missile by the end of the decade, Schriever’s command adopted a number of managerial innovations that would become common practice for the Air Force in future years. One involved reliance on outside technical experts rather than continue with the prime contractor method, which charged the airframe manufacturer with responsibility for all aspects of weapon system design, development, and testing. Despite Convair’s role as prime contractor for the B-58 program, the von Neumann committee had questioned the company’s ability to serve in this capacity for the Atlas. General Schriever agreed, observing that “existing industrial organizations generally lack the across-the-board competence in the physical sciences to the complex systems engineering job” needed for the ICBM. Additional doubts about Convair’s competence arose in the summer of 1954, during discussions of the Atlas design before the Atlas Scientific Advisory Committee, which Gardner formed in April 1954 under the chairmanship of John von Neumann.
Dr. Simon Ramo was born in Salt Lake City, Utah, on 13 May 1913. Ramo earned a B.S. in electrical engineering at the University of Utah and, at twenty-three, a Ph.D. in electrical engineering and physics at Cal Tech. General Electric hired him immediately. At GE, he served as section head of the general engineering laboratory and head of the physics section of the electronics research laboratory. As a GE scientist he attained world recognition as a pioneer in microwave technology and developed GE’s electron microscope. In 1946, unhappy about GE’s diminishing prospects in high technology and eager to return to California, Ramo joined Hughes Aircraft Company.

At Hughes, Ramo served as the director of research in the electronics department and held the titles of Vice President, and Director of Operations. Ramo instituted high-technology research and development at the company. Largely because of his work, Hughes received initial contracts from the Air Force for advanced military electronics and for R&D of guided-missiles.

In 1953, Ramo and Dean E. Wooldridge, who was co-director of research and development laboratories at Hughes, wished to discuss possible solutions to several management problems with Howard Hughes, but Hughes avoided them. Frustrated, the two resigned from Hughes on Friday, 11 September 1953. By the following Wednesday, they had established Ramo-Wooldridge Corporation and by Friday afternoon had a contract to provide science and engineering analysis to a Defense Department strategic-missile planning effort.

The “Teapot Committee” or, as it became officially known, the “Strategic Missile Evaluation Committee” provided overall guidance for the USAF’s ballistic missile effort. It was established by Trevor Gardner who placed both Simon Ramo and Dean Wooldridge on this eleven-man committee. It concluded that a beginning operational capability in long-range missiles could be attained in six years if the U.S. instituted proper management, allocated sufficient funds and the highest priority to the program, and relaxed missile performance standards. The outcome would be the Air Force’s project to develop the ballistic missile; a crash program about twice as big and complex as the Manhattan Project to develop the atomic bomb.

The Western Development Division (later the Ballistic Missile Division) and Ramo-Wooldridge spearheaded the American effort. By December 1957, the two organizations were supervising over 150 first-line contracts. Observers estimated that the Air Force ballistic missile program, in the late 1950s, employed about 2,000 system and subsystem contractors with more than 40,000 personnel. The endeavor not only bested the Soviets in the race to set up the first operational ICBM force, but also was remarkably free of major cost overruns, schedule slippages, and waste. The ballistic missile program was one of great urgency and the highest priority.

Ramo left the ballistic missile effort in October 1958. His effective leadership in the program provided the scientific foundation and forged the essential cooperation between the Air Force and industry necessary to begin the nation’s military space program. He helped the United States become the world’s leader in space technology and its applications.

For his role as the leading civilian in the Air Force’s ballistic missile program, the Air Force awarded him a special citation of honor.

After his days in the ballistic missile program, he continued to remain active in business and serve as a key advisor to the government on science and technology. He was chairman of the President’s Committee on Science and Technology under President Gerald R. Ford and was co-chairman of the Transition Task Force on Science and Technology under President Ronald Reagan. He also was a member of the White House Energy Research and Development Council, the Advisory Committee to the Secretary of State on Science and Foreign Affairs, and a member of the Department of Defense’s Advisory Committee on the Strategic Defense Initiative. Simon Ramo co-founded TRW, the firm that put together the complex systems required for the first American intercontinental ballistic missile.
Together with Ramo-Wooldridge, the Atlas Scientific Advisory Committee sought to convince Convair and the Air Force to design a smaller missile capable of carrying the lighter, powerful hydrogen warhead. Lessening the payload to 1,500 pounds could mean a three- rather than five-engine propulsion configuration, resulting in an overall missile weighing 220,000 pounds rather than 440,000 pounds. In its presentation, Convair continued to favor the five-engine vehicle and lobbied to begin work immediately on the missile as prime contractor. Gardner, Schriever, and the committee members remained unconvinced that Convair could handle the management responsibilities of a prime contractor. That fall, when Schriever chose Ramo-Wooldridge as contractor for Atlas systems engineering and technical direction, a very unhappy Convair was left with responsibility for airframe construction, subsystems integration, and the static and flight test program.51

The crash program also reflected what came to be called parallel development. In the summer of 1954 the Atlas Scientific Advisory Committee, which favored developing a multi-stage ICBM, had recommended that the Western Development Division award alternate subsystem contracts, whereby each Atlas component would be “backed up” by an alternate relying on different technology. Still skeptical of Convair’s capabilities and the as yet unproven Atlas stage-and-a-half design, Air Force officials applied this parallel development concept on a larger scale by producing at the same time a second, more-sophisticated “back-up” ICBM, the Titan. Designers configured the new Titan as a two-stage liquid-propellant missile, with a more advanced guidance system, and rigid frame to permit underground deployment. Parallel or dual source development brought competition into the development process as well and served as an effective risk mitigation approach, allowing Atlas and Titan program managers to replace subsystems in case of failure or technological breakthrough, while advanced designs could be pursued without risk to the overall ICBM program.52

As General Schriever explained that October,

to introduce the element of competition with regard to air frame contractors, it is believed wise to sponsor an alternate configuration and staging approach with a second source....It is possible that such an approach might provide a design substantially superior with the availability of future component development and thus would provide a chance for great advancement even with a late start. In line with this thinking, it is presently believed that the second design should be oriented around a greater technical risk which might offer dramatic 'pay offs.'53

This more costly parallel development approach meshed effectively with the so-called “concurrent” procedures applied on an unprecedented scale by Schriever and his staff. The Air Force had traditionally followed a sequential weapon system development process, whereby managers completed each system component in turn, while prototypes subsequently underwent deliberate and rigorous testing before
production. Often, this process reflected a “philosophy of gradualism,” as illustrated by the fate of the Snark and Navaho cruise missiles, whose completion date slippages averaged five years and cost increases approached 300 percent of initial estimates.

Under concurrency and the systems engineering approach, all measures necessary to construct and deploy the weapon system would proceed simultaneously. In effect, research, development, testing, production, base construction, training, and support infrastructure requirements would be integrated into a master schedule with specific milestones to be met. As General Schriever explained, concurrency “may be defined as moving ahead with everything and everybody, altogether and all at once, toward a specific goal.…Our aim,” he said, “was to bring all elements of our program along so that they all would be ready, at each successive stage, to be dovetailed into each other.” As a rapid implementation of the systems method, concurrency promised to compress the acquisition cycle significantly—an absolute necessity were the program managers to field an operational missile by 1960.

It should be noted, however, that Schriever’s application of concurrency reflected an evolutionary rather than a revolutionary approach to weapon system acquisition. Elements of the weapon system concept had first appeared with the F-102 program that began in 1949 and more fully with the B-58 effort in 1952. They reflected a more central management and design focus, a project management structure, and greater responsibility taken on by industry. With the outbreak of the Korean War in 1950, the Air Force accelerated the B-47 and B-52 programs by beginning full production before completing development, while Convair’s integrated approach to B-52 development also included ground system procurement and Air Force personnel training aids and operational procedures. General Schriever clearly advanced concurrency’s weapon system approach by including as part of the integrated Atlas program missile site selection, site construction, operational and maintenance crew selection and training, and missile organizational structure.

By 1955 the Atlas design designated for “concurrent development” differed markedly from its earlier versions. On 14 January 1955, when the Air Force approved full-scale development of the Atlas, the revised design entailed a three-engine rocket, 82.5 feet long, 10 feet in diameter, and weighing 267,000 pounds when fully loaded. Given the continued uncertainty of being able to ignite an engine in the vacuum of space, Convair and the Air Force agreed to retain the stage-and-a-half propulsion configuration, with the two boosters and single sustainer engine, as well as the vernier engines igniting simultaneously at liftoff. Representing 80 percent of the Atlas’ mass, the two stacked fuel tanks consisted of a top oxidizer tank holding 175,196 pounds of liquid oxygen separated by a bulkhead from the bottom tank containing 77,833 pounds of refined kerosene, or rocket grade RP-1. The 1955 Atlas retained Charlie Bossart’s unique monocoque fuselage design, although in place of aluminum, the “pressurized steel balloon” now had a series of stainless steel bands measuring between 0.010 and 0.051 inches in thickness. With the Atlas design in hand, the Western Development Division devised a five-year development program, calling for the first of three test
vehicles to begin flight testing in the spring of 1957, followed in early 1959 with the initial flight tests of the Atlas D, the first operational ICBM.\textsuperscript{58}

An early historian of the Atlas ICBM asserted that “nothing like the Atlas program… [had ever]…been attempted in this country before.” Not only was the Atlas a totally new and extremely complex weapon system, it also required a completely novel working environment.\textsuperscript{59} Writing in 1958, General Schriever declared “the USAF ballistic missile program…the largest military development program ever undertaken by this nation in peacetime,”\textsuperscript{60} while others involved in the program considered it more complex and ambitious than even the wartime Manhattan project in terms of scope, personnel, and resources.\textsuperscript{61} In any event, the figures are staggering. Already by 1957, two years into the program, Atlas embraced 17 major contractors and as many as 200 subcontractors spread across thirty-two states and employing 70,000 workers.\textsuperscript{62}

At the same time, General Schriever’s task grew more daunting when, by the close of 1955, in addition to a second ICBM, the Titan, his command was also made responsible for developing the nation’s initial military reconnaissance satellite and the Thor intermediate range ballistic missile.\textsuperscript{63} The challenge of producing an operational Atlas in 1960 and an operational Titan shortly thereafter would prove formidable, indeed. At least Schriever’s team could provide better management of risk and program scheduling with its “concurrency” approach to systems development and streamlined administrative procedures with higher headquarters.
Chapter II

Secretary of Defense Thomas S. Gates, writing in September 1960, asserted that creating an operational intercontinental ballistic missile force represented “a wartime operation…undertaken under peacetime conditions with only peacetime authority.”

Another contemporary observer declared, “nothing like the Atlas program has even been attempted in this country before. The nearest thing to it was the Manhattan project….But as big as it was, it did not match the scope of our ICBM effort.”

Both commentators speak to the enormity of the challenge confronting General Schriever and his Western Development Division (WDD) team.

Schriever’s expansion of the “concurrency” management concept offered the best means of meeting the optimistic schedule of fielding a new and complex ICBM by the end of the decade. Although the Atlas missile received the nation’s highest development priority in 1955, prior to the launch of Sputnik I on 4 October 1957, the concurrency development timetable suffered from the Eisenhower administration’s economy drive that severely constrained defense spending. While efforts thereafter to expand force levels and accelerate development to confront the “missile gap” with the Soviet Union ultimately proved successful, Air Force leaders also had to confront serious proposals to cancel the Titan program with the advent of the more capable and cost-effective solid-propellant Minuteman ICBM.

At the same time, concurrency’s requirement for simultaneous completion of all measures needed to deploy an operational system created myriad challenges for the Air Force, the Army Corps of Engineers, and the industrial community involved in this unprecedented project. By the early 1960s, the Air Force-led team had overcome
the most significant development, construction, and site activation obstacles to field an operational fleet of Atlas and Titan I missiles. Beset by safety, survivability, and reliability problems, however, and already considered largely obsolete when placed on alert, this first generation ICBM force required extensive modifications to keep the majority of the missiles operational before their deactivation in 1965. Despite their many weaknesses, the missiles provided a new dimension to the U.S. strategic deterrent and laid the groundwork for the Titan II and Minuteman missile force to follow.

Establishing Force Levels
In order to achieve an early initial operational capability (IOC), planners at the outset of the ICBM program needed to determine the number and type of missiles required and the locations of the launch sites and appropriate configurations needed for both the Atlas and Titan. In December 1955 the Air Staff produced a schedule that called for 10 missiles and launchers operational by 1 April 1959 and the full IOC complement of 120 missiles, consisting of 80 Atlas and 40 Titan, as well as sixty launch sites to be ready by 1 January 1960. Given the time constraints, the sites would be “soft”; that is, constructed above ground and unprotected from nuclear blast. Missile crews were to be capable of launching the first 10 missiles in fifteen minutes, the next 10 in two hours, and 20 more within the following two hours.3

The Air Staff plan remained effective only until the following spring, however, when the Western Development Division (WDD), Strategic Air Command (SAC), and Air Research and Development Command (ARDC) convinced Chief of Staff General Thomas D. White of its impracticality, because it meant production would have to commence before the start of any flight testing. Moreover, Schriever’s staff predicted at least a three-year lead-time would be needed for missile field construction given the lack of experience in this area. As a result, the revised schedule in June 1956 called for a 25-missile operational contingent in place by 1 January 1960 and the operational date of the full force of 120 missiles extended fourteen months, to March 1961.4

By the summer of 1956, however, the Eisenhower administration had begun its austerity program designed to limit defense spending in fiscal years 1957 and 1958. In November, following what Secretary of the Air Force Donald A. Quarles termed a “poor man’s approach,” the Air Force Ballistic Missiles Committee agreed to an ICBM force reduced to eighty missiles (forty Atlas and forty Titan, or four squadrons of ten missiles of each type), with the deployment date remaining March 1961. Additionally, three launchers and six missiles were to be established at a dual-purpose training and operational base by March 1959. Significantly, when President Eisenhower approved the program on 28 March 1957, despite reports emerging of a “missile gap” favoring the Soviet Union, his guidance called for the eighty-missile operational force to be readied not “at the earliest possible date” but rather at “the earliest practicable date.” The latter reflected the administration’s budget austerity priorities. By the summer of 1957, Atlas production rates had been cut from six to four missiles per month, thereby delaying the operational date to October 1961. Titan production also faced cuts, from
seven to four missiles per month, with the full four-squadron force to be operational by October 1962, fully fifteen months behind schedule.\(^5\)

The launching of the Soviet Sputnik satellites in October and November 1957 compelled the Eisenhower administration to address the intensifying missile gap controversy. Sputnik precipitated widespread anxiety, as critics asserted that the administration's cuts in defense spending had endangered national security by creating a missile gap that had the Soviet Union far ahead of the United States in developing operational intermediate range ballistic missiles (IRBMs) and ICBMs. Soviet boasts of missile superiority, culminating in Premier Nikita Khrushchev's January 1959 declaration that the Soviet Union had begun ICBM "serial production," continued to alarm an already nervous public and emboldened critics to exploit the missile gap for their own purposes. Congressional Democrats saw in the missile gap a potent issue for the forthcoming 1960 presidential election campaign, while the Air Force and missile contractors saw a golden opportunity to increase strategic deterrent forces and improve business, respectively.\(^6\)

Following Sputnik, President Eisenhower agreed to end the restrictions placed on the missile programs during his economy drive and to accelerate and enlarge the ICBM program.\(^7\) The missile gap controversy provided the backdrop for Office of the Secretary of Defense (OSD) and Air Force planners, who proceeded to adjust the force-level figures for the Atlas and Titan programs a number of times over the next two years. In April 1958, for example, OSD increased the force level of the strategic missile program from four to nine Atlas squadrons, but chose not to expand the Titan force pending a decision on its future. As the backup for the Atlas, the Titan's development schedule was less critical, and it lagged nearly two years behind that of the Atlas. The Titan's delay fueled those critics who considered a second missile unnecessary and too costly, while the Eisenhower administration's austerity period prior to the Sputnik launches in effect had downgraded the Titan essentially to research and development status by the fall of 1957. Even after the Sputnik crisis convinced the administration to consider accelerating the Titan program, it hesitated to do so given the high cost of deploying only four squadrons and the decisions taken by that time to pursue seriously development of the more capable Minuteman ICBM. General Schriever and his supporters countered criticism of the Titan by highlighting the missile's potential advantages: better range, accuracy, and payload than either the Atlas or the Minuteman; three times the number of Soviet warheads required to destroy the "hardened" Titan sites; superior potential for the space program; and a much greater production base. His arguments were convincing, and by January 1959 OSD had agreed to expand the Titan operational force from four to eleven squadrons by June 1963.\(^8\)

In April of 1960, the Air Force issued its last major ICBM deployment plan. The Titan force would be increased from eleven to fourteen squadrons, with the final eight deploying the upgraded Titan II. The OSD Ballistic Missiles Committee enlarged the Atlas contingent from nine to thirteen squadrons, with the number of launchers
per squadron increased from nine to twelve, and the last six squadrons equipped with the silo-lift Atlas F missile. The Atlas F remained protected in its hardened silo until ready for launch, at which time its silo elevator raised the missile to the surface for fueling and firing. Secretary of Defense Gates asserted that the last of the Atlas and Titan squadrons (the upgraded Titan) would become operational by December 1962 and February 1964, respectively. The Titan I squadrons were to be operational by the fall of 1962. In a cost reduction measure in March 1961, OSD cancelled deployment of the last two Titan II squadrons, leaving the force level at twenty-five squadrons. Although it is difficult to assess the precise impact of force-level changes on the development and deployment schedule, clearly the fluctuating figures contributed to the continuous modifications required of the missiles, their launch sites, and the support equipment, as well as contract revisions and adjustments to maintenance and crew training programs.

**Developing and Testing the Atlas and Titan**

In March 1956, only fourteen months after receiving the Atlas contract, Convair had produced its first Atlas series A prototype missile for static testing, the first category of ICBM testing. The Air Force missile-testing program consisted of four phases, or categories. Category I involved subsystem development testing performed by the contractor, while Category II, comprising research and development (R&D) subsystem and component integration tests, were conducted by contractor and Air Force personnel at the Eastern Missile Test Center at Cape Canaveral, Florida. The latter readied the weapon system for comprehensive Category III tests by the Strategic Air Command under operational conditions. These initial operational tests were to guarantee missile readiness, accuracy, and reliability. Lastly, SAC performed additional Category IV operational tests at the Western Missile Test Range at Vandenberg Air Force Base, California, to ensure performance objectives would be maintained.*

After integrating the booster engines delivered by North American Aviation, Convair transported the missile to its new Sycamore Canyon test area northeast of San Diego, California, in August. By December, with the Atlas 1A missile secured to one of two enormous test stands, Convair engineers looked on with observers from Ramo-Wooldridge and the Western Development Division as a brief but successful firing of the engines demonstrated airframe strength and subsystems compatibility. That same month, the Atlas 4A, the first flight test version, arrived by cross-country truck transport for Category II testing at the Air Force Missile Test Center at Cape Canaveral.

The series A flight missiles did not incorporate a nose cone or sustainer engine, as the tests were to evaluate only airframe and booster engine performance. The first two flights, on 11 June and 25 September 1957, lasted only thirty and thirty-two seconds, respectively, before the range safety officer destroyed the missiles following engine failure in both cases. The third, however, on 17 December, performed its short-range

* See Appendix II-1.
Lieutenant General Otto J. Glasser was born in Wilkes-Barre, Pennsylvania, on 2 October 1918. He graduated from Cornell University in 1940 with a Bachelor’s degree in electrical engineering. In May 1940, he earned a commission as a second lieutenant and began active duty in February 1941. He entered flying training in September 1943, graduated the following June, and then received transition training in the B-17, B-24, and B-29. After World War II, he attended Ohio State University where he earned his Master’s degree in electronic physics in 1947. General Glasser served as the director of the Atlas Intercontinental Ballistic Missile (ICBM) program, the nation’s highest priority military project in the mid-1950s. An original member of General Bernard A. Schriever’s “Schoolhouse Gang” of four at the Western Development Division, his leadership provided the nation with its first deployed ICBM.

In February 1956, General Glasser became the Director of the Atlas program. The Atlas program was distinctive and its urgency deterred the Air Force from undertaking a testing program similar to the one the Germans had used in their V-2 program. They had performed 3,000 flight tests to produce an operational missile. During the Cold War, using so large a number of flight tests was impracticable. The constraints of time, energy, money, and resources militated against it.

Instead, Glasser engineered a program that tested individual parts, then components and assemblies, subsystems and stages, eliminating all possible sources of error before committing the subsystem to a completely integrated missile. Next, personnel tested the integrated missile, firing it up, checking it out, while a captive stand held it down; eliminating, so far as possible in this artificial environment, sources of error. However, captive testing carried with it the advantage of rigor. In this atmosphere, the Air Force used sophisticated monitoring instrumentation that it could not use while the Atlas was in flight. After static evaluation, the organization flight-tested missiles, carrying out a specific list of tests on each flight. However, as General Glasser anticipated, the Atlas program encountered difficulties and he included leeway for mishaps resulting in lost time.

At the same time, he was alert to new possibilities. In early 1957, he deemed that the time was ripe for the inauguration of a solid-propellant missile program. Accordingly, Schriever sent the personable and persuasive Glasser as his emissary to Washington to sell the idea to Air Force Secretary Donald A. Quarles. General Glasser persuaded him to permit the start of a solid-propellant missile “technology program.” A year later, the Air Force was able to initiate the solid-propellant Minuteman ICBM program.

In October 1959, General Glasser became Chief, Ballistic Missiles and Space Systems Division, and later the Assistant Deputy Chief of Staff, Research and Engineering at ARDC. In February 1961, he became the Special Assistant to the Commander, ARDC, with the additional duty as the Chief of the Command Special Projects Office. When Robert S. McNamara became Secretary of Defense, he urged the Chief of Staff of the Air Force, General Thomas D. White, to reorganize the Air Force’s systems management immediately so that McNamara could assign the military space program to the Air Force. After consultation with General Schriever, General White chose General Glasser to study and recommend a method for reorganizing the Air Force’s systems management. As a result of Glasser’s work, the Air Force established Air Force Systems Command and Air Force Logistics Command.

In July 1962, General Glasser became Vice Commander of the Electronic Systems Division, Air Force Systems Command. In July 1965, he moved to Headquarters United States Air Force; first as Deputy Director of Operational Requirements and Development Plans, and then Assistant Deputy Chief of Staff, Research and Development. In February 1970, General Glasser became the Deputy Chief of Staff for Research and Development, and the Military Director of the USAF Scientific Advisory Board. General Glasser retired from active duty on 1 August 1973. From 1973 to 1986, he served in several positions with General Dynamics Corporation culminating as Vice President for Government Relations. He retired in 1986 to Sarasota, Florida, where he died on 26 February 1996.
575-mile flight flawlessly over the South Atlantic. Coming shortly after the two Soviet Sputnik flights and the embarrassing failure of America’s Vanguard launch on 16 December, the Atlas flight served as an important morale boost. The series A tests concluded with the eighth R&D flight on 11 June. Although five of the eight had been considered unsuccessful, each flight had provided a wealth of important data.13

The Air Force Ballistic Missile Division (AFBMD), which had superseded the Western Development Division on 1 June 1957, conducted two additional series of Atlas flight tests. Series B missiles included three more systems integrated into the basic A series airframe: North American Aviation’s complete MA-1 two-booster and sustainer engine cluster, and General Electric’s Mod I radio-inertial guidance system and Mark 2 nose cone. Although the initial launch on 19 July 1958 ended in failure when the missile blew up a minute after liftoff, a 2 August flight effectively demonstrated staging and sustainer operations on its 2,500-mile journey. In the Atlas launch sequence, its two booster and single sustainer engines all fired on the ground, while the two small vernier engines ignited 2.5 seconds following lift-off. Accelerating rapidly from the launch pad, the missile gradually nosed over on its flight to the target. A command from the ground station jettisoned the booster engines and turbo-pumps after 140 seconds, well into its trajectory; then the sustainer engine propelled the missile for another 130 seconds until achieving a velocity of 16,000 miles per hour. The two vernier engines then made necessary course and velocity corrections, after which the nose cone separated from the rocket framework and followed an unguided, ballistic course to the target.14

The remaining four successful series B flights included Project SCORE (Signal Communications by Orbiting Relay Equipment), the placing in orbit on 18 December 1958 of Atlas 10b, with a radio relay transmitter on board that broadcast President Eisenhower’s worldwide Christmas message of peace. Beginning on 23 December 1958, the first of six series C flights stressed weight reduction and improved accuracy with the General Electric Mod II and Mod III radio guidance systems and Burroughs computers. The three successful flights also included the first major test of the RVX-2 ablative reentry vehicle, which was recovered on 21 July 1959 after a 4,385-nautical mile trip into the South Atlantic.15

While the Atlas finished its initial test flight program in mid 1959, the Titan had completed its first successful flight test in February of that year—nearly two years after the Atlas series A tests began. Titan had benefited from a less taxing deployment timetable and its perceived role as a more sophisticated weapon system. In effect, it would become the equivalent of the most capable Atlas, the Series F missile, having taken advantage of its better design and incorporation of improvements in the Atlas program.16

Back in April 1955, when Air Force Secretary Harold Talbott authorized General Schriever’s WDD to proceed with a second, alternative ICBM, he specified that the new missile’s research and development be concentrated in the central part of the country rather than on the east or west coasts. That October the Air Force authorized the
Baltimore, Maryland-based Glenn L. Martin Company to construct the airframe for a two-stage missile designated xsm-68, Weapon System 107A-2 (later termed the Titan) and plan its comprehensive development, with Ramo-Wooldridge providing technical support. Martin considered ninety-four cities before breaking ground in February 1956 for a 300,000 sq. ft. fabrication facility with associated test equipment at the Waterton Canyon site in Littleton, Colorado, southwest of Denver.17

Initially conceived as a source of alternate ICBM subsystems, the Titan liquid-propellant missile differed significantly from the Atlas. Measuring ninety-eight feet in length, sixteen feet longer than the Atlas, the Titan was a genuine two-stage missile. Unlike the Atlas’ pressurized steel balloon design, the Titan’s airframe incorporated structural elements in the propellant tank walls, thereby producing a rigid self-supporting airframe. Using liquid oxygen and RP-1, a kerosene-like fuel, Aerojet’s powerful two-stage propulsion system consisted of two first-stage engines producing 300,000 pounds of thrust at sea level, and a second-stage engine generating 80,000 pounds when ignited in the vacuum of space. The two-stage configuration enabled the Titan to achieve a range of 6,350 miles with a payload of 3,825 pounds, over twice that of the Atlas. Bell Telephone Laboratories developed the radio-inertial guidance system used in the Titan i, while the Bosch Arma Corporation continued to work on an all-inertial guidance system. In the spring of 1958, however, the Air Force transferred the Bosch Arma inertial guidance system contract to the Atlas, where it would be incorporated into the Atlas e and f series missiles. By early 1959, the Titan program had under development a new inertial guidance system from General Motors Corporation’s AC Spark Plug Division, scheduled for completion in late 1962. In August 1958, AVCO Corporation had ceased work on a copper-sheathed heat-sink vehicle for reentry protection in favor of an ablative Mark 4 nose cone that also would be used in the Atlas d and f series missiles. By this point, planners had decided on silo-hardened sites designed to withstand a nuclear blast equal to 100 pounds per square inch (psi) overpressure and were looking ahead to the Titan’s capability as a space booster. At the same time, the Ballistic Missile Division by 1959 had authorized improvements to the Titan beginning with the fifth squadron that would include storable propellants, an in-silo launch capability, and a larger, more powerful second-stage engine. Looking ahead, the upgraded Titan would actually be deployed as the Titan ii beginning with the seventh rather than the fifth squadron.18

The Air Force accepted the first Titan i on 17 June 1958, and scheduled its initial flight for that December after captive (hold-down) tests at the Martin facility. Martin fabricated the Titan i in eight lots, totaling 163 missiles. Six Lot a limited range missiles consisted of a simplified first stage and dummy second stage filled with water. Although the first flight blew up on its Cape Canaveral pad before launch on 20 December 1958, by the end of the Lot a testing, on 4 May 1959, four of the six flights had demonstrated successful stage separation and excellent performance of the radio guidance system.19

The Lot b missile experience proved far less encouraging. Using complete first and second stages, these missile tests were to evaluate stage separation and a brief second
stage flight, as well as compatibility of the airframe and subsystems. A series of accidents during Martin's static testing delayed the initial launch of Titan B-5 until 14 August 1959. Unfortunately, following normal first-stage engine ignition, premature release of the hold-down bolts allowed the missile to launch with insufficient thrust. When the first stage umbilical lanyard pulled free, it caused an engine shutdown, and the missile fell back to the pad after rising to about twelve feet. The resulting explosion severely damaged the service tower.20

Additional test failures at the Denver site following the 14 August 1959 disaster rekindled earlier Air Force concerns expressed by Titan program manager Colonel Benjamin P. “Paul” Blasingame about Martin's management and organization. Following a number of meetings between key Air Force missile officers and top Martin officials, Martin's vice-president took over the Denver operation. Unfortunately, the initial Lot c missile, designed to test key subsystems and separation of a modified reentry vehicle, blew up shortly after launch on 12 December due to an unintentional triggering of the range safety destruct package. This failure precipitated a major Air Force review of Martin's management of the Titan program, as well as another series of Air Force, osd, and congressional assessments of whether to continue with the Titan. The Air Force report on Martin's management strongly recommended centralization of the Martin effort and implementation of new procedures. After meeting with Air Force representatives in early January 1960, Martin president George M. Bunker personally assumed control of the Denver operation. Meanwhile, Air Force and osd leaders once again decided to continue the Titan program and, in effect, support the twenty-seven-squadron Atlas and Titan force.21

The new management arrangement seemed vindicated with the next Titan launch on 2 February 1960. Completing a 2,200-nautical mile flight, it achieved a successful high-altitude, second-stage separation and engine ignition, with the nose cone impacting within two nautical miles of the target. During the following nine months, a variety of Lot c, g, and j missiles achieved ten successful flights, with an additional five partly successful, and three failures. The Lot g and j missiles especially showed consistent engine operation of both stages and a high level of guidance system accuracy. The flawless launch and flight of Titan m-7 on 19 January 1962 concluded the test-flight program at Cape Canaveral. Of the total forty-seven Titan i missiles launched, the Air Force classified thirty-two completely successful, ten partially successful, and five failures. Further Titan test flights would take place at Vandenberg, the newly completed dual training-operational missile base.22

The Development of Vandenberg (Cooke) Air Force Base
With the Air Force finding it difficult to test missiles under operational conditions at Patrick Air Force Base, Florida, and Cape Canaveral in the mid-1950s, sac’s commander-in-chief, General Curtis LeMay met with ardc commander General Thomas S. Power on 20 December 1955 to confirm the requirement for an alternative combined training and operational base for the icbm force as part of their review of the
entire missile program. They also acknowledged that the first missile sites would be above ground and largely unprotected, but that, given rapid technical progress, later sites would deploy missiles vertically in hardened silos below ground. Lastly, the two generals called for the establishment of a site-screening group to examine potential bases for the operational force. 23

In June 1956, after examining over two hundred locations, the missile site selection panel recommended as its choice for the composite training-operational base Camp Cooke, a 65,000-acre inactive Army reservation located on the California coast 120 miles northwest of Los Angeles. Positioned close to the state’s aerospace industry and the Western Development Division’s Los Angeles headquarters, the site also was situated in a relatively unpopulated region, offered ocean access for missile range operations, and benefited from a moderate climate year round. Convincing Secretary of the Air Force Donald A. Quarles to approve the selection, however, proved difficult. This being a period of budget cutbacks, he had balked at authorizing a new West Coast site whose estimated costs would increase from $42 million in fiscal year 1957 to $400 million in fiscal year 1958. 24

As chief of the site selection team, Lieutenant Colonel Vernon L. Hastings attended a long and contentious meeting on 20 August 1956 between Secretary Quarles and his staff and key representatives from Air Force headquarters, Air Research and Development Command, Western Development Division, and Strategic Air Command. Quarles questioned the need to use Cooke for operational missile firings, referred to as “systems exercise,” and strongly recommended all training be continued at Patrick. He criticized the site selection criterion of systems exercise as biasing the process, stating that “he had never approved such [a] requirement and it should not have been used.” A number of Air Force leaders strongly supported the Cooke selection, describing Patrick as overcrowded and presenting an overfly hazard. As noted by General Power, the Air Force needed "some place...to exercise the operational crews, to explode an atomic warhead and to utilize the thousands of missiles that would be built.” Quarles countered each one of these points, but, confronted by a united Air Force opposition, indicated that he would be willing to authorize the Cooke West Coast site but “only if the Air Staff would present a case justifying the need of a missile proving range.” This was done to his satisfaction in September, and on 16 November OSD approved the transfer of the Army’s northern portion to the Air Force. When the formal transfer took place the following spring, the service renamed the site Cooke Air Force Base. On 4 October 1958, the Air Force redesignated the former Army camp Vandenberg Air Force Base in honor of the late Air Force chief of staff. Vandenberg would quickly become the key training base for Atlas, Titan, and Thor missiles, as well as providing an emergency Atlas operational capability. 25

Preliminary design for the first Cooke Atlas complex of three “soft” launch pads began immediately, in August 1956, led by Colonel Hastings, the Western Development Division’s chief of the operational facilities. Because the facility design work, under the concurrency concept, had to begin before any subsystems had been finished
Vernon L. Hastings

Colonel Vernon L. Hastings was born in Table Rock, Nebraska, on 4 August 1917. He attended school in Table Rock and Lincoln, Nebraska, graduating from Lincoln High School in 1935. He enlisted in the Army Air Corps at Chanute Field, Illinois, on 9 November 1939. After serving as a Machinist Instructor during 1940–1941, he went to the first Army Air Forces Officer Candidate School (OCS) in January 1942 and graduated in May 1942. Serving as a second lieutenant under Major General Frederick L. Martin, who initially led the flight of US Air Service planes around the world in 1924, Hastings assumed his first command position—a training detachment for pre-meteorology cadets at the University of Wisconsin—in July 1942. During the remainder of WWII, he had various other technical training assignments in the Army Air Forces.

As an Air Force reserve officer at the end of WWII, he attended the University of Nebraska and graduated in 1949 with a bachelor’s degree in mechanical engineering. During 1949–1951, Colonel Hastings served as base engineer at Goose Bay, Labrador, and site support engineer for several arctic weather and radar stations. He then became chief of the Procurement Branch of the US Army Chemical Procurement District in Chicago, Illinois, from January 1952 to April 1954, before being assigned in May 1953 to July 1954 as deputy chief of Air Force Logistics Command’s Facilities Maintenance Branch at Wright-Patterson AFB, Ohio. In fulfillment of a master’s degree in industrial engineering at Oklahoma Agricultural and Mechanical College in 1955, he wrote a thesis titled “A Study of Activities in an Engineering Research Organization.”

In August 1955, Colonel Hastings joined General Bernard Schriever’s Western Development Division, subsequently renamed as Air Force Ballistic Missile Division, for a four-year stint as chief of the Initial Operational Capability (IOC) Branch. In that capacity, he directed the design of all US operational base facilities for the Atlas intercontinental ballistic missile (ICBM). He also led the site selection team for Camp Cooke, subsequently renamed Vandenberg AFB, as the location for construction of the first Atlas ICBM operational launch complex.

General Curtis LeMay, Air Force vice chief of staff, appointed him in 1959 as Site Activation Task Force (SATAF) commander for two of the earliest ICBM operational squadrons—the 566th Strategic Missile Squadron at Offutt AFB, Nebraska, and the 551st Strategic Missile Squadron at Lincoln AFB, Nebraska. During 1959–1962, Colonel Hastings oversaw launch-base construction of Atlas D “coffin” sites in eastern Nebraska and western Iowa. He also supervised installation of ground-support equipment at the launch sites and completed rigid checkout of missiles and other equipment prior to turnover to Strategic Air Command (SAC). Under his leadership, contractors constructed the first Atlas F sites that featured a hardened design, underground “silo” basing.

In consideration of his skillful handling of miner and machinist strikes at Atlas F construction sites in June 1960, Colonel Hastings earned appointment as chairman of the Missile Sites Labor Committee in Omaha, Nebraska, during 1961–1962. President John Kennedy directed its creation to reduce labor conflicts (i.e., grievances, work stoppages, etc.) and, thereby, foster continuous, peaceful work on projects at missile and space sites throughout the United States. Colonel Hastings began an academic career in 1962 that would extend across a quarter century. From 1962 to 1966 he directed the Civil Engineering Center at the Air Force Institute of Technology (AFIT). Thereafter, he served as assistant to the dean (1966–1969) and assistant dean (1969–1973) of Purdue University’s School of Technology. He became director of the construction program at Arizona State University in 1973 and continued as director of the Division of Construction until retiring with emeritus status in 1987.

More than two decades beyond his official retirement, Professor Hastings continued to travel the country, advising faculty and students on the applicability of the “learn by doing.” During those visits, he even encouraged professors and students to use information from the Atlas ICBM facilities project as tools for learning generally about large-scale construction.
and tested, planners had to develop initial criteria based largely on the system's design and operational objectives. Hastings' team and contractor working groups representing the four major Atlas contractors met to determine criteria based on analysis of the different functional areas and assessment of "all known technical information and criteria requirements." Completed that December, the design included the guidance facility, the launch pads, and the control building. The Ballistic Missile Division awarded construction contracts in the spring of 1957, and ground breaking began in May. By October of the following year, the initial Atlas launcher had been completed, and four months later Convair delivered the first Atlas D to the West Coast base.26

On 15 April 1957, the Air Force activated the 1st Missile Division at Cooke Air Force Base to oversee training, testing, and maintenance for the Atlas, Titan, and Thor missile units. Two and a half months later, the 704th Strategic Missile Wing was activated to manage the missile training squadrons planned for the three missile types. In an effort to accelerate the achievement of operational status following Sputnik, SAC had assumed responsibility on 1 January 1958 from the Ballistic Missile Division for all ballistic missile training and deployment. That same day SAC activated the 672nd Strategic Missile Squadron for the Thor, followed three months later by the 576th Strategic Missile Squadron for the Atlas. The initial three-launcher Vandenberg Atlas D operational complex, 576A, had the missiles deployed upright on open launch pads, serviced by gantry cranes that were detached prior to launch. Complex 576B's Atlas Ds were housed horizontally in above ground “coffin” launchers, with one launch control center for each complex. At the same time, work began in July 1959 on the Atlas E semi-hardened buried coffin launch site, 576C, and that October on the two silo-lift launchers, 576D and 576E, for the Atlas F. Fully eleven Atlas complexes had been constructed at Vandenberg by 1962. On 9 September 1959, nearly a year after the contractors had completed work on the initial Atlas complex, the first operational Atlas D lifted off from its “soft” site on a successful flight to its target close to Wake Island in the Pacific. General Power, who had succeeded LeMay as SAC's commander-in-chief, then declared the Atlas operational and placed the 576th Strategic Missile Squadron missiles on alert a month later.27

Meanwhile, on 31 July 1958 work had begun on the prototype of the silo-lift Titan I launch control facility, designated the Operational System Test Facility, and by late 1960, the Vandenberg Titan area included an additional three training silos as part of operational Launch Complex 395A. On 3 December, however, a fully loaded Titan I being lowered back into the facility plunged to the bottom when a control valve in the elevator hydraulic system failed. The explosion proved sufficiently damaging to convince officials to forego salvaging efforts, make appropriate modifications to elevators for launch complex 395A, and use it for testing and training requirements.28
Atlas Operational Deployment—F. E. Warren Air Force Base Leads the Way

On 1 January 1958, when SAC assumed responsibility for missile deployment, it also took control of F. E. Warren Air Force Base, Wyoming, the first Atlas operational base. During the August 1956 site selection briefing, Secretary Quarles had stressed the importance of “target selection,” calling for the next ICBM locations to be in the Midwest, as far north as needed to provide optimum coverage of Soviet targets. One of the Air Force participants responded by noting the availability of nearly 60,000 acres of government land at Wyoming’s Fort Francis E. Warren near Cheyenne.29

That fall the Ballistic Missile Division established a site-selection panel that included Air Force engineers and representatives from the Army Corps of Engineers and architect-engineer firms. In addition to Secretary Quarles’ criterion of Midwest locations, the panel’s list of site requirements included specific soil and geological parameters for silo construction, available access roads, and nearby government installations and communities of fifty thousand or more residents. After examining more than 250 potential Atlas sites, the panel narrowed the choice to F. E. Warren and nine additional locations. In May 1957 the Air Force Ballistic Missiles Committee approved F. E. Warren as the first Atlas operational base, and OSD sanctioned the choice on 21 November 1957. That December the Air Force authorized the Corps’ Omaha district engineer to acquire nine thousand acres of land in the vicinity of Cheyenne for constructing the missile fields. The Air Force had been strongly lobbied by Republican Senator Frank A. Barrett, who led the Wyoming effort to have Cheyenne become the nation’s “missile headquarters.” He and other Wyoming political figures eagerly looked forward to the expected economic input of $100 million into the greater Cheyenne community. Although not speaking for all of his fellow citizens, Mayor Worth Story declared, “Cheyenne is proud to have the first missile base in the country and proud to be the nation’s No. 1 target for enemy missiles.”30

The F. E. Warren complex would eventually house two Atlas D squadrons, the 564th Strategic Missile Squadron, activated on 1 July 1958, and the 565th Strategic Missile Squadron, activated on 1 December 1958, and referred to as Warren I and Warren II, respectively. Missile design revisions, an almost inevitable result of developing advanced weapons technologies with a concurrent acquisition strategy, delayed the initial construction contract bid opening for Warren I to July 1958, and even then the project was marketed without a number of crucial elements, including instrumentation, power facilities, and the propellant loading system skids—metal pallets which had bolted to them the valves, piping and other required fueling equipment. During construction on Warren I, also referred to as Site A, located on nine hundred acres twenty-one miles north, northwest of Cheyenne, the prime contractor, the George A. Fuller Company of Los Angeles, had to make 35 modifications to the guidance facility and 115 to the launchers. These changes, combined with severe winter weather and labor strikes and work stoppages totaling 6,748 man-days lost, compelled planners to postpone completion from the original target of November 1959 to the summer of 1960. Despite the
Brigadier General Maurice A. Cristadoro, Jr., was born on 8 February 1920 in New Orleans, Louisiana. He earned a Bachelor of Science degree in chemistry from Loyola University in New Orleans. General Cristadoro joined the Army Air Corps in March 1941 and, after receiving his pilot wings and commission in November 1941, was assigned to Ellington Field, Texas, where he became a flying instructor, advanced flight trainer and, eventually, director of flying. From August 1944 to October 1945, he served in Europe as a P-51 “Mustang” flight leader and commander of the 55th Fighter Squadron.

In June 1947, after completing a Master of Science degree in physical chemistry at Ohio State University, General Cristadoro was assigned to the Deputy for Operations at Wright Air Development Center. He rose to become chief of the Special Weapons Branch, where he focused on the compatibility of designs for eight-ton nuclear warheads with aircraft delivery systems. Moving to Headquarters U.S. Air Force (USAF) in 1952, he worked for then Colonel Bernard A. Schriever on advanced systems planning in the Office of the Deputy for Research and Development. In addition to the supersonic B-58 “Hustler” project, General Cristadoro handled site surveys for future deployment of the Atlas ICBM in three different configurations: unprotected, above-ground horizontal launchers; semi-hardened, horizontal launchers; and hardened, vertical silos. Because of his involvement with those site selections, others in the office began calling him “Mr. Atlas.”

In August 1956, General Cristadoro went to Western Development Division, where he served as deputy director of the Atlas ICBM program under General Otto Glasser until March 1958, then became program director until July 1961. He was responsible for all aspects of Atlas acquisition, which had the highest national priority. He was among a very small group of individuals intimately involved with the highly secretive preparations for using an Atlas booster to launch SCORE (Signal Communications by Orbiting Relay Equipment), the world’s first communications satellite, in December 1958. Years later, General Cristadoro would identify the SCORE mission, which resulted in the worldwide broadcast from space of President Eisenhower’s message of peace and goodwill, as the highlight of his military career. It was an amazing jump, he recalled, from launching a small thermonuclear warhead to sending a full-size Atlas canister into orbit.

Assigned to Air Force Systems Command (AFSC) headquarters in July 1961 as project director for ballistic missiles, General Cristadoro oversaw all matters associated with that command’s role in ballistic missile acquisition. He especially shouldered responsibility for shifting resources from Atlas to the Titan and Minuteman ICBM programs. At Wright-Patterson AFB, Ohio, during 1963-66, he engaged in advanced planning for weapon systems based on General Schriever’s Project Forecast. From September 1967 until his retirement from active duty in February 1970, General Cristadoro campaigned vigorously, based on a white paper he wrote, to reorganize systems analysis and development planning within AFSC along mission-related lines. General Cristadoro died on 22 November 2008.
dangerous work at Site A, the labor force experienced no fatalities and only thirty-three disabling injuries, which represented a frequency rate six times better than the national average for the construction industry. On the other hand, Kenneth Calkins, a twenty-three-year-old pacifist from Chicago participating in a four-month protest, experienced a fractured pelvis when hit by a truck he tried to prevent from entering the Site A construction area. Many of the problems that the initial F. E. Warren deployment project encountered would affect the other Atlas site construction efforts.31

By the time Warren I neared completion, the Air Force Ballistic Missile Division had decided to extend the operational lifetime of the site against natural elements and enemy targeteers by housing the missiles, as at the second Vandenberg Atlas D complex, in a horizontal position in above-ground reinforced concrete “coffins.” A heavy concrete movable door allowed the missile to be raised to a vertical position for fueling and launch. Warren I consisted of two complexes of three launchers each (3 x 2 configuration), and arranged in a roughly circular pattern around the launch control complex, power plant, and guidance building.32

The missile’s guidance system largely determined the site configuration. Because the D model relied on a General Electric/Burroughs radio-inertial guidance system, it required an array of antenna installations to provide ground control during the initial flight sequence. As a result, the three launchers had to be grouped closely around the launch control complex, which made the site an ideal target for a single enemy warhead. With the tight IOC schedule, few drastic design changes or time-consuming protective measures could be allowed in the Atlas D facilities at Vandenberg and F. E. Warren. Two additional Atlas D squadrons, Warren II’s 565th Strategic Missile Squadron and the 549th Strategic Missile Squadron at Offutt Air Force Base, Nebraska, reflected efforts to provide increased survivability against nuclear attack. Designated a 3 x 3 configuration, each squadron consisted of three austere complexes of three launchers apiece, separated from each other by fifteen to twenty miles and protected only to an overpressure of 5 psi. The F. E. Warren sites were constructed twenty-four miles to the northeast, east, and west of the base.33

The third F. E. Warren missile squadron, the 549th Strategic Missile Squadron, or Warren III, activated on 1 October 1960 and redesignated the 566th Strategic Missile Squadron on 1 July 1961, consisted of Atlas series E missiles. Reflecting the evolution of Atlas capabilities, the Atlas E’s main improvements included replacing the Mark 3’s 1.44-megaton W-49 warhead with the 4-megaton W-38 and adapting all-inertial guidance that detected flight path deviations and automatically provided midcourse corrections. Given the limitations of the radio-inertial guidance system, the Western Development Division had been pursuing an all-inertial guidance and control capability for the Atlas E and the F series to follow. By March 1960, American Bosch Corporation’s Arma Division had successfully tested its system initially on a flight of an Atlas D.34

* See Appendix II-2.
All-inertial guidance contained on board the missile meant that the Atlas e did not require the series d’s elaborate ground antenna system, with its extensive real estate requirements, and thus could be sited separately and widely dispersed. For the Atlas e, designers also increased missile survivability by constructing the heavier semi-hard coffins first used at Vandenberg. Buried flush with the earth’s surface and protected by concrete overhead doors, they were designed to withstand overpressure of 25 psi. Tunnels connected the underground launch and propellant loading system structure with a buried operations building containing control mechanisms as well as an independent power generating system and other utility equipment. Dispersed approximately fifteen to eighteen miles from each other and the main support facility, launch sites reflected the 1 x 9 unitary design, which configured each of the nine launchers with its own launch control center. The three Atlas e squadrons, the 567th Strategic Missile Squadron at Fairchild Air Force Base, Washington, the 548th Strategic Missile Squadron at Forbes Air Force Base, Kansas, and F. E. Warren’s 549th Strategic Missile Squadron achieved operational status in 1960. F. E. Warren’s nine Atlas e sites stretched over the states of Wyoming, Nebraska, and Colorado.\(^35\)

Progress enhancing Atlas survivability culminated in the silo-lift Atlas series f, which housed an improved all-inertial guidance system. Stored 174 feet below the surface in a concrete-lined silo expected to survive overpressures of 100 psi, the missile rested on an elevator within a heavily reinforced steel crib framework attached to the silo walls by four large “shock-isolation” springs. After opening the massive silo doors and loading the propellant tanks, operators engaged the elevator to raise the missile to the surface for firing. Separated by seven to twelve miles, each 1 x 12 unitary complex occupied only five acres compared to the twenty acres needed by the Atlas d and e facilities.\(^36\)*

Unlike the Atlas d and e construction effort, the massive Atlas f earthmoving and silo construction project meant having to deal with soil and ground water problems and more dangerous safety hazards. Not surprisingly, while the Atlas d sites experienced no deaths during construction and the e sites only three, the f complexes recorded twenty-five deaths and considerably more job-related injuries. The Ballistic Missile Division and the Corps of Engineers completed construction of the six programmed Atlas f sites, comprising twelve silos each, in 1961, with the last squadron, the 556th Strategic Missile Squadron at Plattsburgh Air Force Base, New York, activated on 1 October of that year. The Plattsburgh missiles represented the only icbms deployed east of the Mississippi River.\(^37\)†

---

* See Appendix II-3.
† See Appendix II-4.
Titan I Operational Deployment—Lowry Air Force Base Leads the Way

Like the Atlas F, all Titan I missiles were stored in silos hardened to 100 psi. In fact, the Titan had been programmed for silo-lift deployment early in its research and development process, when WDD Vice Commander Brigadier General Osmond J. Ritland, on 6 November 1955, directed that Titan I planning proceed on the basis of hardening their sites.38

Also dependent on radio-inertial guidance, the Titan I employed a 3 x 3 site configuration similar to that of the Atlas D complexes at Warren II and Offutt Air Force Base. More so than the Atlas, however, the Titan complex represented “a self-contained, underground village with its own utilities.” At one end, twin silos containing the guidance system antennae were linked to the dome-shaped launch control center and the powerhouse in the center, which, in turn, connected to the three missile silos at the other end. Silo-like terminals for each missile stored the propellant loading equipment and additional supporting elements. Personnel accessed the elaborate tunnel system by means of a portal close to the center of the complex.39*

On 19 December 1957, AFMBM’s Ballistic Missile Site Selection Panel recommended Lowry Air Force Base near Denver, Colorado, and close to the Martin Company’s Titan production company as the first operational Titan base. The Air Force Ballistic Missiles Committee approved the choice on 13 March 1958, and construction on two squadron complexes began the following spring. Although plagued by a national 144-day steel strike beginning on 15 July 1959, which required pouring concrete during the winter months and numerous modifications, the project benefited from good labor-management relations and boasted the lowest costs and best safety record of any ICBM site construction team at that time.40

The contractors completed construction on all nine silos by 4 August 1961, a month after SAC had activated the 724th Strategic Missile Squadron at Lowry. It had replaced the 848th Strategic Missile Squadron, which had been the first Titan I squadron to be activated, on 1 February 1960. The command declared the 724th operational on 18 April 1962, and the first Titans went on alert two days later, followed the next month by those of its sister squadron, the 725th Strategic Missile Squadron. Eventually, the Titan fleet would include an additional four squadrons activated between December 1960 and June 1961, at Ellsworth Air Force Base, South Dakota; Beale Air Force Base, California; Larson Air Force Base, Washington; and Mountain Home Air Force Base, Idaho.†

Building the Missile Bases

From the outset, selecting, constructing, and installing the necessary equipment for the missile bases represented a cooperative effort between the Air Force and the

* See Appendix II-5.
† See Appendix II-6.
First-Generation ICBM Force, 1955–1965

Army’s Corps of Engineers. Initially, several dozen survey teams comprising Air Force engineers, Corps of Engineers personnel, architect-engineer firm contractors, and AFBMD representatives made more than 250 site surveys and submitted their recommendations. Once the particular site was selected, the Corps Engineer District Office closest to the site assumed responsibility for acquiring the rights of entry for surveys, exploratory work, site construction, and for conducting negotiations for land purchase and necessary easements.41

Initially, two key Los Angeles-based Air Force elements oversaw the effort. Air Research and Development Command’s Ballistic Missile Division, working with architect-engineer firms, designed and developed the missile and the base facilities, while Air Materiel Command’s Ballistic Missile Center managed the installation and checkout of the missile and associated equipment in the launcher facilities. The Corps of Engineers prepared the contract bids, awarded the contracts, and, through its site engineer, oversaw construction.42

The site construction teams, having no missile site building experience and facing concurrency’s significant time constraints, found themselves under tremendous pressure. Once construction began in July 1958 on the first operational site at F. E. Warren, the acceleration and evolution of the missile program severely complicated and expanded the Corps’ effort. From the above ground Atlas d and semi-hardened Atlas e coffin sites, the Corps took on the difficult task of constructing the Atlas f and Titan i silo launchers.43

The six Atlas f bases, for example, required contractors to excavate 2,700,000 cubic yards of earth, emplace 565,000 cubic yards of concrete, and use nearly 100,000 tons of steel. The process began with an open-cut excavation to a depth of 60 feet, the level of the launch control center floor. From there, contractors mined the silo, 65 feet in diameter, to its final depth of 174 feet below the surface. During this process, workers used steel ring beams, wire mesh lagging, and pumped in concrete to support the silo walls. Next, workers built the huge steel crib framework to support the missile and its associated equipment. When finished, the Atlas silo contained a composite mass comparable to that of a fifteen-story steel building weighing nearly 1,500 tons. Construction of Titan i silos involved procedures similar to those for the Atlas f, although the Titan i squadron, being less dispersed, required 50 percent less excavation and 20 percent less steel. Unlike the Atlas silo, the Titan silo required a diameter of forty feet because of the separate propellant terminals and equipment provided. At the same time, a Titan squadron needed nearly 20 percent additional concrete to harden the “self-contained, underground village.”44

Most difficult of all proved to be constructing the underground propellant loading system capable of storing and pumping huge lots of propellant at temperatures as high as 120 degrees Fahrenheit (°F) to as low as -400 °F, through shock-resistant piping at various flow rates under 6,200 psi of pressure. Above all, the system required taking great care to avoid having any hydrocarbon particles larger than 150 microns in the liquid oxygen pipes. As Army engineer Brigadier General Thomas J. Hayes
observed, the fuel and cryogenic handling equipment required “a degree of cleanliness greater than that found in most laboratories.” Brigadier General Alvin C. Welling, the Corps of Engineers officer directing the construction effort, asserted, “in no other combat construction...[was the Army]...confronted with the requirement...for extremely precise and extremely good workmanship.” Precision, cleanliness, and standardization remained critical criteria throughout the construction process. In addition to building complex launchers and supporting structures, civilian contractors faced a continual stream of modifications to the basic contract. Under concurrency, the Corps of Engineers built the launch facilities at the same time that the Air Force continued designing, fabricating, and testing the missile. Consequently, change became the order of the day and the main reason for schedule delays and complaints from contractors about excessive and unfair expenses resulting from fixed-price contracts. Titan I testing at Vandenberg in 1959, for example, indicated the need for changes to the propellant loading equipment, and the Air Force redesigned the entire system. Because the revised design proved inadequate, new requirements called for over two hundred added supports in each propellant terminal and more than one hundred in each silo launcher. This resulted in a six-month delay achieving operational capability for the first complex at Lowry. By April 1962, the Corps of Engineers had recorded a total of 2,676 modifications and change orders to the contracts for the Atlas D, E, and F sites. At a cost of $96 million, the base contract price had risen by 40 percent.

Above all, concurrency demanded a breakneck pace. In the words of General Welling, facility construction had to “be carried out with the explosive speed of combat.” But by the spring of 1959, the increasing schedule delays and higher program costs found contractors blaming the manufacturers and their Air Force supervisors, while Corps of Engineers and Air Force personnel faulted the contractors, each other, and labor unions. With Congress becoming concerned, the Army leaders decided on an organizational change to provide more centralized control. Realizing that the Corps districts no longer had the resources to provide effective management of the expansive project, in July the Army established a central coordinating branch, the Los Angeles Field Office, under General Welling, that reported directly to the Chief of Engineers. To achieve better liaison with the Air Force, the Army located the new office in close proximity to the Ballistic Missile Division’s Inglewood, California, headquarters.

Even so, continued delays and congressional investigations compelled the Corps of Engineers and the Air Force to respond more forcefully. In July 1960, they initiated several meetings with Secretary of Defense Thomas Gates and fifty-six leaders from industry and labor involved in missile construction. Gates solicited suggestions for improvement while emphasizing the critical importance of the program for the nation’s security and the imperative of staying on schedule. The meetings precipitated major changes the following month in both the Air Force and Corps of Engineers missile project organizations.
On 1 August 1960 the Corps created the Corps of Engineers Ballistic Missile Construction Office (CEBMCO), commanded by General Welling and virtually colocated with the Air Force’s Ballistic Missile Division and Ballistic Missile Center. Charged with bringing uniformity and efficiency to the entire ICBM construction program, the new office assigned highly qualified directors, with “rather autonomous responsibility,” for the Atlas F bases and the Titan I bases to oversee contract construction. Atlas D and E bases, however, remained the responsibility of the various Engineer Districts because they were much further along the path to completion. In conjunction with the advent of the Ballistic Missile Construction Office, the Corps also strengthened its area offices at individual bases by increasing officer strength in the field by 400 percent.50

At the same time, the Air Force responded to the delays and problems of missile site responsibility with its own major organizational changes. In June 1960, Air Force Vice Chief of Staff General LeMay visited the missile sites and realized that the issues involved in activating a site in only two years had been hugely underestimated. Moreover, he found no specific central authority at any level, with as many as seven separate elements providing instructions to construction contractors. Decisions needing prompt action more often took weeks.51

On 9 July General LeMay directed that Air Materiel Command become responsible for the site activation mission, with the exception of the early Atlas sites at Vandenberg, and the Atlas D sites at F. E. Warren and Offutt, where construction progress did not warrant a transfer from the Ballistic Missile Division. He also decided that one officer, soon called the Site Activation Task Force (SATAF) commander, be made responsible at each base for completing the construction, missile installation and checkout, and for turnover of an operational site to SAC on schedule. Two days later, an agreement between the Ballistic Missile Division and Air Materiel Command’s Ballistic Missile Center implemented General LeMay’s instructions. At the same time, Major General Thomas P. Gerrity arrived from the Oklahoma City Air Material Area to assume command of the Ballistic Missile Center, with orders to take charge of the ICBM program.52

General LeMay then had his personal staff select the best eighteen colonels available for SATAF duty at the individual sites. On 21 July 1960, shortly after the officers had been assigned to the Ballistic Missile Center and their specific duty stations, they received the following message from the vice chief of staff: “I want it thoroughly understood that I hold each site commander personally responsible for successful activation of his site and its turnover to SAC in an acceptable operational condition at the earliest possible date. This includes responsibility for construction.”53

Apart from two site managers already in place, now-Colonel Hastings at Offutt and Colonel Edwin A. Swanke at F. E. Warren, the sixteen new Site Activation Task Force commanders, all pilots, had no experience in the missile arena to prepare them for the enormity and complexity of their assignments. While they found that their responsibilities often seemed clear and direct, implementing them proved difficult.
Although made responsible for construction, the SATAF commander had no command authority over the Corps’ Area Engineer. The latter did, indeed, serve under the SATAF commander as deputy for construction, but he also retained on-site authority for construction and reported through CEBMCO channels. At the same time, experienced Air Force Ballistic Missile Division officers already in place at the missile site initially tended to consult on problems with their superiors at their headquarters rather than with the inexperienced Site Activation Task Force chief. Fortunately, Generals Gerrity and Welling set a good example of cooperation for their subordinates, and the Air Force commands and the Corps of Engineers staffed their site units with highly qualified people.\(^5^4\)

Clearly, progress in the wake of the organizational changes in July and August 1960 did not prove significant enough for California Representative Harry R. Sheppard, chairman of the House Subcommittee on Military Construction, to call off hearings he had scheduled on the missile base construction program. “Any way you look at this program,” he said in February 1961, “things are in a mess…this program has been characterized by failure of top-level management to exercise proper control of a complex construction program and by a growing rivalry between the Corps of Engineers and the Air Force.” On a single day, 13 February 1961, the committee heard testimony from twenty-nine key officers and officials from industry and the military, including Generals Gerrity and Welling. Construction industry witnesses complained about the inordinate number of change orders that, they argued, produced delays, increased costs, and at times put their companies and those of their subcontractors in jeopardy because of a cumbersome, untimely compensation process.\(^5^5\)

Typical was the testimony of Francis E. Cornwall, president of Macco Corporation, who noted that his work on the Atlas F silos at Walker Air Force Base, New Mexico, suffered not only from labor strikes and particularly bad weather, but also from modifications amounting to $5 million in added work, “misrepresented” subsurface information, and “changes, errors, and discrepancies in the plans and specifications.” He went on to declare, “The Government has so changed the conditions under which the project was bid that the contractor is now performing an entirely different contract.”\(^5^6\)

Under Secretary of the Air Force Joseph V. Charyk responded by defending the necessity of concurrency to meet the “extreme urgency” to develop “a very large operational force in a minimum of time and in a scientific field where major breakthroughs are frequent.” He went on to support the previous summer’s reorganization that established more centralized control of site construction with the creation of CEBMCO and the SATAF. As for contractor criticism of changed conditions, he highlighted anomalies such as the large differences in cost growth claims and completion dates for three projects undertaken by three different contractors at the same time. “We believe,” he said, “that adequate recourse exists within the contract for equitable compensation…for changed conditions and increased scope of work…but the contractor is obligated to submit properly analyzed and substantiated claims promptly.”\(^5^7\)

The Air Force promised more rapid action on contractor claims, and it authorized the
sataf to create a Change Control Branch to provide fast action and necessary control of changes at the local level.  

While the Sheppard committee deliberated, and the Senate Subcommittee on Government Operations investigated labor problems at the missile bases, the new Kennedy administration assessed the report issued on 10 January 1961 by science advisor Jerome B. Wiesner, George B. Kistiakowsky’s successor in this post, on the state of the nation’s missile and space programs. Citing distractions from the new series of space programs, the Wiesner Report called for more efficient management and funding to accelerate a missile program it found lagging in development, procurement, and site construction.  

Responding to Deputy Secretary of Defense Roswell L. Gilpatric’s suggestion that the Air Force reorganize to win the space mission, Air Force leaders on 17 March 1961 announced that, effective 1 April, Air Force Systems Command and Air Force Logistics Command (AFLC) would replace Air Research and Development Command and Air Materiel Command, respectively. In Los Angeles, both the Ballistic Missile Division and the Ballistic Missile Center were dissolved and reconstituted as Ballistic Systems Division and Space Systems Division under Air Force Systems Command. Added to the Los Angeles contingent, a deputy commander for aerospace systems would help stress the urgency of fielding an operational ICBM force. To further streamline the base construction and activation effort, General Welling now became deputy for site activation responsible to General Gerrity, the new commander of the Ballistic Systems Division. General Welling assumed responsibility for all site activation tasks except installation and checkout. The Area Engineer continued to report to the sataf commander on construction tasks and CEBMCO on contracts, while the sataf commander reported to General Gerrity through General Welling.  

To address labor issues more directly, President John F. Kennedy, on 25 May 1961, created the Missile Sites Labor Commission, with the secretary of labor as chairman. At the same time, each missile site established its own labor relations committee, which included the sataf commander as the military representative. Both the Corps of Engineers and the Air Force hired labor relations advisors at each missile base, while the Federal Mediation Service provided site representatives as well. The new arrangement and high-level attention virtually eliminated work stoppages and lengthy unresolved disputes.  

Yet, as noted years later by retired Lieutenant General Harry E. Goldsworthy, the eighteenth sataf commander selected in July 1960, the reorganization hardly affected the position of the site commander. He continued to be “all things to all people,” as he faced myriad challenges in providing temporary sataf and contractor housing and facilities, performing construction surveillance, and supervising missile installation, checkout, demonstration, acceptance and turnover to SAC. Along the way he had to develop an effective integrated work schedule between installation and checkout contractors and construction contractors, as well as ensure proper “interface” between items of equipment and items of construction. To address the problem of schedule
delays resulting from change orders, the Corps of Engineers allowed the SATAFS to enact joint tenancy agreements. Previously, missile contractors and subcontractors could not enter the site to install their equipment until all base construction had been completed. Under the new joint tenancy arrangement, the Area Engineer accepted elements of the project in increments, which allowed installation of missile support equipment before construction had been completed.62

Beyond their daily site supervisory work, Site Activation Task Force commanders also fostered important community relations programs. The influx of nearly 3,000 contractor and SATAF people into local communities for two to three years, often in rural areas, compelled the initial site selection team to meet with the community to explain the weapon system, the expected size of the influx, and the economic prospects for the region. SATAF commanders sustained the initial good relationship by keeping the community informed, while participation by base personnel in community activities also helped maintain the support and continued cooperation of local citizens.63

Soon the contractors were meeting overall target dates, and SATAFS turned over operational sites to SAC on or ahead of schedule. The Atlas D squadrons at F. E. Warren and Offutt had achieved operational status by 30 March 1961, and the entire Atlas missile force had been turned over to SAC by 20 December 1962. The initial Titan I squadron at Lowry became operational on 18 April 1962, while by 28 September of that year SAC had declared all Titan I squadrons operational. As SATAF commander General Goldsworthy concluded, “contractors, workers, and the military…[showed]…that they could take on the largest peacetime effort in history and produce on schedule.”64*

Training the Operational Force

Concurrency proved especially troublesome for the missile personnel training program that could draw on no previous experience. Organizing and training operational units while at the same time developing and testing a complex weapon system undergoing major modifications meant that training curriculums, training aids, and facilities for training programs underwent continual revision. Moreover, the long training lead time necessary to achieve individual proficiency meant sending missile officers and enlisted men to contractor plants for initial training.

Although Air Force Headquarters approved Air Research and Development Command’s request for 26 officers and 133 airmen as early as November 1956, little training activity occurred until the acceleration of the missile program following Sputnik. After SAC assumed control of the ICBM program from ARDC in January 1958, the Air Force established personnel requirements and formulated an integrated weapon system program. The first class of Atlas supervisors completed training in July 1958, and prepared to conduct integrated training, or crew training, at Vandenberg the following year.65

* See Appendix II-4 and II-6.
While SAC was responsible for crew training and unit training, Air Training Command handled individual training, first by establishing resident schools at contractor plants. In May 1959, Convair began its “over-the-shoulder” individual training in its laboratories, on the production line, and at its Sycamore Canyon test site, covering, according to one launch control officer, “from blueprint to component, system by system how the whole bird is put together.” Classes normally consisted of no more than ten Air Force students and lasted for three months, with other contractors providing similar training programs. Air Training Command also created primary training bases for the Atlas and the Titan at Sheppard Air Force Base, Texas, and Lowry, respectively, and support bases at Chanute Air Force Base, Illinois, for propulsion training and at Keesler Air Force Base, Mississippi, for ground guidance training.66

Later that year, Vandenberg initiated integrated weapon system training “on the pad” for twelve-member Atlas D crews and five-member Atlas E and F crews to become proficient in operating and maintaining the missile and launching it within fifteen minutes. A crew became combat ready following integrated training, which normally lasted three months. Crews could look forward to recurring training at their operational bases every six months to maintain currency, and to corrective training to deal with discrepancies resulting from missile inspections.67

The first Atlas missile crews consisted of experienced, handpicked personnel largely from SAC bombing crews. As noted by Colonel Allen W. Stephens, chief of staff of the 1st Missile Division at then Cooke, retraining crewmen for missile duty created the “two roads” dilemma, whereby SAC weakened the existing manned aircraft deterrent force by building up its fledgling missile units. He went on to argue, “For every man we take out of SAC bomber units, we must train a replacement.”68

At the same time, senior officers worried about retaining missile personnel beyond the initial group of experienced SAC airmen. They expected it to take three years to train a missileman, who then had only one year left on his enlistment. According to statistics, he was likely to leave the service at that point, especially when confronted by the constant companions of “boredom and monotony,” multiple-shift operations, and frequent family separations. With the objective of retaining a trained missile airman for at least eight years, various incentives received attention. One officer in 1958 asserted that “the crew must be kept busy” and be motivated by a spirit of crew excellence. He and other commentators described the need for a standard eight-hour day, adequate pay, good housing, recreational facilities, and additional amenities. They especially noted the housing construction effort at Cooke in early 1958 that was creating “conditions not even dreamed of by service men of the past.” Army barracks housing seventy-four men at a time were being replaced with modern two- and three-man room dormitories, while existing bachelor officer quarters were converted into comfortable apartment units. Families now would have access to one of the more than 1,300 three- and four-bedroom Capehart quarters with modern appliances.69

The problem of retaining motivated missile personnel would continue well beyond the Atlas and Titan I experience. As early as December 1961, SAC discussed the impor-
tance of attracting outstanding people by providing an advanced-degree program that could be pursued during the long hours of alert duty. Nothing came of the suggestion at that time because the maintenance required of the first-generation liquid-propellant missiles left little time for educational pursuits. The advanced degree program would nevertheless become a major incentive for missile crews assigned to future Minuteman squadrons.  

The Operational Force and the Reliability Issue

As previously noted, on 1 September 1959 SAC Commander-in-Chief General Power announced that the first Atlas D missiles at Vandenberg had achieved “operational” status. A week later, following a successful training flight performed by a SAC crew, the command placed one of the three Atlases in the 576th Strategic Missile Squadron on Emergency War Order alert. Transmitted by the president, the Emergency War Order enabled combat crews to launch their missiles against targets determined by the nation’s war plans, especially the Single Integrated Operational Plan (SIOP) developed by a multi-service target selection contingent at Offutt. The SAC commander-in-chief served as the director of strategic target planning and supervised the preparation of a National Strategic Target List that provided the targets for the SIOP. The SAC chief reported directly to the Joint Chiefs of Staff (JCS), which approved the initial SIOP on 9 December 1960. Designated SIOP-62, the plan went into effect on 1 April 1961.  

Strategic Air Command leaders expected the other Vandenberg Atlas ICBM s to go on alert shortly after the site’s first Atlas D, in conjunction with the beginning of an extensive combat training program. Instead, Atlas testing at Vandenberg encountered severe problems with the propellant loading system as well as a series of component issues that led to the destruction of three missiles during the first half of 1960. By that spring, missile reliability issues, together with delays in site activation and slippages in squadron operational dates, led General LeMay to create the SATHF and to revise the missile-testing program. To achieve a rapid operational capability, the Air Force had largely skipped from Category 1 subsystem testing by the contractor to Category IV “continued” operational tests undertaken by SAC. Omitted was substantial Category II subsystem and component integration testing and, especially, Category III initial operational testing by SAC to verify accuracy, readiness, and reliability.  

That August, when the first F. E. Warren Atlas D squadron became operational, Air Force headquarters authorized General Power to begin a year of high-priority Category III missile reliability tests involving the second Vandenberg Atlas complex. Yet, when thirteen of sixteen Atlas launches in September and October 1960 failed, General Power felt compelled to declare that at that time, fully a year after the Air Force had declared the Atlas operational, the unreliability of the deployed missiles meant they had “zero” chance of being launched and reaching their targets. Air Force Chief of Staff General White believed that Atlas’ unreliability resulted from frequent, significant reprogramming actions necessitated by system configuration changes.
His assertion received confirmation in a November 1960 report by an intercommand board that General LeMay had established to investigate the missile failure issue. Along with identifying inadequate configuration and quality control procedures as major reliability problems, the board also cited insufficient technical data and facilities, and inadequate testing. The Air Staff responded to the board's report by directing Vandenberg personnel to conduct a combined Category II and III test exercise for the Atlas D, called Golden Ram, which became a year long effort to thoroughly examine the missile, its supporting equipment and procedures, as well as missile crew and maintenance personnel proficiency.73

At the same time, problems developed with the Atlas E and Titan I. Interface deficiencies involving the Atlas E's hydraulic and control systems contributed to the failure of three Category II test flights that fall. Then, on 3 December 1960, an elevator malfunction at the Titan's Vandenberg Operational Site Training Facility resulted in an explosion that destroyed the facility. Together with ongoing site activation schedule delays, the Atlas E and Titan I problems meant postponing operational dates up to two months.74

By the spring of 1961, Golden Ram had revealed inadequate technical manuals and maintenance and operational procedures as well as hundreds of problems with ground equipment, site facilities, and the missile itself. With over 40,000 identifiable parts, the sheer complexity of the Atlas made operating and maintaining the missile an extremely difficult task. Moreover, its deliberate and dangerous fuel loading procedures prevented both the Atlas and Titan I from achieving the rapid fifteen-minute reaction time established by SAC. An investigation conducted by OSD concluded, "It is too early to have high confidence in the readiness, reliability, and accuracy of ICBMs." In June, three months after the final two Atlas D squadrons achieved operational status, the Air Force began an eight-month retrofit program, involving 1,200 contractor and SAC personnel, at a cost of more than $20 million. The Air Force also established a configuration control board with the authority to "coordinate and control changes, ensure the compatibility of designs and hardware, and control and predict costs and schedules." Officials hoped that the corrective measures would produce an Atlas D reliability figure of between 50 and 75 percent, although General Schriever confidently predicted an 80 percent figure in a few years.75

General Power remained concerned. In December 1961, following a rising number of Titan I problems, he informed General Schriever that the Air Force could not "afford to repeat the Atlas D route of prolonged multiple failures and difficulties…[and endure]…another Golden Ram." Although the other missile systems did not face a Golden Ram, they all underwent “update” modification programs that became routine in the first-generation missile program. Certain missile deficiencies also warranted a “pre-update” effort, as was the case for the Atlas F in August 1962, on the eve of becoming operational. Alarmed that the Atlas F seemed to have more reliability problems than the Titan I and the Atlas D and E series missiles, General Power authorized Clean Sweep, a pre-update effort to address fifty-four identified discrepancies.76
Even after Clean Sweep’s corrections, Atlas F maintenance crews continued to experience problems with the coolant system for the missile guidance and flight control components, cracks in the thirty-two rods supporting the silo elevator, and the ever-present dilemma of corrosion. Hydrocarbon contamination remained a concern throughout the life of the weapon system, given the silo design that had all hydrocarbon-producing devices positioned above the liquid oxygen storage area. To minimize the likelihood of an explosion, every liquid oxygen area had to be “critical clean,” and the liquid oxygen had to be transferred without the piping system experiencing violent shocks.\(^{77}\)

Colonel Robert S. Milner, commander of the 579th Strategic Missile Squadron at Walker observed that the hydrocarbon contamination issue had been long recognized, but only a year after the Atlas F became operational did officials establish a “definition of housekeeping and cleanliness” for the missile. He noted that several efforts at the Walker sites had produced good results. Sealing off silo levels five and six had reduced contamination of the lower levels by 75 percent, while placing drip pans below the work platform hydraulic actuators contained most leakage. At the same time, however, he noted that no solution had been found to eliminate the hydrocarbon produced by the instrument air compressors located on level seven with liquid oxygen transfer equipment. When an Atlas F modification program left Colonel Milner’s complexes requiring a thorough cleaning, he convinced the wing commander to initiate Brite Light, whereby special teams of augmentees from a wide spectrum of Walker units worked on every silo level to thoroughly clean and then paint the equipment. When the four-month effort concluded in late August 1964, the 579th Strategic Missile Squadron was able to maintain high cleanliness standards with the help of corrosion control inspections and continual custodial services cleaning. Even so, he declared, “Contamination…can be fought, sometimes controlled, but never wholly eliminated.”\(^{78}\)

With the Titan I, once the silo elevators had been redesigned and replaced following the Vandenberg explosion, missile reliability focused primarily on engine contamination. During 1962, when the six Titan I squadrons became operational, inspectors found elements of metal and fiber in eight engines. SAC officials elected to provide modifications to prevent future contamination during routine improvements scheduled from the autumn of 1963 to the spring of 1964. Most other Titan I problems affecting operations seemed unique to particular bases. For example, the Larson complex had been located in an irrigated region in eastern Washington state, and began leaking shortly after completion. Although failing to pump out the water, engineers were able to seal the holes tight enough to keep seepage from interrupting operations.\(^{79}\)

Strategic Air Command had outlined several specific requirements for combat-ready status. For one, all missile complexes and supporting facilities, including command post facilities and missile assembly maintenance support, had to be accepted by the unit. The unit must also possess all assigned missiles and all required trajectory kits. Finally, the squadron must have completed operational readiness training.
and have at least four combat-ready crews available for duty at the assigned launch control facilities. Few of the first-generation missile units could meet these demanding requirements.\textsuperscript{80}

When the Atlas and Titan missiles became operational, SAC initially chose to avoid Operational Readiness Inspections because its inexperienced crews would likely fail and the command would have to remove many missiles from alert status. Instead, inspection teams first conducted “shakedowns” that required crews to perform two consecutive successful propellant loading countdown exercises, and also complete procedures showing all subsystems in proper working condition. Even these modest inspections revealed an “inherently low countdown reliability” that was confirmed in the operational readiness tests that followed. The latter evaluated the unit’s wartime preparedness as realistically as possible. This meant focusing on the propellant loading exercise and testing launch readiness by implementing all procedures up to but not including an actual launch. In January 1963, following the Cuban Missile Crisis the preceding fall, and with the last Atlas F and Titan I squadrons having attained operational status by the end of 1962, SAC decided to proceed with Operational Readiness Inspections. Every inspection resulted in an unsatisfactory rating. General LeMay, now Air Force chief of staff, responded to this unacceptable situation by initiating Long Reach, an accelerated maintenance inspection effort intended to improve maintenance procedures and identify required modifications. Carried out from February through June 1963, it produced only slightly better results that year. Of the eight units inspected, two received satisfactory ratings during the first six months, while three passed during the second half of the year.\textsuperscript{81}

Meanwhile, SAC continued with the operational test program initiated at Secretary of Defense Robert S. McNamara’s urging in January 1962 “for the purpose of obtaining valid operational reliability factors under representative combat conditions.” Similar to the earlier Category III and IV tests, these new tests followed the “demonstration and shakedown” phase by evaluating the ability to achieve and maintain established missile readiness, reliability, and accuracy standards. The process began with a countdown at the particular operational site, followed by transporting the missile to Vandenberg for the crew to perform an actual launch. To determine missile reliability and verify its readiness for the missile force, OSD decided to launch five missiles of each type during the demonstration and shakedown period, followed in the operational phase by six launches per year for Atlas E and Titan I, and twelve per year for the Atlas F series. Before the fleet could undergo the operational test launches, however, Secretary McNamara had decided to deactivate the force in favor of the more reliable and cost effective Titan II and Minuteman ICBMs.\textsuperscript{82}

The first-generation force continued to experience problems remaining on alert during its short operational history. The propellant loading system and hydrocarbon contamination remained the most troublesome and dangerous aspects of the Atlas and Titan programs. A number of explosions and “near misses” at Atlas and Titan sites attested to the safety problem that plagued the first-generation missile force. At
Beale’s Titan I Chico, California, site, for example, on 24 May 1962 a blocked vent and a blocked valve produced two separate explosions that destroyed a Titan missile and severely damaged its silo. This was followed on 6 June with a flash fire at another silo that left one worker dead.⁸³

Among a number of close calls reported, Titan I 1st Lieutenant Charles G. Simpson recalled his experience preparing a missile for alert at the Mountain Home Air Force Base, Idaho. The propellant loading exercise called for off-loading the RP-1 fuel, installing ordnance simulators, and using television cameras to observe the liquid oxygen loading and launch sequence countdown. Since it was ahead of schedule, his team elected to replace a defective quick disconnect in the line that supplied helium to pressurize the fuel and oxidizer tanks prior to engine start. When they opened a valve to bleed the helium system, they noticed a fog being released into the silo that they identified as RP-1 fuel. Simpson observed that had they not replaced the quick disconnect before the propellant loading exercise, RP-1 would have covered the full liquid oxygen tanks during the countdown—with the probability of an explosion and the loss of both missile and silo.⁸⁴

The Atlas F had even more mishaps reported. Following a countdown exercise on 19 September 1962, for instance, a fully-loaded missile in Texas at Dyess Air Force Base’s Silo 10 jammed in place after the descending elevator had knocked loose the safety platform. The 3,000-pound platform fell fifteen stories, tearing loose the boil-off valve, damaging fuel lines and valves, and cutting into the RP-1 fuel tank at the silo’s floor. With the liquid oxygen pressure rising and fuel tank pressure falling, launch officials decided not to abandon the site but to try and stabilize the missile’s internal pressure, open the boil-off valve, and detank the liquid oxygen. After seven and a half stressful hours, they managed to drain the missile and save it and the silo.⁸⁵

Commentators have used the word “notorious” to describe the reputation of the Walker Atlas F squadron near Roswell, New Mexico, primarily because of three major explosions that occurred in less than a year. Propellant loading exercises destroyed Launch Complex 579-1 on 1 June 1963, silo 579-5 on 13 February 1964, and Launch Complex 579-2 on 9 March 1964. Despite the destruction, the disasters would have been worse had the missiles been configured with their warheads. Fortunately, no one was killed or seriously injured. The Walker explosions precipitated changes in command at that base, two congressional hearings, and criticism from New Mexico Senator Clinton Anderson, who referred to the missile sites as “nothing but trouble.” Only two months following the third Walker explosion, a propellant loading exercise at the Altus Air Force Base, Oklahoma, site 577-6 destroyed that launch complex.⁸⁶ Two days after the Altus explosion, Secretary of Defense McNamara directed an accelerated deactivation schedule for the Atlas and Titan I missile squadrons.⁸⁷

The secretary of defense’s decision reflected the Air Force’s inability to completely master the reliability weaknesses that had plagued the first-generation Atlas and Titan I ICBMs from the beginning. Most issues involved components associated with the
propellant loading system, the Achilles heel of the liquid-propellant missiles. The deficiencies identified by the Golden Ram program could be minimized but not entirely eliminated. With the more cost-effective, safer, and extremely reliable Minuteman arriving at the operational units, rapid deactivation of the initial force became imperative.

Phaseout of the Atlas and Titan I ICBMs

As early as the spring of 1963, an Air Staff assessment had called for the early phase-out of the Atlas D and E, and Titan I missiles. At that point, the first of the Titan II squadrons had become operational, with the first Minuteman wing to follow in July. Following a review by OSD, the Air Force issued its ICBM phaseout schedule for the Atlas D in the summer of 1964, three years sooner than originally planned, with the Atlas E to follow in 1966, and the Titan I in 1967. With the Atlas D series undergoing deactivation at the same time McNamara confronted the Walker and Altus explosions, the secretary of defense directed that the Atlas E and Titan I phase out be completed in fiscal year 1965, but the Atlas F was to remain operational until 1969. That November, however, he changed his mind and, citing its obsolescence and expected cost savings, added the Atlas F to the fiscal year 1965 list.

With the decision now taken to deactivate the entire first-generation ICBM force, the Air Force assigned Air Force Logistics Command and SAC the massive task of disposing of 149 Atlas and Titan operational launchers at 113 locations from New York to California. With the addition of missiles in storage, those still on the production lines, and operational spares, a total of 216 missiles became surplus. The deactivation plans called for SAC personnel to remove the missile, warhead, fuel, subsystem components, and ready them for shipment by an AFLC-appointed site deactivation task force at each base. AFLC also salvaged remaining equipment, including communications and electronic items and diesel generators, leaving behind only the fixed facilities. By the end of 1966, 97 of the 196 diesel generators had been scheduled for shipment to Southeast Asia to provide power to new airfields. The abandoned site then became the responsibility of the General Services Administration for disposal or Logistics Command for continued Air Force use.

Of the 216 surplus missiles, the Air Force selected 133 Atlas missiles for suborbital space flights, R&D projects that included advanced ballistic missile reentry research, and targets for the Army’s Nike Zeus missile defense test program. With no interest expressed in retaining the Titan I missiles, the Aerospace Corporation recommended against their continued storage at Mira Loma Air Force Station, located close to Vandenberg. Atlas ICBMs had been sent for storage to the San Bernardino Air Material Area at Norton Air Force Base, also in California.

The Air Force also considered possible new missions for the launch complexes. Officials dismissed the twenty-seven Atlas E launchers as too “soft” for further use and

* See Appendix II-4 and II-6.
declared them excess. After reviewing the retention potential of the seventy-two Atlas F and fifty-four Titan I silos, the phaseout team reduced the number to forty-four Atlas and fifteen Titan I complexes, with the latter comprising forty-five launchers. Water table problems at the Plattsburgh sites and fire damage at the Walker and Altus sites had removed them from further consideration, while those complexes at SAC bases scheduled to close also were selected. Even so, fewer than 10 percent of the fifty-nine retained sites proved useful for future Air Force missions. The Aerojet-General Corporation, maker of the Atlas engines, had been contracted to assess available options for use of the Atlas F and Titan I launch complexes. Of the sixteen uses evaluated, the corporation recommended converting a sizeable number of Atlas F and Titan I complexes to accommodate Titan II “storable” ICBMs to facilitate an early operational capability. These silos, Aerojet concluded, should be modified to accept future missiles with payloads up to 35,000 pounds. But by the summer of 1966, the Air Force had chosen to retain no Atlas F and only four Titan sites—apart from Vandenberg’s Atlas F and Titan I silos. Except for approximately twenty complexes awarded to various educational and research agencies, the Air Force turned the remainder over to the General Services Administration for disposal.92

The Balance Sheet—Looking Ahead
By the time the Atlas and Titan I ICBM force became operational, the missile gap had proven to be more myth than reality. President Eisenhower had known from U-2 reconnaissance photography and later satellite imagery that no missile gap existed, but he could not say so publicly without revealing the top-secret intelligence operations. Soon after John F. Kennedy took office, his defense officials also understood the myth of Soviet missile superiority. On 6 February 1961, newly appointed Secretary of Defense McNamara, speaking on “background” to Pentagon news reporters, declared, “If there was a gap, it was in our favor.” The embarrassing revelation produced newspaper headlines the following day, as the secretary attempted to defuse the issue with the argument used by Eisenhower officials in addressing the missile gap. While the United States may lag behind the Soviet Union in the number of ICBMs, he explained, there existed no “deterrent gap” because of the nation’s superior bomber fleet and its Polaris and Minuteman programs. U.S. missile programs would continue to expand to counter predicted Soviet missile fleet expansion. The missile gap issue ceased to exist following a major speech on 21 October 1961 by Deputy Secretary of Defense Gilpatric, who lauded U.S. second-strike capability in confronting a potential Soviet surprise attack.93

General Schriever’s mission—to develop and field an operational Atlas and Titan I missile fleet to close the so-called missile gap—clearly succeeded. Benefitting from the ICBM’s high priority status, increased funding after Sputnik, and highly talented people, Schriever followed the concurrency concept to pursue work simultaneously on missile design, development and testing, as well as site construction, ground equipment and infrastructure, and training of maintenance and missile crews. The
compression of time from system design to alert status resulted in a deployed field force by the end of 1962 of twelve Atlas and six Titan I squadrons, consisting of 123 Atlas and 54 Titan operational missiles, respectively.94

Yet, throughout its three-year operational history, the first-generation force suffered from cost, reliability, and safety problems. Although concurrency produced a deterrent missile force in record time, it led to frequent redesigns and modifications, which increased costs. Whereas a Minuteman missile had a unit cost of $5 million, comparable figures for the Atlas D were $18.5 million, the Atlas E $15.3 million, the Atlas F $17.5 million, and the Titan I $26.5 million. Moreover, the annual cost to keep each first-generation missile combat ready approached $1 million, while the Air Force spent ten times less on each Minuteman ICBM. The latter also represented a substantial cost savings in personnel, as each Minuteman required a contingent of twelve rather than the eighty men needed to support the Atlas and Titan.95

While concurrency also resulted frequently in unrealistic training on a weapon system under development, a more serious issue proved to be missile reliability. Although declared operational, these complex, first-generation liquid-propellant ICBMs, comprising 40,000 parts, required continued modifications and retrofitting to remain on alert. Moreover, the danger prevalent when fueling the missile created an ongoing safety issue with the propellant loading system. Even SAC’s additional training, testing, and update programs, coupled with heroic efforts from maintenance and operational crews, could not produce a missile force assured of launching within the fifteen-minute prescribed reaction time.96

Cost, safety, and reliability concerns prompted accelerated phaseout of the first-generation missiles, especially with their successors already operational. In June 1963, six months after the last Atlas F squadron at Plattsburgh became operational, the first Titan II squadron at Davis-Monthan Air Force Base, Arizona, went on alert. By the end of 1963 the entire fleet of Titan II ICBMs had achieved operational status. With its storable liquid propellants and silo-launch capability, the Titan II was safer and more reliable than the Titan I and Atlas F, and it provided the nation a large payload capability. The first Minuteman flight stood alert during the Cuban Missile Crisis in October 1962. By February 1963, the operational ICBM force had received the first Minuteman wing, the 341st Strategic Missile Wing at Malmstrom Air Force Base, Montana, consisting of three squadrons of fifty missiles each. More cost effective, safer, flexible, survivable, and reliable than the first-generation ICBMs, or the Titan II, the solid-propellant Minuteman represented the major ICBM deterrent force of the future. In the fall of 1964, when Secretary of Defense McNamara decided to deactivate the Atlas and Titan I force by 1965, he did so knowing that six hundred Minuteman and fifty-four Titan II missiles had already achieved operational status.

Despite the many problems with the short-lived Atlas and Titan I ICBMs, they remain a remarkable achievement. SAC Commander-in-Chief General Power, reflecting on missile reliability concerns in the spring of 1961, declared the ICBM program to be extremely successful in view of its magnitude and complexity.97 It provided the nation
its initial, effective Cold War land-based missile deterrent while this first-generation force established the precedent for development and deployment of its Titan II and Minuteman successors.
A map showing the location of ICBM launch sites across the United States.

An Atlas e stands in its coffin launcher, raised from horizontal to vertical position for launch at Vandenberg Air Force Base, California. The missile carries the Mark 3 reentry vehicle. Source: From Snark to Peacekeeper, 1 May 1990, p. 6.

Atlas 10A, the fourth Atlas fired from Cape Canaveral, Florida, launches on a research and development test flight, 10 January 1958. Photo courtesy of Association of Air Force Missileers archive.


Technicians offload the first air-transported Atlas D at F. E. Warren Air Force Base, 3 November 1959. Photo courtesy of 90th Missile Wing History Office.
The first Atlas D to arrive at F. E. Warren Air Force Base is shown next to the Herculus 133B that transported it, 3 November 1959. Photo courtesy of 90th Missile Wing History Office.


A Titan I ICBM is raised from its silo at Vandenberg Air Force Base, California, 18 August 1961. Source: From Snark to Peacekeeper, 1 May 1990, p. 16.
The Titan II launch facilities near Davis-Monthan Air Force Base, Arizona, under construction within the “bathtub” open pit, with control center at left and access portal left of center, and silo at right, 1962. Photo courtesy of Titan Missile Museum.

A Titan I is lowered into its silo near Lowry Air Force Base, Colorado, in 1961. Photo courtesy of Space and Missile Systems Center History Office archive.
Completion of a Titan II ICBM complex near Tucson, Arizona. Source: From Snark to Peacekeeper, 1 May 1990, p. 27.

Giant beams on top of the Titan II silo near Tucson, Arizona, will be submerged in concrete, forming an eight-foot thick wall to support the silo headworks and help absorb the shock wave from a nearby nuclear strike, 1962. Photo courtesy of the Titan Missile Museum.
Captain Patricia M. Fornes, the first Titan II female officer to perform alert, operates the console in a launch control center at McConnell Air Force Base, Kansas, 1982. Photo courtesy of the Titan Missile Museum.

Security teams stand guard as Titan II’s Mark 6 reentry vehicle, containing the nine-megaton W-53 warhead, is removed from the missile and loaded for transport back to the base. Photo courtesy of the Titan Missile Museum.

Loading and unloading the volatile and toxic propellant for Titan II had to be done with great care. Here technicians wear specially designed suits to protect them from the vapors. Photo courtesy of the Titan Missile Museum.
Aftermath of the Titan II explosion at launch complex 374-7 on 18 September 1980 near Damascus, Arkansas. Level one debris scattered outside the front gate includes a nitrogen storage tank used to open and close the silo closure door and a large section of concrete from the silo wall. Photo courtesy of Colonel Rodney L. Holder, USAF (Ret.).
Aftermath of the Titan II explosion at launch complex 374-7 on 18 September 1980 near Damascus, Arkansas. The top of the blown open silo shows only several access platforms remaining. Photo courtesy of Colonel Rodney L. Holder, USAF (Ret.).

Aftermath of the Titan II explosion at launch complex 374-7 on 18 September 1980 near Damascus, Arkansas. Shown here are parts of the 740-ton steel and concrete silo closure door that was blown over one thousand feet and landed in the field behind the site. The steel post and plastic pipe next to it identify one of the wells drilled around the site to verify that no contaminates from the silo leaked into the water table. Photo courtesy of Colonel Rodney L. Holder, USAF (Ret.).
The implosion of Titan II complex 570-8 near Tucson, Arizona. Over a ton of explosives destroyed the top twenty-five feet of the silo, after which the rubble was plowed into the ruins and capped with concrete, 1985. Photo courtesy of the Titan Missile Museum.

A view of deactivated Titan II ICBMS in storage at Davis-Monthan Air Force Base, Arizona, in 2000, showing the two separated airframe stages. Photo courtesy of Space and Missile Systems Center History Office archive.
Chapter III
The “Mighty” Titan II, 1963–1987

The Titan II ICBM represented a revolutionary advance over America’s first-generation Atlas and Titan I missiles. Although the latter provided the nation the initial land-based strategic missile force it required, both liquid-propellant missiles proved unreliable, very costly and dangerous to operate and maintain, and incapable of withstanding the impact of nuclear blasts. The second-generation Titan II overcame all of these weaknesses with its revolutionary design and operational characteristics that enabled crewmembers to launch the ICBM rapidly, directly from its silo. Unlike the Minuteman and Peacekeeper solid-propellant ICBMs, the Titan II required its underground launch control center to be located in close proximity to the missile silo and its crewmembers to take a “hands-on” approach to missile operations and maintenance. Moreover, the Titan II force became the nation’s first to include women in its ranks, both as crewmembers and as maintenance specialists. This chapter describes the revolutionary nature of the Titan II, the modifications that kept the missile operational far beyond its programmed lifespan, and its unique role in U.S. nuclear strategy.

For twenty-four years the Titan II ICBM provided the nation’s Triad of strategic defense forces its most powerful weapon of the Cold War. Comprising less than 6 percent of the ICBM inventory, the Titan II fleet represented fully one-third of the total ICBM megatonnage.¹ When the Strategic Air Command declared the Titan II force operational at the end of 1963, Secretary of Defense Robert McNamara had largely turned against the strategy of counterforce—favored especially by the Air Force—that called for the Single Integrated Operational Plan (SIOP) to target the Soviet Union’s
strategic forces rather than its urban centers. Soon after declaring this “no cities” doctrine in June 1962, however, he discovered that the number of delivery vehicles needed to retaliate following a Soviet first strike would be enormous. Not only would this strategy be economically unsupportable, it would potentially produce what the Soviets would likely consider a first-strike force. Secretary McNamara quickly moved to a finite deterrence targeting approach and a force structure that would provide an “assured destruction” second-strike retaliatory capability under the worst possible circumstances. In effect, while future SOPS would include a limited counterforce capability, 75 percent of the targets would consist of urban and industrial areas. For the ICBM leg of the Triad, the defense secretary would eventually settle on a force numbering one thousand Minuteman and fifty-four Titan II missiles.

The Titan II’s long range, heavy-lift capability, and high-yield warhead would appear to make it extremely effective against hardened military and industrial facilities as well as area targets requiring a wider dispersal pattern. From the beginning of its deployment, however, the Titan II’s future remained in doubt. Planners initially predicted an operational lifespan of five years, and during the late 1960s they repeatedly scheduled the Titan II for imminent retirement. Either the safer, more cost effective Minuteman III or a more advanced ICBM was to fill the gap left by the loss of the Titan. Yet, with the buildup of Soviet strategic forces in the 1970s, the Office of the Secretary of Defense proved reluctant to give up a missile with the Titan’s capabilities. Not only was it an effective weapon for SOPS targeting, it could be a valuable bargaining chip in future arms control negotiations because Soviet strategic doctrine appreciated large, high-yield missiles. Ironically, when the Reagan administration decided in late 1981 to deactivate the aging missile, the Air Force considered the weapon system to be more effective than at any time in its operational history and lobbied for its retention into the 1990s. Administration officials disagreed, and the Titan ICBM era came to an end.

From Titan I to Titan II
During the development of the Titan I, planners identified ways to improve key elements of the weapon system. But rather than make these technical changes as they became available and financially affordable, as had been done in the Atlas program, Major General Bernard Schriever’s Ballistic Missile Division team decided to consolidate the advanced features in a new model of the missile. In November 1959, OSD approved the Air Force request to proceed with the second-generation Titan, beginning with deployment of the seventh squadron. In April 1960, the Air Force issued the first development plan and officially designated the follow-on missile the Titan II. The next month the Martin Company received the contract to begin development, production, and testing of the new missile.
The Titan II reflected major improvements over its predecessor—and the Atlas ICBM—in the areas of propellants, airframe, propulsion, reentry vehicle and ordnance, and guidance capability. The use of non-cryogenic storable propellants offered the promise of eliminating the Titan I’s central weaknesses: the fifteen minutes required to raise, fuel, and launch the missile, and its dependency on complex in-silo propellant loading equipment and the safety hazard associated with the use of highly volatile cryogenic (extremely cold) liquid oxygen. Following World War II, the Air Force and Navy conducted research on hypergolic propellants, those that would ignite on contact. From the early 1950s, a number of private and government laboratories had been investigating the potential of both hydrazine and unsymmetrical dimethyl hydrazine as storable rocket fuels, but neither proved satisfactory alone. Unsymmetrical dimethyl hydrazine lacked a high enough specific impulse required for the Titan. The better performing hydrazine, on the other hand, could explode if used to cool the engine thrust chamber walls. Aerojet-General Corporation, the main developer of hydrazine, successfully addressed the weaknesses of both propellant candidates by combining them in equal parts. Aerojet named the new fuel Aerogine 50, and used nitrogen tetroxide to ignite the mixture hypergically.

In January 1958 Schriever’s Ballistic Missile Division declared its support of the new propellants, and directed a study of various possible non-cryogenic propellants to use on the Titan. By the following spring, the investigation had concluded in favor of using the Aerogine 50-nitrogen tetroxide combination, determining that only modest sealing and plumbing modifications would be needed. In March 1958, the Ballistic Missile Division called for introducing storable propellants for the Titan beginning with the seventh squadron.

A second improvement over the Titan I’s performance involved the Titan II airframe and silo launch. The adoption of storable propellants reduced the launch time of the Titan II to less than a minute, thereby limiting its vulnerability to enemy attack. An in-silo launch capability would provide the missile additional survivability. As early as the spring of 1956, the Air Force supported efforts by Aerojet-General and Ramo-Wooldridge corporations to study the feasibility of launching missiles from within the silo and determining the particular design characteristics required. Aerojet had been contracted by Space Technology Laboratories, the successor to Ramo-Wooldridge, to construct a one-sixth-scale model above ground of the proposed Titan II silo and airframe, powered by Nike Ajax surface-to-air missile engines, to test the effects of intense heat and acoustical vibration.

At the same time, the British had been examining the possibility of an underground launch of their Blue Streak IRBM, and General Schriever discussed the British results with his staff in November 1958. Impressed by the promise of reduced costs,
Dr. Benjamin Paul Blasingame was born in State College, Centre County, Pennsylvania, on 1 August 1919. He attended Pennsylvania State College, where he majored in mechanical engineering and joined the Reserve Officer Training Corps (ROTC) program. He graduated from Penn State in 1940 and was called to active duty in early 1941. After working on ground-based radar systems in Panama, he moved to the Armament Laboratory at Wright Field, Ohio.

Under Air Force sponsorship, Dr. Blasingame began his graduate studies in 1947 at Charles Stark Draper's Instrumentation Laboratory at the Massachusetts Institute of Technology (MIT) and received his Doctor of Science degree in 1950. Bernard A. Schriever, then a colonel on the Air Staff immediately recruited this newest member of Draper’s “inertial mafia” to work in the recently formed Office of Development Planning. While there, he developed specifications for a new Strategic Air Command (SAC) bomber, with attention toward base hardening to ensure security and safety of the new aircraft and its crews.

In 1954, when Dr. John von Neumann’s Strategic Missiles Evaluation Committee recommended acceleration of the intercontinental ballistic missile (ICBM) program, General Schriever was appointed to lead that effort as commander of the newly established Western Development Division (WDD). Authorized to handpick his initial cadre, General Schriever identified then Colonel Blasingame as one of his first four choices. Not long after reporting to WDD in July 1954, he scheduled a private meeting with General Schriever and convinced the latter that too little attention had been paid to the security and safety of the planned ICBM bases. From that time forward, everything was reexamined with an eye toward hardening the missile bases for purposes of survivability and safety.

As Chief Guidance and Control Project Officer, Colonel Blasingame soon became an in-house advocate for equipping ICBMs with inertial guidance, which put him at odds with many experts, who considered it too experimental and too heavy compared to radio guidance. Colonel Blasingame became convinced that AC Spark Plug Division of General Motors Corporation, backed by MIT, could produce a workable inertial guidance system for the ICBM. Consequently, he won approval for using inertial guidance as a backup for radio guidance on the Atlas ICBM and as the primary guidance system on the Thor intermediate range ballistic missile.

From 1956 to May 1958, Colonel Blasingame served as the first program manager for Weapon System (WS) 107A-2, the Titan ICBM. He recommended ways to accelerate Titan development and worked on plans for using storable, non-cryogenic propellants in a second-generation Titan. He also became a champion of solid-propellant technology. Colonel Blasingame left AFBMD for an assignment at the newly constructed US Air Force Academy near Colorado Springs, Colorado, where he created the Department of Aeronautics and Astronautics. Colonel Blasingame resigned his commission in 1959 to become director of engineering, later manager, at AC Spark Plug, the Electronics Division (Delco) of General Motors Corporation in Milwaukee, Wisconsin. In April 1959, AC Spark Plug had received an Air Force contract to build the guidance system for Titan II, the first all-inertial Air Force ICBM. On the civilian side, Dr. Blasingame contributed extensively to development of the highly precise Carousel inertial navigation and guidance system used with the Global Positioning System and by the USAF for the C-5A Galaxy and C-141 Starlifter transports and KC-135 tankers. Under Dr. Blasingame’s leadership, Delco became the prime contractor for building NASA’s Apollo guidance and navigation system, plus the Lunar Roving Vehicle used on the last three lunar-landing missions. Over the years, Dr. Blasingame patented some of his innovative designs and shared many of his insights in publications. Dr. Blasingame’s own textbook, simply titled *Astronautics*, appeared in 1964 as part of the McGraw-Hill Series in Missile and Space Technology.
greater survivability because of reduced exposure time, and “simplicity in launch apparatus,” Schriever sent a team to England to assess the British in-silo design, while his staff examined in-silo launch advantages. In particular, Colonel Albert J. “Red” Wetzel, who had replaced Colonel Paul Blasingame as Titan program manager, calculated cost savings resulting from elimination of the Titan I’s propellant loading system and the elevator needed to lift the missile to the surface. Convinced by their findings, on 19 January 1959, Schriever gave the go-ahead for in-silo launch of the improved Titan. On 17 August OSD approved both Schriever’s decision, beginning with the seventh Titan squadron, and also the Air Force request to build a facility at Vandenberg Air Force Base to test the silo launch concept. 8

In June 1959, Aerojet initiated the first of thirty-six test “launches” of the Titan II model that revealed a wealth of data on thermal, aerodynamic, and acoustic conditions that produced sound-induced vibrations in the silo. The scale-model test results convinced planners that launching from the silo would require strengthening the Titan airframe. In March 1961 a captive test-firing of Titan I vs-1 at Vandenberg, followed by the successful full-scale vs-1 launch from the Vandenberg silo test facility on 3 May 1961, confirmed Aerojet’s scale model results. Relying on Aerojet data and vs-1 flight results, Martin Company engineers used sirens to create the noise level needed to assess the airframe requirements for Titan II. Their evaluation convinced them to increase tank skin thickness and the number of internal ring frames, in order to handle the greater in-silo acoustical loads resulting from the denser storable propellants. 9

Compared to the Titan I’s airframe design, the Titan II’s key modifications included a second stage measuring 10 feet in diameter rather than 8; an increase in overall length from 98 to 103.4 feet; and a staging sequence that omitted staging rockets. After explosive bolts separated the two stages, Titan I used solid-propellant staging rockets to drive the second stage forward and the propellants back down to the pumps. With Titan II, by contrast, the second stage ignited while connected to the first stage. Vent holes allowed the exhaust to escape, while a protective ablative covering on the first stage forward tank dome prevented overheating. Once the explosive bolts separated the two stages, the second stage’s acceleration assured continuous feed to the combustion chamber. 10

A sturdier airframe permitted a more powerful propulsion system. Aerojet engineers received approval in October 1959 to proceed with the Titan Engine Storable Propellant Conversion Program and worked to achieve improved performance of the Titan II from its first-stage engine with two thrust chambers, designated XLR87-AJ-5, and its single second-stage XLR91-AJ-5 engine. Beginning in early 1960, improvements included a specially configured baffle cooled by the oxidizer to overcome combustion instability in the second-stage engine. Redesigned turbo pumps accepted the increased flow rates of the storable propellants, while engineers developed a self-generating system for propellant tank pressurization in place of the pressurized gasses used in the Titan I. Eliminating the latter’s pressurized gas storage tanks and undependable pressure regulators resulted in significant weight savings and a more efficient system.
Colonel Albert J. “Red” Wetzel was born on 29 December 1917 in New Orleans, Louisiana. He graduated from Tulane University in 1939 with a bachelor’s degree in electrical engineering. Called to active duty in December 1940, Colonel Wetzel completed pilot training and, by late 1943, was serving as a project officer and test pilot in the Special Weapons Branch at Materiel Command headquarters, Wright Field, where he worked on problems related to glide bombs, navigation, and remote control. Two of his technical papers in 1944—“Error Analysis of Guidance Systems of Rocket and Space Systems Utilizing Single and Two Degree of Freedom Gyroscopes and Associated Platforms” and “Analysis of Certain Technical Considerations in the Design, Development and Use of Ballistic Rockets”—presaged his later contributions to missile and space technology.

Colonel Wetzel served as chief project engineer for Matador, the Air Force’s first ground-launched cruise missile, during 1947–1948. He earned a master’s degree in aeronautical and astronautical engineering from The Johns Hopkins University in 1950, became Executive Officer to President Harry Truman’s guided missile advisor, K.T. Keller, in 1952 served as USAF executive to Assistant Secretary of Defense for Applications Engineering Frank D. Newbury during 1953–1955. Even as a Strategic Air Command bomb squadron, and deputy wing, commander during the mid-1950s, he contemplated missile and space-related topics: “Potential of Manned and Unmanned Space Vehicles,” “Design of Surface to Surface Rockets of Intercontinental Range,” and “Capabilities and Use of Space Vehicles for Strategic Reconnaissance.”

From 1958 to 1961, Colonel Wetzel directed the Titan (WS 107A-2) Intercontinental Ballistic Missile Program from its concept stage to operational readiness. His leadership resulted in the decision to make a complete configuration change for Titan II, rather than rely on incremental changes in Titan I. Among the most significant accomplishments during Colonel Wetzel’s tenure as Titan Program Director were: a self-contained, all-inertial guidance system for Titan II, unlike Titan I, that allowed a “salvo” launch of the entire force; rapid operational response through use of storable, hypergolic propellants instead of cryogenic fuels; launch from hardened, underground silos; a system involving two main thrusters that allowed for “steering” the missile in a novel fashion; and much greater “throw weight” to permit delivery of heavier thermonuclear payloads anywhere on the globe, as well as launch of NASA’s manned Gemini spacecraft into Earth orbit. The legacy of Titan II included a series of even more powerful variants—III, 23B, 24B, 34B&D and IV—that permitted the launch of large space platforms into the 21st century.

As Executive Assistant to the Commander of Ballistic Systems Division during 1961-1962, Colonel Wetzel oversaw numerous studies or surveys related to ICBMs and established an advisory group of nationally prominent scientists. Then, as Executive Director of the Air Force Council, he crafted a cohesive realignment of Air Staff technical and production functions associated with procurement of weapon systems. In his final assignment as a USAF officer, Colonel Wetzel served as Director of Strategic Programs in the in the Office of the Under Secretary of Defense for Research and Engineering. He retired from active duty in 1965 and returned to Tulane University where he held a variety of appointments until 1995 when he received the title Vice President Emeritus. Meanwhile, during 1965–1971, he served on the Rocket and Space Panel of the President’s Science Advisory Board. Colonel Wetzel died on 26 December 2009.
Simplicity in the conversion of the Titan I to the Titan II propulsion system is also reflected in the decline of active control components from 125 to 30, and regulators and valves from ninety-one to sixteen.11

Aerojet’s engine improvements are apparent in the Titan II thrust figures. Compared to the Titan I’s combined first-stage thrust of 300,000 pounds at sea level, the Titan II’s first-stage engines achieved 430,000 pounds of thrust. Second-stage engine performance increased from 80,000 pounds of thrust for the Titan I at 250,000 feet altitude, to 100,850 pounds of thrust at ignition altitude for the Titan II. In July and August 1961, the Air Force accepted the initial production first- and second-stage engines. With the missile’s improved propulsion system, the Titan II could boost the Titan I’s 4,500-pound Mark 4 reentry vehicle to a range of 8,400 nautical miles, or nearly 3,000 nautical miles further than the Titan I’s range.12

More importantly, the Titan II could achieve a range of 5,500 nautical miles with its heavier, more powerful Mark 6 reentry vehicle. On 26 July 1960, General Electric Company received the contract to develop the Mark 6 reentry vehicle for the Titan II. This reentry vehicle used ablative materials for its nose cone as well as its heat shield. Pressure molded molded sections of a nylon cloth saturated with phenolic resin adhered to the nose cone shape. For the heat shield, General Electric technicians used a plastic developed from epoxy and three other ingredients that was poured into conical shaped molds and hardened in an oven. Then they attached the nose cap and two of the plastic conical pieces to the reentry airframe, which consisted of aluminum insulated by neoprene rubber.13

The Mark 6 represented a significant improvement over the Titan I’s Mark 4, which had been plagued by inaccuracy caused by ablation problems. The Mark 6 reentry vehicle shielded a W-53 warhead weighing 8,380 pounds when accompanied by decoys. Compared to the Mark 4’s 4-megaton warhead, the W-53’s 9-megaton yield provided the Titan II the most powerful nuclear warhead in the nation’s strategic arsenal.14

In the final major upgrade, the Titan II received an inertial guidance system in place of the Titan I’s radio-inertial guidance and control arrangement. In April 1959, AC Spark Plug, now led by former Titan program manager B. Paul Blasingame, received a contract to develop an inertial guidance system for the improved Titan. As it had with the Thor missile, the company worked with a design from the leader in the field, Dr. Charles “Stark” Draper, director of MIT’s Air Force supported Instrumentation Laboratory. Installed between the two propellant tanks in the second stage, the inertial platform relied on gimbal suspension and gyroscopic stabilization. With the platform supplying accurate altitude data, its three gyro-accelerometers furnished acceleration measurements. These sensors then sent signals to an IBM digital computer that assessed and transmitted position and velocity data to the system’s autopilot. The latter controlled operation of the first- and second-stage engine gimbals and the second-stage vernier engines to achieve correct missile trajectory. Once the missile achieved the desired position and velocity, the computer directed engine cutoff and the arming of the warhead.15
Although the Titan II’s CEP of approximately 0.8 nautical miles proved roughly equal to that produced by the Titan I’s radio-inertial system, the Titan II’s inertial guidance and control system provided other advantages. Requiring no radio control, the Titan II avoided the need for expensive ground-based radio equipment and radars susceptible to enemy jamming and attack. Freed from this dependency by its inertial guidance system, the Titan II also proved more survivable. Whereas the Titan I missiles had to remain clustered in groups of three, the Titan II could be deployed at individual sites in a 1 x 9 configuration, or one launch control facility for each of nine launchers, and dispersed at least seven miles from one another.16

The upgrades made to the Titan, in effect, produced a new missile that overcame the chief weaknesses of the Titan I. The Air Force now had a large, heavy-lift missile with greater range and payload that could launch from the silo itself in under a minute. It would also prove safer to operate, easier to maintain, and require fewer personnel.17 Initially, officials expected the missile to remain in its silo for three years before requiring major servicing. Unfortunately, many missiles developed propellant leaks during deployment and had to be recycled to and from the Martin Company for repair. Even so, some missiles remained in their silos for ten years without needing a propellant download. Titan II missiles averaged fifteen years in the same launch complex before being removed from the silo for major maintenance.18

The Titan II Takes Flight

The Titan II R&D test flight program got underway on 16 March 1962 with the launch of missile N-2 from Cape Canaveral on a successful 5,000 nautical-mile flight, with the reentry vehicle impacting within the designated target area. The program concluded on 9 April 1964, after totaling thirty-three N-series flights, comprising twenty-three from Cape Canaveral and ten from Vandenberg. Records indicate a success rate of between 70 and 76 percent, with no more than ten flights considered partial successes or failures.19

Testing began at the Cape because two available Titan I launch pads, Pad 15 and Pad 16, could be converted readily, while the three silos programmed for the Vandenberg test flights remained under construction when flight testing started. Furthermore, the National Aeronautics and Space Administration (NASA) had selected the Titan II for its Gemini program, and those Titan launches were to occur at Cape Canaveral. Officials directing the flight test program needed to determine the missile characteristics involving subsystem performance, sequencing of the stages, and reentry vehicle performance, including the prototype decoy system, before in-silo launch testing later at Vandenberg. Their agenda also called for validating the supporting ground and maintenance equipment.20

The test flights revealed a variety of problems, including minor oxidizer and fuel pump leaks that would plague the weapon system throughout its history. The main areas of concern, however, involved second-stage gas generator failure, combustion instability, and, above all, longitudinal oscillation. Approximately ninety seconds into the initial 16 March 1962 N-2 flight, longitudinal vibrations occurred for about thirty
The “Mighty” Titan II

seconds throughout the airframe. Although Air Force officials declared the flight a success, NASA worried that what came to be termed the “pogo” effect could add an additional +/- 2.5 Gs of missile acceleration to the 2.5 Gs that the astronaut would already experience. This might very well prove incapacitating during an emergency.21

The problem intensified when the Ballistic Systems Division of the Air Force Systems Command and NASA disagreed about the acceptable pogo level. When increased first-stage fuel tank pressure and replacement of steel feed lines with ones made of aluminum oxidizer lowered the level to +/- 0.6 Gs on the 10 January 1963 N-15 flight, the Ballistic Systems Division decided to accept the new low rather than pursue efforts to achieve the NASA figure of +/- 0.25 Gs. NASA objected, and Brainard Holmes, the agency’s deputy associate administrator for manned space flight, appealed directly to General Schriever, now commander of Air Force Systems Command, who established a committee to study both the pogo effect and the problem of unstable combustion. Ultimately, investigators determined the solution to be a combination of a surge-suppression standpipe, the higher fuel tank pressure and aluminum oxidizer feed lines, and a fuel surge chamber added to the fuel lines. With these modifications, missile N-25 achieved a pogo level considerably below NASA’s maximum on its 1 November 1963 flight. Subsequent test flights confirmed the success of the changes.22

Repeated testing eventually solved the problems of combustion instability and failing gas generators, as well. Aerojet’s static testing of second-stage engines had revealed several instances whereby “hard starts” had resulted in combustion chambers falling from the injector domes. Although occurring in only two percent of the tests, NASA considered this too high for Gemini’s “man-rating” requirement. Aerojet and Air Force engineers solved the problem by modifying the baffles and using a new injector with larger orifices. On several flights the second-stage engine lost nearly half of its programmed thrust shortly after engine start. Tests determined that the gas generator’s small injector openings were being blocked by small particles from the start cartridge, which served to restrict propellant flow. When the second-stage engine ignited at 250,000 feet, the extremely thin atmosphere at that altitude failed to protect the injectors from the particles. Engineers overcame this problem by using a rupture disc with the gas generator’s exhaust to restrict the flow of particles.23

While test flights continued at Cape Canaveral until 9 April 1964, they had already begun at Vandenberg early the previous year. The Vandenberg program centered on in-silo launch capability. The Army Corps of Engineers oversaw the construction of three Titan II missile launch complexes. One, 395-B, would be used only for assessing technical data and maintenance training, while the other two, 395-C and 395-D, would support R&D launches. The operational flight test programs of the future would rely on all three facilities.24

Once Vandenberg received its first Titan II missile on 21 August 1962, technicians spent the next four months testing and modifying equipment and procedures in preparation for the initial in-silo launch in February 1963. On the sixteenth of that month, missile N-7 rose from complex 395-C, but failure of the three second-stage umbilical
connectors to detach correctly damaged parts of the missile guidance cabling which produced an uncontrollable roll. At an altitude of 18,800 feet the missile self-destructed. Launch officials considered the mission a success because the missile cleared the silo, its primary objective, but they certainly had work to do before the Titan II could be declared operational. Of the remaining nine flights from Vandenberg, however, all proved successful except for that of missile N-22, flown on 20 June 1963, whose second-stage gas generator failure prompted a suspension of further flights until the problem could be solved. Flights resumed later that September, and the contractor-directed R&D flight test program concluded with the launch of missile N-30 on 13 March 1964. That summer reliability and accuracy testing would commence with missiles from operational sites that had been removed from their silos and shipped to Vandenberg. Indeed, well before the Vandenberg R&D flight program had concluded, the Titan II force had been deployed and declared operational.25

**Deploying the Titan II**

In November 1959, when OSD approved development of the Titan II, beginning with the seventh Titan squadron, Air Force officials had already been considering deployment locations. The previous year, the Strategic Air Command’s Site Selection Team had identified Davis-Monthan Air Force Base, near Tucson, Arizona, and McConnell Air Force Base, near Wichita, Kansas, as support bases for future Titan missile units, and in October 1959 the Air Force Ballistic Missiles Committee authorized Davis-Monthan to host the seventh squadron. In April 1960 the committee agreed with the Ballistic Missile Division and SAC that placing two squadrons of nine dispersed single-launcher sites (1 x 9 configuration) adjacent to one support base would be both cost effective and operationally sound. At this time SAC also selected Davis-Monthan Air Force Base for the site of the eighth squadron, McConnell Air Force Base for squadrons nine and ten, and Little Rock Air Force Base, Arkansas, for the eleventh and twelfth squadrons.26

The site selection criteria for Titan II basing proved similar to that for the first-generation Atlas and Titan I missiles. Requirements included the availability of a central Air Force support base, access roads and railways, and real estate with appropriate soil characteristics. Planners also wanted to have local communities nearby to provide construction support, but not have major population centers under the projected flight path of the missile. The major difference in basing the Titan II is seen in the location of the three missile wings, in Arizona, Kansas, and Arkansas. This reflected not only a desire to achieve a wider distribution pattern, but the feasibility of basing the longer-range Titan II south of the northern tier Titan I bases.27

Surprisingly enough, in the summer of 1960 it was not clear that the Army Corps of Engineers would undertake the Titan II construction effort. Responding to Air Force criticism of schedule delays and inefficiency, Army leaders had created the Corps of Engineers Ballistic Missile Construction Office (CEBMCO) on 1 August 1960 under Brigadier General A.C. Welling to better centralize their construction program. The
next day, however, Air Force Secretary Dudley C. Sharp wrote to his Army counter-
part, Wilber M. Brucker, expressing continued displeasure about the Corps’ contract
procedures and lack of coordination between the Air Force commander and Army
Engineer at each construction site. Sharp stated that he was discussing with the Navy
the possibility of having the Navy’s Bureau of Yards and Docks undertake the Titan
II construction program. Alarmed by this prospect, Secretary Brucker responded
three days later with a lengthy memorandum for the Air Force secretary that force-
fully argued the case for awarding the Titan II project to the Corps of Engineers.
He explained that major improvements had been made in the contract award and
monitoring process, including advertising and awarding contracts only to prequali-
fied contractors and subcontractors. He also predicted that the establishment of the
Corps of Engineers Ballistic Missile Construction Office would solve the site coordi-
nation problem, and he lauded the experience and competence of General Welling, his
deputy, Colonel T. J. Hayes, III, and his four newly assigned principal assistants, each
of whom would be responsible for directing a particular ICBM construction program.28

The Army Secretary also pointed to the Corps’ successful completion of the proto-
type Titan II installations at Vandenberg. These tested and proven engineers, he said,
together with those soon to complete the Atlas and Titan I projects, would provide
the experienced missile contingent needed for the Titan II program. Already Corps
personnel had finished all prior construction for the Air Force at the three designated
Titan II bases, were thoroughly familiar with local soil and labor conditions, and
continued to support the site selection teams and acquire the required real estate.
He concluded by stating that “any decision to take the Titan II construction program
from the Army would be detrimental to the National interest in that it would seri-
ously delay the program and fail to make use of experience already gained….Working
together,” he argued, “we can alleviate the effects of strikes, the inevitable changes
inherent in a program being constructed concurrently with missile development and
meet the required beneficial occupancy dates.”29 Clearly, the Army secretary’s argu-
ments and the recent Air Force and Army reorganization measures helped convince
the Air Force to assign the Titan II construction program to the Corps of Engineers.
As with Atlas and Titan I site construction, this task would prove formidable.

The Titan II’s inertial guidance system allowed planners to site missiles individu-
ally, and hardening studies had determined an optimum of seven to ten miles separa-
tion between silos. Each Titan II complex of approximately 3.3 acres consisted of the
silo, or launch facility, and a launch control center, blast lock, and access portal, all
underground and interconnected by tunnels.30*

Measuring 160 feet deep and 55 feet in diameter, each silo consumed 5,800 cubic
feet of concrete, heavily reinforced by 845 tons of rebar. The Titan II’s silo required a
diameter eleven feet greater than that of Titan I, because launching the missile from
the silo required a flame deflector at its base and two large exhaust ducts running up

* See Appendix III-2.
the silo walls to vents at the surface. Nine levels within the silo housed equipment areas and work platforms for missile access. Covering the silo was a huge 743-ton steel and concrete door that could be opened in only seventeen to twenty seconds.31

Placed eight feet below the surface, the launch control center consisted of a three-level concrete domed cylinder forty-two feet high and thirty-seven feet in diameter. Within the control center, a steel cage suspended on springs isolated the three floors from ground shock and provided protection against blasts up to 100 psi of overpressure. Later, hardening increased to 300 psi of overpressure. The second level housed the launch control equipment, while the third floor contained the communications and utility equipment and the first floor provided living facilities for the four-person combat crew.32

An access tunnel connected the launch control center to the silo, and a reinforced concrete blast lock located between the silo and launch control center protected the underground facilities from surface blasts. Personnel entered the launch facility through an access portal that extended thirty-five feet below ground and opened into the single-level, two-room blast lock facility. Blast doors six and seven formed one room, blast doors eight and nine formed another. Located at each end of the blast lock, two sets of 6,000-pound steel blast doors, designed to protect against overpressure up to 1,000 psi, served to shield the launch control center from either a missile explosion in the silo or a nuclear detonation on the surface. Two cableways, one 25 feet long and the other 140 feet in length, connected the blast locks to the launch control center and to the silo, respectively.33

Seeking to benefit from the hard lessons of concurrency experienced during the Atlas and Titan i construction process, planners decided to stagger the construction schedules for the launch sites at each of the bases. By doing so, they argued, they could more effectively use construction personnel and equipment. For example, at Davis-Monthan work on the first three sites began in early December 1960, while work got underway at the last four of the eighteen sites two months later. The Air Force-Army team also decided to implement at all three bases a three-phase design and construction process they hoped would save time and minimize the problem of contract modifications that had driven up costs and frustrated schedules during construction of the Atlas and Titan i sites.34

The Air Force Ballistic Missile Division initially wanted to divide the facility construction endeavor into two parts so that phase 1 work could start promptly, and missile system technicians be allowed additional time to “finalize” equipment forms for phase 2 before the Corps of Engineers awarded subsequent contracts. In August 1960, Ralph M. Parsons Company of Los Angeles, which had received the contract to design the Titan ii launch complexes, agreed to divide the facility design into two phases. Yet, when weapon system developers sought additional changes that would delay implementing the second phase, the Air Force directed Parsons to divide the second package into phase 2 and phase 2a construction segments. Integrated into the second phase schedule, phase 2a elements comprised a separate contract, and
this work would often extend into the phase 3 period, when installation and check-out occurred.\textsuperscript{35}

**Building the Davis-Monthan Missile Complex**

By early January 1961 phase 1 work was underway at all three bases. The Corps of Engineers awarded phase 2 contracts for Davis-Monthan, McConnell, and Little Rock on 29 May, 26 June, and 14 July 1961, respectively, and phase 2A contracts for all three bases on 27 October 1961.\textsuperscript{36} Although each of the three Titan II bases encountered problems unique to that particular location, on balance the site construction process proved remarkably similar. A review of the three-phase Davis-Monthan construction experience illustrates the major challenges confronted and the means used to overcome them.

The Corps issued real estate directives on 15 June and 27 July 1960 that authorized acquisition of eighteen base sites around Tucson, Arizona. Reflecting a horseshoe pattern and located near the five major roads extending out from Tucson, the eighteen sites were arranged in the following five geographical groups, or “Residencies”: Oracle Residency (complexes 1, 16, 17, and 18); Benson Residency (complexes 2, 3, 4, and 5); Nogales Residency (complexes 6, 7, and 8); Ajo Residency (complexes 9, 10, and 11); and Rillito Residency (complexes 12, 13, 14, and 15).\textsuperscript{37*}

The state of Arizona owned the land for sixteen of the eighteen sites, while the federal government owned the land for the remaining two sites, numbers 6 and 12. Arizona officials strongly supported providing rights-of-entry for the desired land, but only after the federal government went through the state-required condemnation process. A portion of the access road to two sites (7 and 12) crossed privately owned property, and the refusal of one owner to grant an easement compelled the Corps to resort to condemnation for access to site 7. Additional real estate directives authorized acquiring rights-of-entry for constructing azimuth markers as well for survey, exploration, and construction of the inter-site communications system. Army representatives also proposed obtaining restrictive easements covering roughly 233 acres at each Titan site, but later determined that roughly 10 acres would be sufficient.\textsuperscript{38}

Phase 1 began with groundbreaking by Air Force Colonel Strother B. Hardwick, Site Activation Task Force commander, at complex 570-2 (site 11) on 9 December 1960, fully fifteen months before the first Titan II R&D flight would take place at Cape Canaveral. Given the complexity of the project, the importance of completing the work on schedule, and mindful of Air Force concerns, the Corps of Engineers Ballistic Missile Construction Office allowed only experienced prime contractors on a pre-approved list to bid on the project and screened subcontractors in advance, as well. Colonel Clayton A. Rust, the Corps of Engineers Ballistic Missile Construction Office’s Area Engineer and site Contracting Officer, selected a joint venture consisting of three companies, Jones, Teer, and Winkelman, which together then employed

\* See Appendix III-3.
twenty subcontractors, also chosen from a pre-screened list. Phase 1 work lasted from seven to eleven months depending on soil conditions at the eighteen sites. During this phase of heavy construction, workers cleared the sites, built all-weather access roads, excavated the sites, and built the silos, launch control centers, and blast locks.39

Phase 2 began as early as 28 June 1961 at complex 570-2 and as late as 21 December 1961 at complex 571-1, with the entire phase lasting from eleven to thirteen months. Second-phase work involved completing the heavy construction and putting in place key components, such as the launch duct, silo work levels, ventilation exhaust ducts, the tunnel linking the launch control center to the blast lock and silo, the silo closure door, and the mechanical, electrical, and supporting equipment.40

In principle, phase 2 construction started where the first-phase contractors finished, yet the engineers found that phase 1 and phase 2 equipment tolerances often proved incompatible. This required on-site adjustments or new materials ordered and shop-fabricated, which contributed to numerous change orders and problems maintaining contract sequencing of scheduled work. The Corps of Engineers Ballistic Missile Construction Office history of the Davis-Monthan project faults the division of the contract into several phases, with no single prime contractor for the whole project. While the new, phased construction approach resulted in fewer contract changes, it increased the challenge of coordinating the workloads in the three phases. Moreover, Fluor Corporation of Los Angeles, the second-phase contractor, had to begin work alongside the first-phase contractors, who had gotten behind schedule because of unexpected trouble in the open-cut and shaft excavation segment and needed five additional weeks to complete the first three launch complexes.41

The Corps of Engineers Ballistic Missile Construction Office incorporated the three to six months of phase 2a work into the phase 2 schedule. Again, complex 570-2 led the way, with phase 2a work at the site beginning on 7 January 1962 and finishing four months later, on 23 May 1962. During phase 2a, the contractor completed the propellant transfer system, hydraulic and pneumatic systems, elevators, air conditioning, acoustical lining of the launch and exhaust ducts, and put in place the retractable access platforms and related operating equipment. Fluor Corporation completed all phase 2a work by mid-December in preparation for the third and final phase. Joint occupancy characterized phase 3, as it had with the Titan I program. In this last phase, Fluor worked with Martin Company, the Titan missile contractor, and the Site Activation Task Force to perform final aspects of missile installation and checkout needed for activation and turnover to SAC.42

Along the way to completing the eighteen Titan II missile complexes at Davis-Monthan, Army engineers and the construction contractors had to deal with a variety of problems. Fluor Corporation, for example, implemented more than 750 multiple-part modifications requiring over 25,000 separate action items, and created its own critical path scheduling system to speed the process. Fluor also installed a high-frequency radio net to provide communications among the eighteen sites, which had no telephone connections and comprised nearly 420 miles of travel distance from Davis-
Monthan. Water shortages in this desert region remained a constant problem. Water for drinking, washing, and concrete work had to be trucked to the sites, although the concrete subcontractor established centrally located batch plants with access to the wells of area ranchers.\textsuperscript{43}

Given the large number of subcontractors and the various unions represented, labor problems proved unavoidable. Fortunately, Davis-Monthan generally experienced good labor relations, as reflected in only twenty work stoppages, due primarily to personnel grievances and jurisdictional disputes. “Wildcat” strikes proved most prevalent. In response, Fluor issued a policy letter, with subcontractor and union support, that stated, “Employees participating in unauthorized work stoppages in violation of existing labor contracts, as well as existing ‘no strike’ pledges, shall be discharged.” After the policy took effect, on 2 April 1962, the company used it only twice. While the work stoppages resulted in the loss of 1,758 man-days, their impact on construction schedules proved minimal when weighed against the figure of more than 1,000,000 man-days worked.\textsuperscript{44}

Worker grievances often focused on site safety because of the hazardous nature of missile construction. Both phase 1 and phase 2 contractors employed a safety engineer, and a safety consultant remained at the sites during the more difficult steel work involving arc welding. Even so, over the three-phase construction cycle, accidents claimed the lives of five workers and resulted in injury to fifty-two more. Safety complaints, along with assertions of waste and cost overruns, involving all three bases brought a team from a Senate Preparedness Subcommittee to Tucson in August 1962 to investigate the charges. Ultimately, the committee determined that cost increases at Davis-Monthan were similar to those incurred at the other two bases and largely reflected the design modifications inherent in the concurrency approach.\textsuperscript{45}

On 31 March 1963, the first Titan II went on alert at complex 570-2, only twenty-eight months after construction began. Nine months later, on 30 November, all Titan IIs of Davis-Monthan’s 390th Strategic Missile Wing had achieved alert status, making it the first of the three Titan II wings to do so. By the end of the year, the 381st Strategic Missile Wing at McConnell had achieved alert status, while the 308th Strategic Missile Wing at Little Rock had been granted emergency combat capability status.\textsuperscript{46} The Titan II construction effort represents an impressive engineering and construction achievement. Relying on the lessons learned in the Atlas and Titan I design and construction process, the Air Force and the Corps of Engineers overcame a range of difficulties to produce an operational force of fifty-four missile complexes in less than three years.

The Strategic Air Command would likely have declared all three wings operational earlier had it not been for the occurrence of oxidizer vapor leaks. Although detected early in 1962, the problem became serious only that summer with the arrival of warm weather and high humidity. Minute nitrogen tetroxide leaks in the oxidizer tank welds exposed them to the highly humid launch duct conditions, which produced extremely corrosive nitric acid. As a result, the small leaks became larger and needed fixing before the missile could be operational.\textsuperscript{47}
In mid-August 1962, the Ballistic Systems Division and the Martin Company implemented a recall program termed Project Wrap Up. If the affected missiles could not be repaired at the operational base, they were sent to Martin's Denver facility for modification. There, Martin technicians rewelded problem areas and subjected the tanks to two series of pressure checks before returning them to their sites. When Project Wrap Up began, eighteen complexes had already been turned over to SAC, but fifteen of these missiles required repairs. By year's end, with completion of the recall project, twenty-four of the seventy-eight missiles installed had been removed because of leaks. For the problem missiles, maintenance crews needed to pump out the fuel, remove and then later reinstall the missile, and load new fuel. They had to repeat this process often, at roughly the same time and with a limited supply of propellant loading equipment. Even so, Davis-Monthan and McConnell turned their sites over to SAC fourteen and twenty-three days ahead of the Wrap Up schedule, respectively; Little Rock, which had an unusually high number of missile leaks, achieved turnover status only one day late. On 31 December, with the sixth and final Titan unit, Little Rock's 374th Strategic Missile Squadron, declared operational, the Air Force had completed deployment of the entire Titan II force.48

Into an Uncertain Future, 1964–1969

The Titan II faced an uncertain future when it joined the nation's strategic deterrent force in 1964. During its initial five-year predicted lifespan, OSD and the Air Force favored developing a more cost-effective, capable replacement to complement a Minuteman force that would reach its full contingent of 1,000 missiles by 1967. Only by the end of the decade would planners decide they could not eliminate the most powerful weapon in the nation's Triad of strategic deterrent forces. Meanwhile, SAC sought to assure the continued effectiveness of the new missile by means of system modifications through operational flight-testing at Vandenberg Air Force Base.

Modifications began immediately, in the wake of the oxidizer leaks. During Project Wrap Up, Martin had implemented fifteen production fabrication changes that would minimize but not completely eliminate the oxidizer leak problem. The leak repair effort proved to be the first of many improvements made over the lifetime of the Titan II. In 1964 Project Green Jug, for example, involved installing dehumidification equipment in the launch ducts over a six-month period, while the missiles remained on alert.49 SAC followed this modification effort with Projects Top Banana and Yard Fence. Begun in July 1964 and finished in the fall of 1965, Top Banana addressed engine and hydraulic problems, and improved propellant pressure switches and silo closure doors. The more ambitious Yard Fence focused on improving the reliability of equipment installed in and around the silos. This thirty-four-month program that started in January 1965 included adding new seals and connections to blast lock doors, and acoustical lining and increased neutron shielding on the silo closure door to protect the launch ducts.50
To determine the reliability of the Green Jug modification as well as the impact of the silo environment on operational readiness, SAC carried out a three-year program, Long-Term Readiness Evaluation. From 1965 to 1967, evaluators selected twelve missiles from various sites and shipped them to Denver’s Martin plant for a comprehensive assessment of all elements and to develop an effective process of identifying those components most likely to degrade the system. The results from missile and ground equipment testing for the most part indicated only minor degradation. Such was the case when inspectors discovered small cracks in the longerons that hold the missile to the silo thrust mount. Although the cracks posed no major threat during launch or standing alert, the missile’s ability to withstand a ground shock seemed more problematic. The command elected not only to repair the longeron cracks in the thirteen missiles affected, but also to reinforce the longerons throughout the entire fleet. The Yard Fence modifications dealt directly with many of the affected components identified in the Long-Term Readiness Evaluation program.51

Since the missiles involved in the readiness evaluation program would have their engines overhauled afterwards, they were included in the major Titan II engine repair project designed to verify the original service life estimate of forty-two months and replace degraded components. Beginning in September 1965, SAC authorized two recycles per month from the operational fleet, and determined from its tests that the command could wait forty-eight months before overhauling the missile engines. Once the engine had been refurbished and reinstalled, the ICBM would be sent to a different operational site.52

Strategic Air Command had intended to have the Yard Fence modifications concluded in the spring of 1966, but the Air Force temporarily suspended the program following the worst accident in the history of the ICBM program. On 9 August 1965, fifty-three contractors lost their lives in a silo fire while working on the 308th Strategic Missile Wing’s launch complex 373-4, near Searcy, Arkansas. Work stopped on the five sites yet to be completed and was postponed at the remaining twenty-eight sites scheduled for Yard Fence modifications. Following a three-month investigation, the Air Force secretary approved a new safety program, and Yard Fence work resumed and continued for the next twelve months.53

Flight testing at Vandenberg provided another means of ensuring the Titan II’s reliability. Operational testing and evaluation at Vandenberg comprised the essence of SAC’s ICBM program. Launching missiles provided the realism needed to bridge the divide between formal readiness inspections and launching from operational sites with missiles armed with nuclear warheads. The three-phase operational cycle began with demonstration and shakedown operations consisting of five missile launches designed to determine reliability and refine procedures. The initial launch on 30 July 1964 represented the first time a SAC crew had launched a Titan II without contractor participation. By the time of the final flight, on 4 November, the combat crews and maintenance teams had reduced preflight preparation time from sixteen to ten days. Evaluators deemed all five flights successful.54
Second-phase operational testing commenced with SAC headquarters notifying an operational base that one of its missiles had been selected at random for test firing at Vandenberg. The particular missile would be examined before removal, then transported to Vandenberg, where personnel from its field unit would lower it into one of test site’s three silos. After the installation of range safety and telemetry equipment, the missile would be on alert for ten days, with the combat crew providing normal maintenance and correct calibration of the guidance system. At the end of the alert readiness period, the SAC commander would direct a no-notice launch.\(^55\)

During this phase, crews conducted nineteen flights, extending from March 1965 to April 1966. Fourteen of the missiles successfully reached the target area with an overall CEP of 0.785 nautical miles, which more than met the original goal of striking within one nautical mile. In December 1965, when the program experienced the fourth and fifth failures, Secretary of the Air Force Harold Brown and SAC leaders became alarmed; they formed a group consisting of contractor and Air Force personnel to examine the problem. Its investigation, concluded in February 1965, found no pattern of system failure in the five flights. Given the random nature of the problems and the success of the last five flights, SAC could declare the operational test phase a success.\(^56\)

The Titan II entered its follow-on testing phase in May 1966. Designed to ensure that reliability achieved during operational testing would remain constant over the course of the missile’s lifetime, this third phase differed little from its predecessor. Of the fourteen scheduled flights over the four-year period, eleven were successful. Two failed in flight, one due to a problem with the reentry vehicle release device and the other a failure of the second-stage yaw rate gyro, while a third flight had to be aborted when the hold-down bolts failed to fire and release the missile. On balance, the follow-on operational flight results clearly verified the Titan II’s reliability.\(^57\)

Yet, signs of trouble had appeared, raising questions about the Titan’s future. The precipitating issue centered on how many Titan II missiles had to be launched annually during follow-on operational testing to produce sufficient verification results. Although plans originally called for launching six missiles per year during this phase, Titan II crews actually launched four missiles the first year, five in each of the next two years, and only one in 1969, which turned out to be the final year of formal operational flight testing for the system. The disparity in planned versus actual test flights reflected SAC’s effort to delay the retirement of the missile in the face of Defense Department pressure to do so.\(^58\)

By early 1966, Secretary of Defense McNamara had determined that the Minuteman ICBM represented the wave of the future, and that no Titan replacement missiles would be purchased after June of that year. With the advent of Minuteman III, programmed for 1970, as well as the Navy’s Poseidon Sea Launched Ballistic Missile, the Titan’s payload and range advantages, according to OSD officials, would diminish and no longer justify the high operating cost. With steady attrition awaiting the Titan force, OSD decided to begin planning the missile’s retirement, to begin in fiscal year

When notified in July 1966 that OSD wanted to begin phasing out the missile in fiscal year 1971, SAC defended its retention because of the Titan's unique range and payload advantages and requested it be upgraded with warhead hardening or the same multiple reentry vehicle capability afforded Minuteman III. The Air Staff refused to support an upgrade but agreed with SAC that the Titan II should remain in the inventory until replaced by an advanced ICBM with similar heavy-lift capabilities.60 With the Soviet Union's unveiling of the SS-9 Scarp “city buster,” it seemed unwise to decommission precipitously America's only equivalent missile. In September 1966, when OSD proposed retiring the entire force by June 1973, Air Force Secretary Brown proposed an extended phase-out schedule that would keep the Titan operational until 1975. Production capability would continue until June 1968, and the retirement timetable called for three squadrons phased out in fiscal years 1971, 1973, and 1974, with the final three in fiscal year 1975. That November Secretary McNamara approved Brown's proposal, which explains the reduction in annual launches during follow-on operational testing. With fewer of these flights, SAC requested that one of the three Vandenberg launch sites join the alert force. Initially, authorities approved complex 395-D for alert duty, but by the end of June 1968 they had put all three complexes on alert. By 8 February 1967, however, OSD had decided to eliminate only half of the Titan II force by June 1975, but later that fall seemed certain only that all fifty-four missiles would remain operational through 1973. No further planning took place over the next two years.61

The arrival of the administration of President Richard M. Nixon in 1969 produced the traditional review of the nation's strategic deterrent forces. Surprisingly, the Titan II emerged from this process with a new lease on life. The budget-conscious administration took a number of immediate steps to reduce defense expenditures. Citing budgetary pressures, it decided at the end of 1969 to retain only one of Vandenberg's Titan launch complexes and phase out the remaining two that had been on alert status. The Office of the Secretary of Defense (OSD) also declined to support the Air Force's proposal to develop an advanced ICBM to replace the Titan. With a new ICBM now unattainable, the Air Force argued that the Titan II's long range, heavy-lift capability, and high warhead yield warranted its retention. Apparently, planners had resurrected the earlier proposal to begin phasing out the missile in fiscal year 1971. OSD now agreed with the Air Force argument and in September 1969 issued a revised retirement schedule that called for one Titan II squadron to be retired in each of fiscal years 1974, 1976, and 1978. Presumably the surviving three would remain operational. Even so, no one seemed certain how long Titan II would continue in service.62

At this point, OSD took two steps to help afford retaining the Titan. First, it postponed funding the nine new Titan systems that had been programmed for fiscal years 1969 and 1970. Defense officials also decided to cancel the follow-on operational test program by the end of June 1969. They argued that the Titan's proven accuracy and reliability made it possible to replace follow-on testing with a ground bench-
testing program that would effectively evaluate subsystem performance. Although the Air Force objected, Secretary of Defense Melvin R. Laird confirmed that April the decision to end the program. At the same time he noted that the Titan II, along with Minuteman I, would be used as test targets in the Army’s Safeguard ground-based interceptor anti-missile defense program. Authorizing eleven Titan II launches, Secretary Laird expressed his desire “that these firings also contribute to the purpose of follow-on testing insofar as is possible.” In fact, from May 1971 through the end of December 1975, Titan units launched nine Titan II flights from Vandenberg in support of Army missile defense programs. The final Titan II flight occurred on 27 June 1976, when the 308th Strategic Missile Wing launched a Rivet Hawk missile that successfully tested a new inertial guidance unit. Meanwhile, SAC relied on its ground bench-testing Reliability and Aging Surveillance Program, discussed below, to ensure the Titan II’s continued viability.63

The Titan Combat Crew Experience

It is doubtful Titan crewmembers and support personnel knew of the trials and tribulations of their missile in the late 1960s. They did, however, realize that missile duty, important as it was, could be extremely stressful, monotonous, and potentially harmful to one’s career.

Personnel selected for the missile career field needed to pass a physical examination, receive a Top Secret security clearance, and meet the requirements of the Personnel Reliability Program. The latter ensured that only reliable and emotionally stable men and women would be approved for duty with nuclear weapons. Initial training began with twelve weeks of individual and classroom instruction at Sheppard Air Force Base, Texas, which focused on missile theory, concepts and procedures. Then the crewmember traveled to Vandenberg Air Force Base for initial qualification training. Taught by the 4315th Combat Crew Training Squadron, this five-to-seven week course emphasized emergency war order (EWO) requirements and SAC procedures through use of a missile procedures training simulator.64

After initial qualification training, the crewmember went to his or her assigned base for approximately seven weeks of unit upgrade training that included missile procedures trainer rides, site training, thirty to forty hours of EWO training, the upgrade check, and certification. From six to nine comprehensive simulator rides, lasting about four hours each, provided the opportunity to learn the system checklists. Added realism occurred with the four to six site training tours. Supervised by an instructor crew, the site tours required the crewmember to perform the checklist actions in the control center and acquire a sense of the real alert tour to come.65

The upgrade check came after the instructors considered the crewmember capable of performing alert unsupervised. Given by the wing standardization-evaluation division, or “standboard” shop, it consisted of the site phase, which evaluated performance in the everyday operational environment, and the missile procedures trainer portion, which tested non-routine actions like hazards, malfunctions, and potential
war scenarios. The EWO certification briefing represented the final step in upgrade training. This involved briefing the wing commander or his representative on the crewmember's individual duties and EWO procedures. With a successful presentation, the crewmember would be certified for alert duty.66

Newly certified officers would normally join a regular four-person line crew as deputy missile combat crew commander. The deputy commander served as crew communications officer, oversaw the security of the complex, submitted exercise combat reports, and assisted the missile combat crew commander in carrying out his or her responsibilities. The crew commander ensured that missile and ground equipment remained in a constant state of readiness and supervised the crew in all operations during launch and hazard and emergency situations. The team also included two enlisted members. The ballistic missile analyst technician continually monitored the status of the missile and operational ground equipment for launch readiness, while the missile facilities technician kept an eye on the operation of all facility supporting equipment.67

The line crew's primary duty was to pull a 24-hour alert at one of the wing's eighteen operational sites. The alert tour started at 0730 hours with the mandatory pre-departure briefing that covered road and weather conditions, scheduled maintenance work, and safety and intelligence items. The briefing also included an EWO test to evaluate crew proficiency in the copying, decoding, and authenticating of emergency war order messages. Then crewmembers picked up foil-packed food, bedding material, and their personal briefcases and traveled to the assigned site. Upon arrival, the crew began coding procedures and performed a topside inspection before entering the underground launch control center. There, the changeover process took place, with the departing crew briefing the new crew on the status of the site, including classified material on hand, as well as planned and ongoing maintenance activities.68

After formal transfer of launch keys and classified documents, the crew finishing alert left the site; the new crew began alert operations with a safety equipment inspection and a performance briefing by the commander on his or her expectations for the crew. Next came daily shift verification, which involved a comprehensive walk-around inspection, during which the officers focused primarily on the second level of the control center while the two enlisted crewmembers examined every valve on all nine levels of the silo. During its tour, the crew also made every effort to keep the equipment clean, and to help monitor any maintenance activity. The verification check normally took from four to five hours to complete. Eight-hour sleep shifts for all crewmembers began at 1600 hours. Under SAC's "no-lone" zone, an officer and enlisted person remained on duty at all times. While on duty, crewmembers constantly observed the system, studied technical data, and finished training assignments. Crews also coordinated closely with the two to four maintenance teams working in the silo during the week, and needed to be prepared for unannounced standboard evaluation visits. In preparation for arrival of the relief crew, they cleaned the control center and living area. After completing the changeover procedures with the incoming crew, the
departing crew returned to base about 1000 hours, turned in required materials, and had the remainder of the day off. Normally crews pulled alert about eight times a month. When not on alert, or resting the day coming off alert, crewmembers could look forward to nine free days, one day on standby, and four days of training. The crewmember often averaged up to fifteen days of training each month, with recurring training normally handled on alert and standby days.

Additionally, crewmembers underwent a variety of inspections and evaluations to maintain combat capability. At least twice each year the wing standardization-evaluation division required each crewmember to take a fifty-question test and perform a series of activities to demonstrate job proficiency. Next in the series of evaluations came the Operational Readiness Inspection. Administered by SAC’s 3901st Strategic Missile Evaluation Squadron, based at Vandenberg, the Operational Readiness Inspection determined “the effectiveness of SAC ballistic missile units under realistically simulated operational conditions.” This inspection combined elements of the standardization assessment with an evaluation of the weapon system’s readiness. A generation phase tested the unit’s ability to put the highest number of missiles on alert, while the missile procedures trainer phase assessed the state of system hardware and crew reaction to various EWO scenarios.

Addressing Crewmember Morale

The missile career field represented one of the most demanding and challenging of any in the Air Force. The Strategic Air Command expected crewmembers to perform consistently at the highest level, accept rigid routine, and undergo frequent evaluations. These requirements put great pressure on crewmembers. At the same time, the command expected its missile officers and airmen to remain highly motivated by the vital importance of their work, the camaraderie that developed among crew personnel, as well as the career stability that came from having no overseas assignments, little to no temporary duty at other locations, and a four-year controlled tour. SAC also touted the advantages of assignments that provided valuable operational experience and command opportunities early in one’s career.

During the first decade of the Titan II era, a number of studies by missile officers addressed what they considered a growing morale problem among crewmembers. They cited the repetitious and monotonous nature of alert duties that had to be performed to rigid checklists. This, they argued, destroyed individual initiative and contributed to boredom and crew fatigue. One author, writing in 1969, concluded, “There have been no positive moves to solve the boredom and monotony in the Titan II force.” While there seemed little prospect of eliminating much of the monotony of missile duty, the critics noted that boredom could be reduced in two ways. First, they recommended an educational program for crewmembers similar to that provided Minuteman personnel. Begun in 1963 to make silo duty more attractive, the Minute-

* See pp. 126–128.
man Education Program offered four different, fully funded masters degree programs, with class attendance programmed into the weekly schedule. Second, many assessments of morale in the Titan force also indicated that combat crewmembers should be rewarded with hazardous-duty pay as an incentive for the responsibility and stress associated with alert. Extra pay, especially, would be suggested repeatedly in the future as a good morale booster and an incentive to remain in the missile career field.

Concerns about individual, crew and unit morale, in fact, represented one of the major reasons SAC introduced the competition known as Olympic Arena. Beginning in 1967 the command sought to increase the “overall capability of the individual and the command to perform its primary mission” by inviting four combat-ready crews from each missile wing to Vandenberg every spring for a week of intense competition. Along with developing and enhancing command-wide esprit de corps, the competition promoted a sharing of ideas and information among the various competitors, encouraged participants to update operations and maintenance procedures, and recognized outstanding personnel, wings, and other participating agencies. Supervised by the 3901st Strategic Missile Evaluation Squadron, competitors vied for more than twenty-five awards, including the prestigious Blanchard Perpetual Trophy, awarded to the best missile wing in the command.

Over the years, SAC expanded the types of support teams in the competition. In 1975, security police units joined the competitors, while the 1976 affair for the first time included engineering, communications, and vehicle support teams as well as civilians and non-SAC personnel. Apart from the addition of new participants and event scenarios, the most significant change came in 1978, when evaluators permanently moved the Titan II maintenance events to McConnell following the closure of the last Titan launch facility at Vandenberg. During the operations evaluation, which proved to be the most important event, crews working in missile procedures trainers wrestled with a set of two-hour exercises during two days of competition that focused on their ability to identify and correct faulty equipment and deal with a variety of emergency contingencies. Despite the totally different Minuteman and Titan II systems, their crews saw the same EWO messages with the same problems. To ensure fairness, evaluators also provided crews similar scripts with the same number of potential errors. Strategic Air Command viewed Olympic Arena as a significant contributor to its support of deterrence. The innovations and techniques demonstrated during the competition were applied throughout the force when the participants returned to their units. Strategic Air Command also considered important the enthusiastic unit competition that served to improve proficiency and enhance overall morale during the intense selection process to earn the honor of representing the unit at Olympic Arena.

As important as Olympic Arena proved to be in fostering high morale and esprit de corps, it could not address the many irritants experienced in the missile career field. By the 1970s, after the Titan received a new lease on life, SAC decided to directly address the “historical irritants associated with missile crew duty.” In May 1971, it issued the “Results of a Survey of SAC Missile Combat Crews.” Questionnaires from 625
captains and lieutenants assigned to missile duty at five bases revealed that the same irritants present when the Atlas and Titan I first went on alert continued to trouble missile officers a decade later. Grumbling about the quality of the food and transportation, for example, was to be expected. So, too, were the complaints about boredom and monotony. But the command became alarmed when 40 percent of those surveyed considered missile duty a “dead-end” for career progression, while only 14 percent viewed it as a positive career opportunity. Both officers and airmen they cited objected especially to the four-year tour of duty, although statistics showed that the average time a Titan crewmember served on crew was 1.72 years. 

When a Fifteenth Air Force missile symposium, convened earlier in March, also revealed considerable dissatisfaction with missile duty, SAC Commander-in-Chief General Bruce K. Holloway requested that the command do something “decisive” to improve the morale, welfare, and effectiveness of missile personnel. The command responded by creating the Missile Management Working Group, composed of headquarters staff officers with line crew experience, as well as airmen and civilians. After several meetings to assess the issue, the group decided to focus on the boredom of alert duty, inadequate communication between units and SAC headquarters, and poor job satisfaction. Overall, the group hoped its efforts would help attract more volunteers and convince experienced personnel to remain in the missile career field. Six-man field teams made up of personnel representing a variety of career development areas visited the missile bases, where they conducted group briefings and also met privately with officers and airmen at their request.

They found the main irritant to be the standardized four-year tour for crewmembers. Yet, the four-year tour had long been viewed as essential for developing the older, experienced missile crews SAC desired. When statistics in June 1972 showed that the average age for Titan II crewmembers was twenty-five years and one month and they had served on crew only an average of one year and nine months, the Working Group recommended retention of the four-year tour to build up the missile force experience level. At the same time, the group convinced the Air Force Military Personnel Center to end the restriction that prevented officers from serving more than just one year beyond the four-year tour. Now, officers could volunteer in twelve-month increments for missile duty beyond the five-year limit.

In addressing alert duty irritants, the group eventually succeeded, for example, in gaining permission for crews to use AM/FM receivers and televisions in the launch control centers. On the other hand, the group failed in its efforts to obtain “responsibility pay” for alert duty tours, even though survey results indicated that incentive pay would be a major factor in retaining missile officers and that the predicted number of officers retained would offset the cost of the bonuses. Surprisingly, the investigators did not even address the suggestion by some critics to provide an advanced degree education program similar to that available for Minuteman crews. This may have reflected the difference in Minuteman and Titan crew responsibilities, which the assessment did not discuss. Unlike Minuteman crewmembers, Titan officers and airmen
were just down the cableway from their missile, which required frequent attention and much of their time. Even so, they took the opportunity to work on training lesson plans, masters program courses, along with general reading, television, and card games to pass the time. As one enlisted crewmember observed, “I don’t care what I did, it was always hard between 0100–0500 to stay alert, occupied and not bored.”

Already by the spring of 1973, the success of the working group’s travel team could be seen in the increase in crewmembers moving from one missile system to another, more requests for career broadening assignments from officers seeking to move from crew duty to maintenance, and vice versa, and in the rise in fifth-year extensions. That spring, for example, 140 officers volunteered for a fifth year on crew in contrast to only 75 in 1971.

These positive trends did not continue, however, as the career field experienced a low retention of captains in the six to eleven year group between 1977 and 1981. By the early 1980s, SAC leaders worried about lieutenants making up 75 percent of a missile force that had less than two years of combat crew experience. SAC viewed the problem as the result of allowing officers to leave the missile career field after their controlled four-year tours. Yet, SAC released officers from the four-year obligation if disqualified for medical or personal reliability reasons or reassigned to unit staff positions. As a result, experienced captains and field grade officers remained in short supply. One effort to raise the experience level involved the “crossflow” program that brought support officers into the missile field in the ratio of 80 percent lieutenants and 20 percent captains and field grade officers. This program received mixed reviews, however, because the many non-volunteer captains and majors posed a morale problem that could affect the more impressionable lieutenants with whom they served. Above all, the command agreed in June 1983 to enforce completion of the four-year tour for crewmembers as a requisite for a follow-on assignment, whether in or out of missile operations.

In 1983, SAC leaders looked ahead to ending crossflow, relying on personnel returning in 1985 from the Ground Launched Cruise Missile program in Europe, and drawing on Titan crewmembers who would be available once the missile phased out. The command also focused on recruiting more Air Force Academy graduates, noting with concern that only three entered the missile field in 1983 as opposed to forty-five in 1977. Setting a goal of twenty-five graduates per year, SAC promoted the missile career field by sponsoring Missile Career Symposia at the Academy, led by 381st Strategic Missile Wing Commander Colonel Jay W. Kelley. Beginning in November 1984, the symposia also invited interested cadets to the yearly missile competition at Vandenberg. The initial symposium proved successful, when shortly thereafter nineteen cadets committed to entering the missile field.

**Bringing Women into the Titan Force**

Earlier, the Strategic Air Command reluctantly had embraced another source to enhance its officer and enlisted missile force. In the wake of growing national equal
opportunity concerns about gender fairness in the workplace and under considerable congressional pressure, SAC opened the Titan II combat crew career field to female officers and airmen in 1978.

In late 1975, SAC conducted an internal study on the advantages and disadvantages of bringing women onto missile crews. With women about to enter pilot training, SAC leaders thought it prudent to be prepared in the likely event that the command would be directed to open the field to women. Discussion focused on issues of privacy and morale and the nature of alert duty in the more confined Minuteman launch control center. Nuclear safety rules required crewmembers to remain at least in partial sight of each other. Spartan toilet facilities were located within feet of the consoles, closed off only by a modest privacy curtain. The study determined that, from the standpoint of managerial necessity, illness, TDY [temporary duty], unit upgrade procedures, and unit experience requirements ruled out gender-specific, or all female crews, in favor of mixed crews. Yet, placing mixed crews in the small capsule might provoke a spousal backlash and seriously affect morale. As expressed by Major General John W. Burkhardt, SAC's deputy chief of staff for operations, gender equity gains achieved with a few women missileers would be offset by the "tremendous disadvantage of the impact on the morale of missile combat crewmembers and their families." Although the study also raised the specter of women in a combat role, SAC legal authorities informed the command that the "limitation on the utilization of women in combat [was] expressly restricted to aircrew duties."83

The advent of President Jimmy Carter's administration in early 1977 contributed to the growing momentum to allow women to serve as missile crewmembers. In February 1977 Air Force headquarters requested SAC's "candid comments" on this issue, so that the Air Force could effectively "defend current policies" or provide a sound basis for placing limits on accepting women in the missile career field. SAC's reply in March attempted to delay acceptance without forcefully opposing the change. Arguing that women had expressed little interest in missile duty in the past, and with only twenty-five to fifty female officers expected to join the field yearly, the command urged postponement of the question until the service had a physical strength standard and pregnancy policy in place.84

Increased congressional and Defense Department interest that spring and summer, however, compelled Air Force Chief of Staff General David C. Jones, on 21 September 1977, to notify all major commands that having women trained and assigned to launch crews would be "in the best interest of the Air Force." The Titan experience, he said, would be "used in any decision on utilization of women in the Minuteman system." In a public announcement two days later, the Air Force observed that women missileers would be restricted to the Titan II program. The new policy, in fact, proved to be a compromise, as expressed in the phrase, "Titan Yes, Minuteman No," a position that reflected the inherent disparity in the two ICBM systems in terms of launch facility design and crew pairing. Unlike the cramped Minuteman launch capsule, the larger Titan crew environment included separate sleeping,
kitchen, and lavatory facilities that could be readily modified to provide the required privacy. Moreover, Titan’s four-person mixed crew, unlike its one-man, one-woman Minuteman counterpart, would seemingly lessen spousal and public concerns about possible sexual misbehavior. Finally, the Titan program offered enlisted women, as well as officers, the opportunity to serve on a missile combat crew. Titan would be the logical testing arena to assess women crewmembers and to provide the Air Force time to evaluate the experience before affirming the Titan program and, especially, before permitting women in Minuteman.85

The missile units had little to no advanced warning of the decision to bring women into the Titan II program. The 390th Strategic Missile Wing Deputy Commander for Operations Colonel Ronald V. Bouchert, for example, recalled that both he and the wing commander heard the 23 September 1977 announcement while driving home from work. During the six months the wing had to prepare, he and other wing leaders and squadron commanders met often among themselves and with crewmembers and their wives. “We discussed every conceivable possible problem and situation,” he said. The sleeping and bathroom arrangements occupied most of their attention.86

In early 1978, an Air Force panel of experienced missile officers selected fifteen women officers and twenty-five female enlisted volunteers to undergo Titan II crew training. On 13 March 1978, the first three female officers began their twelve-week individual instruction course at Sheppard, followed by seven weeks of combat crew training at Vandenberg, and concluding with unit upgrade training at their assigned bases. Having been upgraded to mission-ready status, First Lieutenant Patricia M. Fornes, stationed at McConnell, made history on 16 September 1978 when she became the first female officer to perform alert. One month earlier, Airman First Class Tina M. Ponzer had become the first female airman to go on alert.87

To evaluate the initial group of female missileers, SAC turned to the Air Force’s Human Resources Laboratory at Lackland Air Force Base, Texas, to devise a three-phase evaluation that addressed the women’s performance and perceptions for the period November 1978 to January 1980. The respondents included the women and their male peers and supervisors. SAC personnel administered phase-one and phase-two questionnaires to the female participants following their training courses at Sheppard and Vandenberg, respectively. The third-phase response embraced wing staff members as well and followed the initial recurring standardization evaluation, which occurred nearly six months after the women had attained mission-ready certification. The study found that the women expressed no dissatisfaction with their treatment, and the evaluators discovered no significant differences between women and men in any category measured by the survey. In the area of training, one minor exception involved “instructor efficiency,” for which the men provided much higher ratings than the women. In the unit upgrade portion of the survey, most men surveyed believed that the physical requirements of the job should limit the number of women on crew to two, while 70 percent of the women thought that all four crewmembers could be female. Although women performed slightly better on standardized evaluations and
the men scored higher on the emergency war order tests, most supervisors rated the performance of the men and women equal.  

Given the overwhelmingly positive results of the survey, SAC representatives, meeting in January 1980, concluded that “female crewmembers are performing as well as their male counterparts,” and that female officer and enlisted personnel would be eligible to serve on an equal basis alongside their male colleagues in the Titan II operational career field. By the early 1980s, Titan II women missileers had clearly performed admirably and had become an important part of the force. By June 1983, women represented fully 16 percent, or 93 out of 567, of Titan alert crew officers, although the enlisted numbers remained quite low at 4 percent, with 27 out of 662 airmen women.  

Yet, the unresolved question centered on the eligibility of women for Minuteman combat crew duty. Both the Air Force and the Strategic Air Command declined in the early 1980s to see the positive results of the Titan II experiment as the basis for introducing women into the Minuteman force. Their approach of “Titan Yes, Minuteman No” became progressively more difficult to defend, however, given the success of the Titan experience and the uncertain future facing female missileers. Most women, in fact, had entered the Titan II program after deactivation of the ICBM had already gotten underway, and they preferred to transfer into the Minuteman and Peacekeeper programs rather than move into another career field.

**Deactivating the Titan II**

Ironically, when OSD made the decision in late 1982 to deactivate the Titan II, the Strategic Air Command and especially personnel directly involved in the Titan program considered the missile more capable than at any time in its operational history. Indeed, SAC leaders believed the system could continue to be an effective element of the Triad well into the 1990s because of the upgrades made to the system dating from the early 1970s. Although the Titan II had received a new lease on life in 1969, its future had remained unclear. When the Air Force proved reluctant to fund major improvements to the system over the next five years, subsystems continued to age and component replacements became more difficult to acquire.

In 1974, however, the Joint Chiefs of Staff approved an Air Force request to keep the Titan operational through the 1980s. As a result, the Air Force implemented the Extended Life Program to either repair or replace deteriorating launch facility and launch control center equipment. Air Force Logistics Command’s Ogden Air Logistics Center in Utah played the key role because of its responsibility for ICBM ground equipment repair and as headquarters for the Titan II and Minuteman system managers. By 1977 contractors had completed the first two increments that included repairing buried exterior water piping and replacing old equipment at all three Titan bases. The last increments addressed problems with structural equipment, interior piping, electrical components, and site environmental systems. With the aging system, small electrical fires had become a frequent issue, and the air conditioning system required
constant attention to maintain a temperature of \(60 \pm 2\) degrees Fahrenheit in the launch duct. Beginning in May 1978 at Davis-Monthan, the Extended Life Program modifications would continue until deactivation of the missile.\(^91\)

When SAC began the Extended Life Program, it already had in place the Reliability and Aging Surveillance Program. The Ogden Logistics Center had begun this effort in 1971 to provide ground testing following termination in 1969 of the Titan's follow-on operational flight program. By 1977 this three-phase program had become the key method of providing weapon system reliability data for the SIOP. Phase one consisted of a yearly comprehensive examination of from two to four missiles and ground system hardware. Because this costly process necessitated a complete recycle lasting approximately sixty-eight days, it occurred only when followed by scheduled static engine tests performed at Aerojet's Sacramento facility under the Service Life Analysis Program. Once completed, technicians installed new engines, and the missile then joined the spares in storage at its operational base. One of the most important Titan II modifications proved to be the Coded Switch System, a new and more secure launch enable system. Strategic Air Command decided to install this device in 1974 and 1975, in conjunction with a new hold-down bolt electrical connector. The Reliability and Aging Surveillance Program's phase-one tests had discovered a number of inoperative hold down bolts that, according to Ogden engineers, might very well have resulted in launch failure. All future phase-one tests would also include examining the Coded Switch System’s butterfly valve primary lock.\(^92\)

A more abbreviated phase-two on-site evaluation focused on airborne wiring and launch and flight controls. Strategic Air Command ended phase two in early 1977 when the command found that a new combined system test set at each wing duplicated Reliability and Aging Surveillance Program procedures. During phase three laboratory testing, Ogden technicians assessed the performance of the inertial measurement unit and, when necessary, recalibrated the device. Yet, the rapid aging of the inertial guidance system, together with the shortage of replacement parts, had compelled Ogden Air Logistics Center in 1974 to predict that, given the device's programmed failure rate, the entire Titan II force would be non-operational by December 1977. In September 1975, SAC found a replacement, the readily available and extremely reliable Universal Space Guidance system used by the Titan IIIC space booster. After being tested on the last Titan II launch, on 27 June 1976, the new guidance system underwent a lengthy analysis before gaining production approval in October 1977. Strategic Air Command decided to terminate phase three of the Reliability and Aging Surveillance Program after determining that the existing guidance system database could provide enough remaining reliability projections until replaced. All Titan IIs would have the new guidance system installed in 1978 and 1979. Phase one of the Reliability and Aging Surveillance Program would continue with both comprehensive recycles and spot checks of chosen equipment.\(^93\)

Despite the important improvements to the Titan, it could not overcome the specter of an aging, unsafe weapon system raised by fatal accidents at McConnell
in 1978 and Little Rock in 1980. Given the awesome destructive power of the Titan’s propellant and nuclear warhead, SAC had always made safety a major part of every aspect of ICBM operations. Although there might have been more risks involved with the Titan than with most weapons, the command believed that as long as procedures were followed accidents should not happen. The command also realized that missile accidents usually brought unwanted publicity and public doubts about the weapon itself. The McConnell accident precipitated both critical media scrutiny and doubts about the Titan’s continued role as part of the nation’s strategic deterrent forces.

On 24 August 1978, a propellant transfer team loaded the highly corrosive nitrogen tetroxide propellant oxidizer into the first-stage booster of the newly emplaced Titan II at complex 533-7 of McConnell’s 381st Strategic Missile Wing, located near the small community of Rock, Kansas. For protection and accident prevention, transfer specialists donned protective clothing and followed detailed safety procedures. The major risk of propellant leakage came at the end of the process, when the team disconnected the hoses between the propellant holding vehicle on the surface and the fully loaded ICBM. When the valves of the quick disconnect apparatus were completely closed, oxidizer could not escape from the missile once specialists removed the transfer lines. In this case, however, an o-ring seal that had been unintentionally left in the closed propellant system had become dislodged during fueling and kept the valves from totally closing. This resulted in 13,800 gallons of highly pressurized liquid nitrogen tetroxide bursting from the valves and vaporizing.94

Tragically, two propellant transfer specialists died as a result of the spill. One died on site after attempting to rescue two stranded colleagues, one of whom died later in the hospital. With a rust-colored cloud appearing over the area, SAC personnel evacuated the Rock residents, who remained calm during the two days away from their homes. The subsequent investigation blamed bad maintenance control procedures, especially the failure to put in a filter that would have prevented the o-ring getting into the valves. Investigators also noted that propellant team members disconnected the transfer lines from the ICBM too rapidly and concluded they had been neither adequately trained nor properly supervised in the procedure. After reviewing the investigation report, SAC Commander-in-Chief General Richard H. Ellis informed Air Force Chief of Staff General Lew Allen, Jr., that “the accident was the product of personnel error.” Promising training and management improvements, he authorized a high-level SAC Titan II Safety Enhancement Committee to examine thoroughly all critical aspects of Titan II maintenance. The committee’s work resulted in revised technical orders, higher training standards for propellant transfer personnel, and an engineering program to develop many modifications to improve weapon system safety. Following an assessment of the accident site, SAC decided to rebuild the launch complex under a project termed Pacer Down.95

By 1980, Ogden had completed four major improvements. Mobile propellant transfer system trailers received a reconditioning to eliminate all leak-prone components,
and improved radio network antennas eliminated radio outages that had occurred between transfer specialists working topside and their colleagues in the silo. Technicians also enlarged the work area for specialists connecting hoses in the silo, and shelters for propellant transporter vehicles were designed to detect vapor leaks and control liquid spills. Other modifications underway in 1980 included a new Rocket Fuel Handlers Clothing Outfit and corrosion-resistant valves and seals, with two other important improvements in the planning stages. A vapor suppression and neutralization system was to replace the current vapor sensing apparatus and a new propellant transfer system trainer using water as propellant would enhance proficiency training.96

Despite the SAC Accident Investigation Board’s conclusion that system failure did not cause the McConnell accident, critics in Congress and OSD questioned the Titan II’s worthiness to remain operational. Tasked by Congress to assess the missile’s physical condition and maintenance procedures, the Air Force assembled an experienced group of service and contractor personnel, led by Ogden’s Titan II program manager, to respond. Submitted in May 1980, the Titan II Weapon Condition Safety Report referred to the modifications implemented and asserted that, not only was the Titan more effective in 1980 than it was in the 1960s, it would be effective throughout the 1990s. The report also argued that the system’s safety record remained favorable when compared to accident rates for “comparable” government agencies and industrial concerns. Moreover, its safety record would improve with the upgrades implemented and planned. The Ogden report also cited progress in personnel training and maintenance management to support its conclusion that the Titan II continued to represent a reliable system capable of defending the nation’s interests.97

Unfortunately, shortly after Congress received the Air Force report, the Titan II program experienced another accident, even more alarming than the McConnell tragedy and more momentous in determining the missile’s fate. In the early evening of 18 September 1980 at Little Rock launch complex 374-7, near Damascus, Arkansas, a propellant transfer technician, working with an untethered socket wrench (rather than the torque wrench prescribed) to restore pressure to the second-stage oxidizer tank, had the 8.75-pound socket detach from the ratchet and fall nearly eighty feet. The socket ricocheted off the thrust mount ring and punctured the first-stage propellant tank. Spotting fuel vapor almost immediately, the two-person propellant transfer team retreated to the launch control center, where they helped the combat crew for the next two hours try to neutralize the vapor and prevent a fire. When the 100,000 gallons of water available failed to quench the vapor, first-stage fuel pressure dropped while other tank pressure readings rose to dangerous levels. Having turned off the launch duct air conditioning and seen smoke in one of the blast locks, the crew and propellant specialists left the facility through the emergency tunnel at about 2030 hours.98

Shortly after the accident occurred, Colonel John T. Moser, 308th Strategic Missile Wing commander, activated the Missile Potential Hazard Network that linked the wing command post, the launch control center, Martin Marietta, Headquarters Eighth Air Force, the Ogden Air Logistics Center, and Headquarters SAC. After the
launch complex had been vacated, the network conferees sent a disaster control group to evacuate all civilians living within two miles of the site. They also decided to call on volunteers to reenter the launch control center to monitor tank pressure readings. After donning their Rocket Fuel Handlers Clothing Outfits, one two-person team worked its way to blast door 6 in the access portal, but could not manually open the lock pins and had to return to the surface when the air supply ran low. A second two-member team then took their place, successfully opened blast doors 6 and 7, but found fuel vapor readings at critical levels and withdrew. Less than a minute later, at 0300 on the 19th, the silo blew up. The blast killed one airman, injured twenty-one more, and hurled debris more than 3,000 feet from the silo. More alarming, the Mark 6 reentry vehicle housing the W-53 nuclear warhead separated from the second stage and landed close to the helicopter pad access road. Although damaged, it was found to be largely intact, with no radioactive contamination readings detected near the warhead or at the surface of the site. An Air Force response team arrived the morning of the 19th to take soil, water, and air samples, but found no radiological health risk present. Authorities then allowed evacuated civilians to go back to their homes. After a thorough examination of the physical evidence, the response to the crisis, and the testimony of participants, two accident investigation teams determined the cause to be human error rather than a weapon system failure.99

Yet, intense public criticism began immediately after the accident. Kansas Senator Robert J. “Bob” Dole, for example, speaking on the Senate floor the week following the accident, labeled the Titan II the “problem missile in our ICBM arsenal.” A skeptical media also joined the fray, characterizing the missile as hazardous and obsolete. When the Defense Department’s statements of support for the Titan failed to stem the growing criticism, Air Force Secretary Hans M. Mark, on 25 September 1980, directed the establishment of a special Titan II Executive Committee, or Review Group, led by General Bennie L. Davis, commander of Air Training Command, to assess the Titan II in terms of effectiveness, safety, and maintenance challenges. The committee relied not only on the official accident investigation reports for their review of the missile program, but also on the Ogden Air Logistics Center’s May 1980 Titan II Weapon Condition Safety Report. Completed in December 1980 and made public in early January 1981, the committee’s report largely confirmed the Ogden study’s conclusion that the Titan remained a reliable weapon the Air Force could continue to support with a strong modernization effort.100

The report also recommended a number of specific improvements, such as acquiring a new, upgraded missile procedures trainer, providing hazardous duty pay to help retain experienced maintenance personnel, and especially developing better crisis management capabilities. The Air Force, it declared, should conduct more frequent and realistic crisis management scenarios in conjunction with local authorities. Above all, there should be much more interaction with the general public. Air Force representatives needed to issue timely public statements that “confirm the presence or absence of nuclear weapons in the accident and frankly discuss safety features and
potential hazards.” The review group also called for improved methods to keep interested members of Congress and other key government agencies informed. Overall, the report affirmed, “Safety has been a pervasive and paramount consideration in every stage of the Titan II life cycle….The basic design was and is safe. System currency is being maintained adequately. Operations and maintenance procedures are adequate to ensure safety and supportability….Thus, the Titan as a weapon system is…safe and supportable.”

Public criticism of the missile’s age and its accident history, however, continued into the spring and summer while the Reagan administration’s defense program took shape. Even though the Air Force considered the Titan II in better condition than at any time in its operational history, it became clear by the fall that the Reagan administration did not envision the missile as part of its strategic modernization plan. On 2 October 1981, Deputy Secretary of Defense Frank C. Carlucci ordered deactivation of the ICBM to start as soon as possible. Although analysts determined that shutting down the Titan would save $500 million over a six-year period, those savings were small in the larger context of a strategic modernization program expected to cost $180 billion. The decision more likely reflected the realities of arms control treaty restrictions. Under the terms of the ratified SALT [Strategic Arms Limitation Treaty] I and the unratified SALT II, which the administration pledged to uphold, new strategic weapon systems could not be introduced until older ones had been dismantled. In this case, the Navy’s Trident II sea-launched ballistic missile had to await the deactivation of the Titan II before becoming operational.

Strategic Air Command had been preparing for the prospect of phasing out the Titan since October 1980, and, after the announcement, proceeded to implement its deactivation plan, nicknamed Rivet Cap. The command established a broad-based management structure to oversee this mammoth undertaking, and quickly moved to restrict the Titan II logistic network and cancel the project to rebuild McConnell’s damaged launch complex 533-7. It also declared that all Titan missile sites would stand alert and support their SIOP commitments until deactivated. Nevertheless, deactivation remained unsettled throughout much of 1982, as senators debated the merits of waiting for the MX missile to become operational before eliminating a missile force representing 11 percent of the nation’s offensive nuclear warhead capability. By early August, when a House-Senate authorization conference deleted funds to retain the Titan II, Rivet Cap organizers received the green light to proceed.

Rivet Cap’s five-year schedule called for deactivation to begin with the 390th Strategic Missile Wing at Davis-Monthan on 1 October 1982 and be completed by July 1984. McConnell’s 381st Strategic Missile Wing would next undergo deactivation, between July 1984 and October 1986, followed by the 308th Strategic Missile Wing at Little Rock, from October 1985 to October 1987. At first SAC prescribed deactivating one site per month, but experience soon convinced planners to settle on a forty-five-day deactivation period. In determining the order of site deactivation, SAC and the missile wings gave priority to sites especially close to private or public facilities and those
scheduled for recycle testing under the Reliability and Aging Surveillance Program and Service Life Analysis Program.\textsuperscript{105}

The actual deactivation sequence began with SAC taking the selected launch complex off alert, followed by removing the reentry vehicle with its warhead, downloading the propellant, and extracting the missile. Site dismantlement concluded with salvaging reusable equipment; dispersing the missile, supporting equipment, and propellant; and dismantling the site. To meet SALT I protocols, SAC’s team needed to level the surface facilities and demolish the silo to a depth of at least sixteen feet. Using satellite photography, or “national technical means,” the Soviet Union then had six months to verify the site’s status before the process concluded with demolition of the massive silo headworks that had supported the silo door. At that point, officials declared the site inactive. Planning called for reentry vehicles to be shipped to the San Antonio Air Logistic Center for dismantlement by the Department of Energy and their nuclear materials reused by other weapon systems. Strategic Air Command shipped the Titan II boosters and related equipment by rail to the Military Aircraft Storage and Disposition Center at Norton Air Force Base, California. Eventually, Air Force Space Command would be the beneficiary of refurbished Titan IIs for use as space launch vehicles.\textsuperscript{106}

The deactivation process demanded thorough and deliberate planning, with carefully balanced timetables designed to ensure that the Titan II’s components would be shipped on time to specified locations. No issue proved more vexing than propellant transfer and storage. The always dangerous propellant download process at each site took two weeks to complete, even under the best of conditions, and demanded more of the twelve-member propellant transfer teams than perhaps any other group involved in deactivation. They often worked twelve-hour days during the hot summers in their uncomfortable protective gear handling the 250,000 pounds of dangerous propellants. Each site required three tanker trucks to offload the Aerozine 50 fuel and six to contain the oxidizer.\textsuperscript{107}

Strategic Air Command planned to have the fuel stored at the Army’s Rocky Mountain Arsenal in Denver, Colorado, and facilities at Cape Canaveral Air Force Station and at Vandenberg. The oxidizer would be shipped to Aerojet-General’s relatively small Sacramento, California storage facility, to Vandenberg for future use in the space program, or sold commercially. Oxidizer scheduled for commercial sale, for conversion to fertilizer, was pumped into railroad cars owned by the Defense Department and stored outside Vicksburg, Mississippi.\textsuperscript{108}

Problems plagued the storage effort throughout the five-year period. Propellant storage space never remained more than adequate, and continually threatened to delay the deactivation schedule. The Rocky Mountain Arsenal, for example, failed certification testing and had to be eliminated from the program. The storage facilities at Cape Canaveral, Vandenberg, and Aerojet proved extremely limited, and leaks developed at these sites making them temporarily unusable. At one point, Rivet Cap could proceed uninterrupted only after Cape Canaveral officials decided to store pro-
pellant in railroad cars. Strategic Air Command’s policy of requiring both a firm primary and alternate fuel destination before a shipment could leave a missile wing also worsened the situation by what amounted to doubling the needed storage capacity for each site. The long-term solution involved constructing new hypergolic stockpile storage facilities at Vandenberg and Cape Canaveral, scheduled to open in early 1985 and 1986, respectively. But Vandenberg’s new storage facility failed inspection shortly after it opened and remained closed for the remainder of Rivet Cap. The fuel storage issue continued to be a chronic problem for SAC and grew worse with each site deactivation.109

A variety of other problems affected the tight schedule. A seemingly minor issue like non-standard valves grounded two oxidizer transporter trailers at Davis-Monthan for seven months. In 1985, leaking valves put seven of the nine available transport trailers out of service. Although rapid repairs kept existing schedules intact, the problem occurred periodically throughout the year. More serious was the impact of winter conditions at McConnell. Unlike the Davis-Monthan winter experience, the harsh winters in Kansas led to weather delays and equipment malfunctions and by late February 1985 had put the 381st Strategic Missile Wing forty-four days behind schedule. In the spring, wing commander Colonel Kelley received permission to dismantle one site every thirty-six days, rather than the prescribed forty-five. The accelerated schedule helped the wing’s 533rd Strategic Missile Squadron inactivate on 1 November 1985, only a month behind schedule. Given the 381st Wing’s experience with winter conditions, SAC requested an earlier start for Little Rock’s deactivation to compensate for the Arkansas winters. Commencing on 24 April 1985, the 308th Strategic Missile Wing was able to complete inactivation on schedule, on 18 August 1987.110

From the outset, Rivet Cap planners focused on personnel issues. They expected to confront morale problems, given the physical and mental stress associated with deactivation and the uncertainty about future assignments. Teams from the Air Force’s Occupational and Environmental Health Laboratory from Brooks Air Force Base, Texas, periodically visited launch complexes to monitor fuel vapor readings. To minimize the decline of morale, SAC and Air Training Command decided to maintain personnel authorizations sufficient to support deactivation and remaining operations by extending missile maintenance training until 1983 and crew training until 1984. As for assignments, some officers and airmen rotated to another Titan wing after completing their initial duty tour. Those having served at two wings that inactivated would only be assigned to a third on a voluntary basis. With the phase-down of the Titan II, women crewmembers initially faced the prospect of no follow-on missile assignment in Minuteman or the future Peacekeeper. That would change in 1985, when SAC grudgingly bowed to pressure and opened the Minuteman career field to gender-specific crews.111

Maintaining a force in readiness while identifying suitable subsequent assignments proved a major challenge for SAC, the Military Personnel Center, and wing commanders. Yet, inspections and evaluations during Rivet Cap suggest that morale remained
high and the force experienced no drop in operational performance. Perhaps most indicative of continued capability is the record of the Titan II wings at the Olympic Arena competition during deactivation. In 1983, the “Year of the Titan,” the three Titan wings took first, second, and third place, with the 381st Strategic Missile Wing from McConnell winning nine trophies, including the Blanchard Trophy, and the other two wings capturing three trophies each. In 1984, Davis-Monhan’s 390th Strategic Missile Wing could not compete, but the other two finished a very close second and third. The following year, the 308th Strategic Missile Wing from Little Rock won first place going away, while the 381st placed second. In 1986, the two Titan wings made their nineteenth and final appearance in Olympic Arena, bowing out tied for second place. As the official history of the competition concluded, “The occasion was certainly a fitting farewell for the Titan weapon system.”

The termination of Rivet Cap on 18 August 1987 brought to a close the Titan II’s nearly quarter-century standing alert as the powerhouse of America’s strategic forces. It had long outlasted its early critics and its original design specifications. With no continuous flight-testing program after 1969, maintainers and operators had to rely on ground assessments and a series of relatively modest improvements to ensure its continued reliability and high state of readiness. Into the 1980s, they argued that their missile hardly fit the profile of the “geriatric giants” of the critics, but rather, it continued to perform as required and should remain in the inventory well into the future. But the mighty Titan could not weather the firestorm of criticism following the McConnell and Little Rock tragedies. In the end, it was felled less by old age than by arms control constraints and a new administration’s agenda.

The Titan II left behind a legacy of strong support of national defense strategy, a national historical landmark museum to celebrate and memorialize that contribution, fourteen deactivated missiles refurbished to serve as space launch vehicles, and a large contingent of highly professional men and women who would rely on their Titan II experience when they moved on to serve in the Minuteman and Peacekeeper programs.
Chapter IV
The “Ace in the Hole” Minuteman, 1945–1991

The first ten Minuteman ICBMs joined the nation’s strategic deterrent forces in October 1962, during the Cuban Missile Crisis. President Kennedy supposedly had in mind these Minuteman missiles of the 10th Strategic Missile Squadron, 341st Strategic Missile Wing, Malmstrom Air Force Base, Montana, when, shortly after the crisis ended, he reportedly said, “I had confidence in the final outcome of our diplomacy…. Of course, Mr. Khrushchev knew we had an ace in the hole in our improved strategic forces.”

Although the Kennedy statement has proven to be apocryphal, the Minuteman would, indeed, become America’s ace in the hole. From the very beginning, Minuteman planners had envisioned a large force of highly efficient, reliable, and survivable solid-propellant ICBMs, capable of launching rapidly and effectively against all types of Soviet targets. By December 1964, Secretary of Defense Robert McNamara had decided to eliminate the first generation Atlas and Titan I ICBMs, retain fifty-four liquid-propellant Titan II ICBMs, and cap the Minuteman force at one thousand missiles. In April 1967, when Malmstrom’s 564th Strategic Missile Squadron became operational with the Minuteman II, the Strategic Air Command (SAC) completed deployment of the programmed one thousand Minuteman force in six locations. Modifications and improvements would continue to make this weapon system the bedrock of America’s land-based nuclear deterrent throughout the remainder of the Cold War.
Colonel Edward N. Hall Envisions a Revolutionary ICBM, 1945–1959

The Minuteman ICBM owes its emergence and development to the “near-fanatic determination” of Colonel Edward N. “Ed” Hall, a brilliant if contentious engineer who became the champion of solid-propellant research in the Air Force research and development community.³

The solid-propellant rockets produced during World War II used double-base and polysulfide composites that both limited the motor’s size and specific impulse and proved dangerous to store and handle. As a result, after the war engineers from the Jet Propulsion Laboratory at Caltech and Thiokol Chemical Corporation experimented with more effective castable composite propellant grains. In this process, engineers poured a composite granular mixture of fuel and oxidizer into a combustion chamber or other heavy casing, where it cured into a solid grain that served as a binder and fuel. In principle, a pyrotechnic device ignited the grain, which would burn from an inner open port area evenly from the inside out. The gases produced then became the source of the thrust.⁴

The challenges ahead, however, remained formidable. To create a solid-propellant ICBM, engineers and technicians would need to develop new technologies to produce large-diameter, steel rocket-motor cases and methods to pour and cure large high-performance propellant batches without cracking. They would also need to manufacture nozzle materials able to withstand the erosion created by propellants burning at higher temperatures, devices to ignite the propellant and terminate thrust on command, and movable nozzles to effectively steer the missile.⁵

In the late 1940s, then-Major Hall followed solid-propellant developments closely while assigned to the Air Materiel Command’s Wright Air Development Center and during his MA work at Caltech. Then, in 1950 he became assistant chief of the Non-Rotating Engine Branch in Wright’s Power Plant Laboratory. Problems producing an effective jet-assisted-take-off unit for the B-47 swept-wing jet bomber led the Air Force in late 1951 to fund his branch to study solid-propellant rocketry with the ultimate objective of producing “long-range ballistic missiles.” Hall and his team at Wright-Patterson Air Force Base in Dayton, Ohio, worked with several contractors to manufacture more effective solid propellants at lower cost. When he left the Wright Air Development Center to join General Bernard Schriever’s Western Development Division in August 1954 as chief for propulsion development, Lieutenant Colonel Hall assumed responsibility for developing the liquid-propellant Atlas, and two years later became the program director for the Thor ICBM. While the division’s liquid-propellant ICBMs remained his primary mission, Hall continued to advocate that the Air Force establish a strong research program whose focus should be developing large solid-fuel rockets.⁶

In early 1955, the Air Force directed General Schriever’s organization to undertake the alternative Titan ICBM program, as well as examine all possible approaches to producing a tactical ballistic missile. Schriever assigned Hall to evaluate the state of solid-propellant rocket motors. Responding in mid-June, Hall described significant progress in solid-propellant research by firms under Air Force contract. Aerojet-Gen-
Colonel Edward N. Hall was born in New York City on 4 August 1914. He received a Bachelor of Science degree in engineering from College of the City of New York in 1935 and a professional degree in chemical engineering in 1936. In 1948 he earned a Master of Science in aeronautical engineering (propulsion option) from California Institute of Technology.

Hall entered the Air Corps on 26 September 1939. During World War II he served in England in engineering assignments associated with aircraft repair. His introduction to missiles came near war’s end when he was assigned to acquire intelligence on Germany’s wartime propulsion work. He analyzed German rocket equipment, insofar as parts recovered from exploded V-2 specimens or retrieved through spy networks allowed. At war’s end, he led an Air Force Propulsion Group through German rocket plants—especially the underground assembly facilities at Work Camp Dora—and, subsequently, assisted in the division of captured missile equipment between the U.S. and England.

After a second European tour, which covered further propulsion developments, Hall became Assistant Chief, Non-Rotating Engine Branch, Power Plant Laboratory, Wright-Patterson AFB, where he participated in the development of solid and liquid rocket power plants. These included work on the propulsion systems for the Bomarc, Navaho, Snark, Rascal, and Falcon. In 1951 he was one of four people at Wright Air Development Center (WADC) who was instrumental in the initiation of Project MX-1593, the Atlas program. During this period, Hall authored and delivered a paper to the American Rocket Society on the subject of solid propulsion for long-range rockets. Between November 1953 and February 1954 he served as the WADC representative at meetings of the Air Force Strategic Missiles Evaluation Committee—popularly dubbed the Teapot Committee.

On 3 August 1954 Hall joined Western Development Division as Chief, Propulsion Development, where he was responsible for the programs leading to development of engines for the Atlas, Titan, and Thor missiles. In the summer of 1957, after receiving the Goddard award, he became director of the Weapon System 315A (Thor) development program and, subsequently, oversaw the installation of Thor missiles in England. He next took advantage of a Navy request for DoD approval of a solid-propellant ballistic missile and obtained permission for the Air Force to undertake general work on such a capability. Led by Colonel Charles Terhune, his immediate supervisor, Hall briefed Air Force Deputy Chief of Staff General Curtis LeMay on the potential of solid-propellant ICBMs. The briefing so impressed LeMay that he arranged for Hall to brief the Secretary of Defense, who as a result supported acceleration of the Air Force effort with a $50 million infusion of funds. Hall directed the Weapon System 133A (Minuteman) program until the eve of the missile’s first complete flight test, when he received orders to report to Paris.

Following his success with the Minuteman program Colonel Hall was expected to take the lead in designing, developing, producing, and deploying a nuclear-tipped intermediate-range ballistic missile (IRBM) for the North Atlantic Treaty Organization (NATO). Hall served as founding director and chief engineer for a group of French, German, Italian, and English engineers who set up the largest solid-rocket engine plant in Europe at St. Medard, France. Their labor resulted in the only European nuclear IRBM—the French Diamant. After retiring from the Air Force on 27 October 1959, Hall joined United Aircraft Corporation, and later, Chromalloy American Corporation. During those years he played major roles in numerous innovative projects. These included solid and nuclear rocket propulsion systems, high-powered laser development, design of “The Air City,” ocean farming, bioengineering (synthetic sight and hearing), computer-aided design and manufacturing, the turbo train, and space transport system design. Colonel Hall died on 15 January 2006.
eral Corporation, among others, had carried out propellant experiments centering on dispersing oxygen-rich ammonium perchlorate as an oxidizer and polyurethane propellant as the organic binder. To produce a steady thrust, engineers settled on an internal-burning, star-shaped grain configuration. Beginning in 1954 the Atlantic Research Corporation and Air Force researchers initiated successful experiments with aluminum powder as a grain additive to increase specific impulse. The following year the Air Force successfully tested the first igniters suitable for large-scale engines.\(^7\)

Hall could justifiably extol the advances in propellant storability, increased specific impulse, and control of burning rates and case bond ability over wider temperature ranges. At the same time, he readily acknowledged continuing unresolved problems associated with thrust termination, grain-to-case bond structural integrity under conditions of high temperature and acceleration, and the manufacture of large quantities of solid fuel in uniform batches consistently over time. These deficiencies, he admitted, precluded any near-term application of solid-propellant technology to ICBMs. Despite General Schriever’s skepticism about the prospects for a solid-propellant ICBM, he supported Hall’s work on solids. At this time, Hall worked closely with Barnet R. Adelman, Ramo-Wooldridge Corporation’s vehicle engineering director assigned to the Western Development Division. In December 1955, Hall and Adelman submitted a proposal to develop large solid-propellant rocket motors that, in February 1956, received formal approval as the Air Force Large [Solid] Rocket Feasibility Program, initially centering on solid-propellant research to produce an Intermediate Range Ballistic Missile.\(^8\)

Although in early 1956 General Schriever appointed Hall program director for the Thor, he allowed his propulsion chief to remain in control of the solid-propellant studies underway by Aerojet-General Corporation, Phillips Petroleum Company, Grand Central Rocket Company, and Standard Oil Company of Indiana under the Large Solid Rocket Feasibility Program. These included research on lightweight thrust-vectoring nozzles, large solid-rocket motors, high-energy propellant mixtures, high-strength lightweight engine cases, and thrust termination devices. While laying the groundwork for a future ICBM, much of the Air Force design and development work also contributed to the Navy’s Polaris IRBM program.\(^9\)

Partly to maintain the division’s focus on its primary mission of developing liquid-propellant missiles, General Schriever had the solid-propellant program transferred to the Wright Air Development Center (now a part of the Air Research and Development Command) in June 1956. Hall and his team, however, continued to do research and to monitor and study progress with solids. By late 1957, engineers had produced solid-rocket engines weighing 25,000 pounds—over three times the weight of earlier motors—by using multi-batch mixing techniques. Technicians also developed stronger motor cases and solved problems associated with nozzle cooling and nozzle gimballing for thrust vector control.\(^10\)

In early 1957, the Air Staff’s interest in producing a new tactical missile for operations in Europe brought renewed focus on the solid-fuel program. Citing the high
costs of current systems, the Air Staff required maximum use of the Navy's solid-propellant efforts in the Polaris program, even suggesting that the Navy IRBM might be compatible with Air Force requirements for a land-based missile. The solid-fuel program received another boost that summer when Colonel Paul Blasingame, the Ballistic Missile Division’s (formerly the Western Development Division) Titan ICBM program director, proposed using a solid-propellant second stage for the Titan. He argued, “We can have an early application of solid propellant systems to an ICBM and can by this means support the development of the large solid rockets with a minimum expenditure.”

By the summer of 1957, growing Air Staff interest in solids, pressure to explore use of the Navy’s Polaris missile, and Blasingame’s proposal to consider a Titan solid-propellant second stage convinced the Air Force to accelerate its solid-propellant research program. Early that summer General Schriever created an informal working group, that included Colonel Hall, and charged it to produce a draft development plan for a solid-propellant ICBM, whose stages also could meet the requirements for an IRBM and a tactical ballistic missile. Potential solid-propellant weapon systems were to be assessed on the basis of “non-interference with current programs.” In late September, Schriever responded to increased interest in solid-propellant missiles by transforming the informal group into a “solid” weapon system office, designated WDTQ, directed by Colonel Hall. Relieved of his responsibilities as Thor program director that August, Hall resented what he considered his firing and relocation to a new office in a small, windowless, former storage room with minimum staff. Nevertheless, he vigorously thrust himself into his new assignment—to develop a proposal for Weapon System “Q,” a solid-rocket intercontinental ballistic missile that also could satisfy Air Force tactical missile requirements.

With the launch of Sputnik on 4 October providing the incentive to refine his concept of a three-stage missile, Hall and his team also addressed basing requirements, including ground support equipment and training programs. By the end of December 1957, Hall had fine-tuned his operational concept and specific weapon system proposal for what was termed the Q ICBM. It called for a three-stage, solid-propellant missile approximately fifty-seven feet long and weighing nearly 65,000 pounds. Capable of generating 100 to 120 thousand pounds of thrust, the new ICBM would deliver a ½-ton warhead to within one to two nautical miles of a target at a distance of 5,500–6,500 nautical miles. Hall believed this level of accuracy and destructive power was sufficient for a deterrent missile force expected to launch as a single salvo against enemy cities in support of the Eisenhower administration’s strategy of massive retaliation. He vehemently opposed Ramo-Wooldridge Corporation’s intentions to achieve “super-accuracies with ballistic missiles.” The Titan ICBM, he argued, should be the weapon of choice for any counter-force role requiring high accuracy against military targets.

In marked contrast to the liquid-propellant missiles under development, simplicity and cost effectiveness characterized the Q missile system. Cost assessments had confirmed Colonel Blasingame’s experience with the Titan that, apart from its initial
Ruben F. Mettler

Born February 23, 1924, Dr. Ruben F. "Rube" Mettler grew up on a farm near Shafter, California. An outstanding student, he received a scholarship to attend Stanford University, where he matriculated in 1941, planning to study law. With America's entry into World War II, however, Mettler volunteered for the U.S. Navy. The Navy sent him to an accelerated program at the California Institute of Technology, where he earned a Bachelor of Science degree in eighteen months. He next attended midshipman school and the radar training school at the Massachusetts Institute of Technology, then served in the Pacific. After the war ended, the Navy assigned him to the instrumentation team for the Bikini atomic bomb tests where he witnessed at close range the weapon explosions. Following these experiences, Mettler decided to pursue further education in electrical and aeronautical engineering at Caltech, where he earned a Master of Science degree in 1947 and a Ph.D. in 1949, graduating at the top of his class.

Recruited into Hughes Aircraft Corporation, Mettler rose quickly through the ranks. Within a year his work with Jack Irving on the lead collision fire control system for the Falcon missile and guided rockets had resulted in a significant expansion of business, and Mettler became Project Manager for Radar, Guidance and Fire Control Systems for Fighter Aircraft. He remained with Hughes Aircraft until 1954, when he moved to Washington as a consultant to the Department of Defense. In that capacity he reported to, among others, Donald Quarles, Assistant Secretary of Defense for Research and Development, and Trevor Gardner, Special Assistant for Research and Development in the Office of the Secretary of the Air Force.

Mettler joined Ramo-Wooldridge Corporation in 1955 as assistant director of the Guided Missile Research Division and Director of System Engineering and Technical Direction (SE&TD) for the Thor intermediate-range ballistic missile (IRBM) program. Together with his Air Force counterparts, Mettler oversaw one of the most ambitious, fast-paced development programs ever undertaken—Thor, the first Air Force missile to use inertial guidance. Just thirteen months after the start of the program, the first Thor was ready for flight testing, and Thor missiles were produced and deployed in England in three and a half years. He managed SE&TD for the Minuteman intercontinental ballistic missile (ICBM) program in 1957 and the following year, assumed the title of Director of SE&TD for Thor, Atlas, Titan, and Minuteman. In that capacity, he worked closely with Air Force engineers to overcome serious technical challenges, especially in the Minuteman program. In mid-1959, when the Air Force accelerated Minuteman’s date of initial operational capability by a year, Mettler recalled going “into a frenzy” because “it required moving heaven and earth” to meet the new goal. Nonetheless, the Minuteman team successfully met the challenge.

With the 1958 transition from Ramo-Wooldridge to TRW, Inc., Mettler’s responsibilities grew. He served as the executive vice-president for Space Technology Laboratories (STL) during 1959-1962, then as STL president, replacing Louis Dunn. During that period, TRW/STL was the first commercial company to design and build proprietary satellites, and the first contractor to invest in a large satellite test and production facility, without government funding. STL then became the first contractor selected by NASA to design and build a large scientific spacecraft. In 1963 he became president of TRW Systems Group, which grew out of STL and expanded its leadership in development of large, complex spacecraft for both the Air Force and NASA. Mettler was elected as TRW’s president and chief operating officer during 1969-1977 and as its chairman and chief executive officer during 1977-1988. He maintained the corporation’s focus during the 1980s by continued strong participation in Air Force and NASA space programs and ballistic missile programs, along with a growing automotive business and by launching initiatives in quality, productivity, technology, manpower development, and management systems. Although he retired in January 1989, Mettler continued on TRW’s board of directors until 1994, having occupied a seat there for nearly thirty years. He died on 23 May 2006.
expense, the weapon system’s greatest funding requirements involved the support facilities, equipment, and personnel. To address these concerns, the Q ICBM would be stored indefinitely in underground silos, needing minimum maintenance and capable of rapidly launching directly from the silo. For survivability, Hall envisioned a Q “missile forest” with each missile dispersed about three miles apart in hardened, well-protected underground silos. With an automatic monitoring and redundant, remote launch capability, only seven to nine personnel were needed per missile, in contrast to the forty-five to fifty-five men required to monitor and maintain each Atlas and Titan missile. Projections at this time also determined that a solid-propellant ICBM squadron would operate at 30 percent less cost than would a comparable liquid-propellant unit.14

Hall refused to compromise on the necessity of his solid ICBM remaining a simple, reliable, survivable, and affordable missile. As he stated, “It is fundamental that all elements of the missile including guidance system, be simple, reliable, [and] highly producible so that they lend themselves to mass production, and be low in cost.” Hall went on to argue that, “by keeping the missile small and the weapon system cost low, we can more readily afford to size the force so that a sufficiently large portion of the force will survive, irrespective of actions taken by the enemy.” Initially, he suggested the nation might need as many as 4,000 of the new missiles by 1965.15

In the wake of Sputnik and apparently prompted by the “threat” of the Navy’s Polaris being considered for use as an Air Force land-based ICBM, General Schriever, his deputy Colonel Charles H. Terhune, Jr., and Colonel Hall flew to Washington, D.C., in early February 1958 to have Hall brief Air Force and OSD officials on the merits of the Q system concept. In a series of briefings to Chief of Staff General Thomas White, his new Vice Chief of Staff General Curtis LeMay, Chairman of the Joint Chiefs of Staff (JCS) General Nathan Twining, Secretary of the Air Force James H. Douglas, Jr., and finally, Secretary of Defense Neil McElroy, Hall stressed the new missile’s advantages of simplicity, reliability, responsiveness, and survivability. Describing a plan to deploy a smaller force of 1,616 ICBMs by the end of 1965, he forcefully argued for immediate approval of the Ballistic Missile Division’s development plan with formal weapon system status.16

On 21 February 1958, Air Force leaders accepted the development plan for the new missile, now referred to as Minuteman, that called for one hundred operational missiles in 1963 and four hundred in 1964. On 27 February the secretary of defense authorized the Air Force to proceed with the Minuteman, but as a research effort only and without priority status. At the same time, Hall had to fend off efforts to make his system more complex. That spring, when SAC proposed to increase hardening of the silos and launch control centers, Hall argued that this would increase facility costs by 650 percent. Meanwhile, General Schriever received only one-third of the funding he considered essential for initial research and development. The spending restrictions clearly reflected the pessimistic view of the administration’s civilian scientist advisors on the state of solid-propellant development. Hall’s outspoken, proprietary view of his affordable system also created friction. Schriever, increasingly convinced that Hall...
Lieutenant General Charles H. Terhune Jr. was born in Dayton, Ohio, on 7 May 1916, and grew up in Indianapolis, Indiana. He attended Purdue University, where he studied mechanical engineering with an emphasis in aeronautics. In 1938, he earned his Bachelor of Science before attending basic and advanced flying schools and receiving his pilot wings in May 1939 at Kelly Field, Texas. Early assignments included service with the 1st Pursuit Group, Selfridge Field, Michigan, flying P-35s and P-36s and at the Wright Field Materiel Division, Army Air Corps. In May 1940 he entered the California Institute of Technology where he received the Professional Aeronautical Engineering (Ae.E.) degree in June 1941. He then returned to Wright Field in July 1941 where he worked on the development and evaluation of the XP-39 and P-80, the Army Air Forces’ first jet aircraft.

After service in Asia General Terhune transferred to Washington D.C., first becoming involved in the Air Force’s guided-missile program in April 1947, while Chief, Air to Surface Section, Guided Missile Branch, Headquarters Army Air Forces. In 1950 he became Chief, Guided Missiles Branch, Deputy Chief of Staff Developments, Headquarters U.S. Air Force, and later as the Air Force Assistant to the Director of Guided Missiles in the Office of the Secretary of Defense. He became one of the first five officers working the Air Force ballistic missile program when in August 1954 he took the post of the Deputy Commander of Technical Operations, Western Development Division (WDD). In June 1957 the Western Development Division became the Air Force Ballistic Missile Division (AFBMD) and his title changed to Deputy Commander for Ballistic Missiles. He became Vice Commander, AFBMD, in May 1959. During the six year period from August 1954 to August 1960 he played a key role in the management of the Air Force’s ballistic missile program. He headed the source selection boards for the Thor and Titan ballistic missiles.

He also played an important part in saving the Titan I program from cancellation when officials in the Defense Department advocated such a step in early 1958. To forestall such action, General Schriever, commander of the Ballistic Missile Division (BMD), asked him to lead an effort to brief officials in Washington on the importance of the two-stage Titan. His briefing to the President’s Scientific Advisory Committee (PSAC) succeeded in persuading them that multi-staging was an important step forward and the country needed the Titan. Their decision persuaded Secretary of Defense Neil H. McElroy to approve the continuation of the Titan.

General Terhune’s contribution to the success of the ballistic missile program was broad. On 12 February 1958 Air Force headquarters directed submission of a fully-defined program for the development of a solid-propellant weapon system “as soon as possible.” He responded immediately with a thoroughgoing proposal for a solid-propellant ICBM. General Schriever was so convinced that he, in turn, called Lieutenant General Donald L. Putt, commander of Air Research and Development Command, to impress upon him the cogency of the proposal. Schriever convinced General Putt that the solid-propulsion missile (later called the Minuteman) best suited the Air Force’s needs. Following Schriever’s conversation with him, Putt asked Schriever to bring Terhune to Washington immediately to present the proposal to key officials at Air Force headquarters and the Defense Department. There, the team won over officials they were briefing, and within one week, the Secretary of Defense approved the start of the Minuteman program.

In August 1960 he left the space program and during the remainder of his career, he served as commander of the Electronic Systems Division working on command and control projects, as Commander of the Aeronautical Systems Division working on R&D of aircraft and air-launched missiles, and, finally, as vice commander of the Air Force Systems Command. In March 1963 General Schriever, commander of AFSC, assigned General Terhune to manage Project Forecast, which presented a vision of what the Air Force would look like in the mid-1970s and beyond and identified the R&D necessary to accomplish specified goals. General Terhune retired from the Air Force on 1 September 1969 and then worked for the Jet Propulsion Laboratory until 1983. He died on 30 August 2006.
could not manage the program effectively, had him transferred to Paris to oversee
development of what became Diamant, a European-produced solid-propellant IRBM
originally intended for NATO. Ed Hall’s original concept for Minuteman would evolve
into a program of great complexity, with increased sophistication and capability.17

Initial efforts to have the JCS upgrade the program to weapon system status and establish
firm force level and timing objectives proved unsuccessful. In March 1958 the Air
Force designated the Minuteman, Weapon System 133A, and the missile itself, SM-80,
yet OSD declined to sanction the Air Force designation until early December 1958.
Even then, the decision to accord Minuteman weapon system status and “high prior-
ity” also restricted program managers to planning only for concurrent activities, such
as production, construction, training, and deployment. Opposition to the Minuteman
and Air Force attempts to accelerate its development came largely from the Navy.
While Army leaders cited funding concerns, the Navy clearly viewed its Polaris IRBM
as a superior solid-propellant missile and Fleet Ballistic Missile system, one far more
survivable than land-based ICBMs. The Air Force countered by emphasizing the high
cost of the Navy’s system and the hardened and dispersed deployment of the Minute-
man. The Polaris, it claimed, cost as much as $6 million per missile compared to the
Minuteman’s $200,000 price tag, and the new missile could be readied earlier with
increased funding and accelerated development. Although the JCS, in the first part of
1959, declared an early Minuteman operational capability to be “an important military
requirement,” it declined to issue a specific operational date and stated only that it
should become operational “as soon as possible” on a non-crash basis.18

Congressional hearings in early 1959 on the likelihood of Soviet missile progress
leading to a possible missile gap in 1961–1963 buttressed Air Force arguments to
expand and accelerate the Minuteman program. By the spring of 1959 congressional
pressure had convinced OSD to expand projected Minuteman force levels to 150 op-
erational missiles by July 1963, 445 by January 1964, and 800 by June of that year. The
new schedule also called for an initial operational capability by July 1962, which meant
accelerating deployment by a year. On 13 May 1959, Secretary of Defense McElroy ap-
proved accelerating the Minuteman program, which produced corresponding requests
for additional funding from an OSD already burdened with supporting a costly, acceler-
ated priority effort with the Atlas and Titan liquid-propellant missile force.19

On 15 August 1959, the Air Force Ballistic Missile Division’s revised development
plan clearly described a weapon system taking shape. The plan proposed that each
Minuteman squadron consist of fifty missiles and five launch control centers, with the
control centers hardened to 500 pounds per square inch and the launch facilities to
100 pounds per square inch. Silos would be spaced five to seven nautical miles apart.
While awaiting OSD approval in late 1959, the Air Staff proceeded with a number of
important decisions dealing with deployment. Initial units would be located west of
Omaha, Nebraska, to minimize their proximity to large population centers. Hall had
proposed deploying the entire Minuteman force in a single area, and planners had
tentatively chosen the area around Hastings, Nebraska, for the missile farm, because
the town's old Navy ordnance plant could serve as the missile assembly and recycle
facility. By the end of the year, however, the Air Force Ballistic Missile Committee had
approved Malmstrom Air Force Base, near Great Falls, Montana, as the initial Min-
uteman support base that would be home to a wing of three squadrons. In November
1959, the Air Staff selected Ogden Air Material Area, at Hill Air Force Base, Utah,
as the primary Minuteman depot and nearby Brigham City as the site for the initial
production and assembly and recovery plant. All Minuteman operational sites were to
be located within five hundred miles of the Utah facilities.20

Air Force plans also called for Hill Air Force Base to serve as the central support
base for a mobile version of the Minuteman ICBM that drew increasing support during
the last two years of the Eisenhower administration. Under study since September
1958, the mobile concept represented a viable alternative to the Navy's Polaris and
increased Minuteman survivability as a retaliatory force that would compound Soviet
targeting. While Colonel Hall had considered mobile Minuteman a budget-buster and
threat to the entire program, SAC Commander-in-Chief General Thomas Power be-
came a champion of deceptive mobility. In early 1959, he submitted SAC's requirement
for a mobile force of fifty to one hundred missiles to be operational by July 1963.21

The Ballistic Missile Division's revised Minuteman development plan, issued in
May 1959, included a provision for an operational rail-mobility system. That July the
Air Staff authorized planning for and technical evaluation of a mobile Minuteman
that would complement the top-priority hardened and dispersed land-based force.
Air Force Ballistic Missile Division Commander Major General Osmond J. Ritland
recognized that his division had now become responsible for two systems with differ-
ent and demanding development schedules. Despite the danger of deployment delays,
he confidently noted, “Pursuing both programs in parallel at high priority might
result in a delay in the operational dates by some small amount, but the urgency of
each is so high as to justify the risk.”22

Of the 805 missiles programmed to be operational by 1964, early planning called
for 150 to be deployed on trains. An operational mobile squadron would consist of
ten trains, each with three to five missiles. Contractors for the land-based Minute-
man would also develop the mobile variant. Although they needed to make no major
design changes in the missile itself, they confronted significant technical challenges
in producing a rail launch car that could effectively and safely transport, erect, align,
and launch the missile from designated sites along the rail line. The launch cars would
also need to be accompanied by railroad cars with supporting equipment and accom-
modations for squadron personnel.23*

Initially, the Ballistic Missile Division worked closely with SAC to conduct a fea-
sibility test program, termed Operation Big Star, that called for six trains to operate

* See Appendix iv-1.
Major General Osmond J. Ritland was born in Berthoud, Colorado, on 30 October 1909. He majored in mechanical engineering for three years at San Diego State College, California, before beginning his Air Force career as a flying cadet at Randolph Field, Texas, in 1932. He served as a fighter pilot and flew Army Air Mail from 1933-35. He then left the service to work as a pilot for United Airlines for four-and-one-half years. He reentered the Army Air Forces in 1939, accepting a regular commission, and served as an experimental test pilot at Wright Field Ohio for five years. He transferred to the China-Burma-India theater in December 1944, serving as the commander of the Assam Air Depot, India, until February 1946. Returning to Wright Field, he worked in the development and acquisition of Air Force experimental aircraft and in aircraft research and development.

In February 1950, General Ritland organized the 4925th Test Group (Atomic), which he then commanded. This group was responsible for development testing of all equipment needed to attain the Air Force's nuclear weapons capability. From July 1954 to December 1954, he served as Chief, Atomic Energy Division, HQ USAF where he supervised and coordinated all atomic energy matters involving Air Force nuclear programs. From December 1954 until April 1956, he was Special Assistant to the Deputy Chief of Staff, Development, HQ USAF, and served as the Air Force's project manager for the U-2.

The Air Force assigned him to the Air Force Western Development Division (WDD, later the Ballistic Missile Division) as Vice Commander in April 1956. Major General Bernard A. Schriever, commander of the WDD, who spent a great deal of his time in Washington, had General Ritland handle the beginnings of the space effort. In 1956 he was responsible for the day-to-day management of the organization and its ambitious Weapon System 117L satellite program, the forerunner of the entire Air Force space program. The ballistic missile program, of which he was part, had succeeded. The Strategic Missile Evaluation Committee (SMEC) had believed that, under an accelerated program, an ICBM could reach operational status in six to eight years; that such a weapon could have circular error probability (CEP), or accuracy radius, of five miles; that it could deliver a significant nuclear payload over a distance of 5,500 miles. The Atlas program, the first of the ICBM programs, however, exceeded even these optimistic projections. It became operational in just five years. It had a modestly advertised CEP of two miles instead of five. It could carry a greater payload than the SMEC anticipated. Its demonstrated range was well in excess of 5,500 nautical miles.

In 1956, the President's Scientific Advisory Board (SAB) decided that it wanted to have an update on where the nation's satellite capability stood. General Ritland assembled a group for this purpose that recommended that the U.S. pursue an electronic readout satellite, but nothing came of the suggestion. General Ritland took a similar briefing before the SAB in mid-1957 with similar results, except that the SAB was now convinced that a reconnaissance satellite was technically feasible. Following the launch of Sputnik in 1957, General Ritland helped the U.S. start a program to realize an operational photographic reconnaissance satellite employing a recoverable capsule in the spring of 1959. The program was partially funded by the Air Force but predominantly by the CIA. After a series of failures, the program achieved success, proving that this approach to satellite information gathering would work.

from seven to fourteen days over routes in central, north central, and northwest sections of the country. Big Star was to determine whether railroads could support the Minuteman mobility concept as well as identify problems needing further attention. During lengthy negotiations, Air Force and railroad representatives determined operating schedules and rail rates, while Boeing provided technical assistance and equipped the cars. Strategic Air Command would direct operations from the command post at Hill Air Force Base.24

The first Operation Big Star train left Hill on 20 June 1960 for a seven-day test run through Utah, Nevada, Idaho, and Wyoming. The fourteen-car train contingent included the train commander, along with seven other officers, seventeen airmen, and nine Boeing technicians. The first two trains consisted of a variety of traditional railroad cars and carried out a prearranged plan directed by the command post. The third and fourth trains, however, operated under the direction of the train commander and included pre-prototype cars with steel tanks simulating missile configuration and weight. The train operations provided a great deal of useful information on optimum train length and weight for parking trains on sidings; they also exposed problems with communications in mountainous terrain and inadequate alert and execute procedures. With the return of the fourth train on 26 August, after a route that extended as far east as the Iowa-Illinois border, Air Force planners agreed that the test deployment operation had validated all elements of the mobile concept. Consequently, they cancelled the final two train trips.25

The success of Big Star convinced planners to proceed in late fall of 1960 with hardware design and development of the components for the complex missile launching car as well as other unique mobile equipment and specialized electronic items. In October 1960, the Air Force authorized Boeing to design a mobile train integration facility next to Air Force Plant 77 at Hill, which had been chosen as the support base for the first two mobile squadrons. Air Force leaders optimistically expected the new administration to sanction full development and deployment following its review of the Minuteman program.26

The mobile Minuteman had markedly increased Minuteman program costs. So, too, had acceleration and significant cost under-estimations. In the spring of 1960, a concerned General Ritland explained to the Air Force chief of staff that his division would need a major increase of $180 million above the fiscal year 1961 Minuteman budget ceiling were it to meet established operational objectives. That summer, Minuteman funding did, indeed, increase when the Eisenhower administration authorized a general expansion of the Defense budget in response to Democratic accusations that it was weak on defense. Even so, the Minuteman development program approved by OSD in mid-December 1960 was considerably more modest than the Air Force program submitted in August.27

The approved plan limited production to 30 rather than 60 missiles per month, neglected to fund a second missile production facility, and reduced the force objective from 805 to 540 missiles, to consist of 450 silo-based and 90 mobile ICBMs. Even
with the reduced target figure and increased Minuteman funding in 1960, the Air Force determined that programmed funding would prove sufficient to produce only 460 operational missiles, while the budget included no financial support to build 71 missiles needed for flight testing. On the other hand, the Air Force received authorization to increase silo hardening to three hundred pounds per square inch and launch control center hardening to one thousand pounds per square inch. This meant that the silo separation distance could be reduced to between three and five nautical miles, with the enemy still required to consider the silos as separate targets.28

In late 1960, while the Air Force worried about budget shortfalls and program restrictions, the Minuteman team prepared for the first all-up test launch from the Eastern Missile Range at Cape Canaveral, Florida. During the previous two years, the Ballistic Missile Division and its contractors had made tremendous strides in overcoming the key technical hurdles in propulsion, guidance and control, and reentry vehicle development on the path toward Minuteman I production.

The Minuteman I Takes Flight
The multi-stage Minuteman ICBM that Air Force and Boeing technicians prepared for its maiden flight in December 1960 reflected a team development approach and the benefits of concurrency. In June and July 1958, the Air Force Ballistic Missile Division had contracted with Thiokol and Aerojet to work on engine hardware, propellants, and movable nozzles for all three stages. A third company, Hercules Powder, received a contract to focus only on the third stage. By January 1960, sufficient progress had convinced the Ballistic Missile Division to direct Thiokol to work exclusively on the first stage and Aerojet on the second stage; that August, Hercules became solely responsible for the third. In October 1958 the Air Force Ballistic Missile Division had selected the Boeing Company to provide missile assembly and testing, and later system integration and facility check-out at operational sites. North American's Autonetics would provide guidance and control equipment, while General Electric AVCO would supply the reentry vehicle. Space Technology Laboratories, a division of Ramo-Wooldridge Corporation, continued to provide overall systems engineering and technical direction throughout the development process.29

By the end of the Eisenhower administration, engineers had resolved two problems that had long bedeviled solid-propellant rocket development. One involved finding materials that would resist erosion of the inner surfaces of the four nozzle throats and the exit cones used on all three stage motors. While aluminum propellant additive produced sufficient specific impulse for the Minuteman, the escaping hot gasses eroded the exhaust devices before attaining the minimum sixty seconds required for initial missile operation. After many frustrating attempts, only in July 1960 did the Minuteman team first succeed with a sixty-two-second test of movable nozzles that used tungsten throat inserts and a special Fiberite compound in the exit cones. By that fall, further tests convinced engineers that they had eliminated the problem. Fortunately, with the first all-up test fast approaching in December, Colonel Samuel C.
Phillips, director of the Minuteman program since August 1959, earlier had instructed Thiokol to begin first-stage manufacturing, but without installation of the nozzles until the problem could be solved.\footnote{30}

A second, related issue concerned thrust vector control. For Minuteman’s first stage, the nozzles needed to vector the engine’s thrust eight degrees from the plane of the missile’s fuselage. To solve the steering issue for Polaris, the Navy had used jetavators, special devices attached to the nozzles that provided steering by swiveling into and deflecting the exhaust flow. Minuteman engineers, however, considered the wide arc required of their nozzles too demanding for jetavators to handle. By 1959 Thiokol had developed the largest solid-propellant engine yet built, but tests that year resulted in a series of explosions that blew out all four nozzles after only thirty milliseconds of firing, well before first-stage ignition. Focusing on internal engine case insulation, which consisted of silica-bearing rubber and molded phenolic resin, Thiokol engineers determined that the propellant and internal insulation tended to separate in the rear area during firing. By the summer of 1960 they had eliminated the problem through a new method of applying the internal insulation uniformly.\footnote{31}

The three-stage missile that Boeing assembled in the fall of 1960 measured 53.8 feet long, six feet in diameter, and weighed 65,000 pounds. For the first stage, Thiokol developed a new propellant, consisting of a polybutadiene and acrylic acid binder and epoxy resin curing agent, together with ammonium perchlorate oxidizer and aluminum fuel. Thirteen batches of the mixed propellant filled an extremely strong, rubber-lined steel case in which a Teflon-coated mandrel formed the inter-burning cavity in the shape of a tapered, six-pointed star. Like the other stages, a type of pyrogen igniter fired the engine propellant, while the four movable nozzles directed by the guidance and control system handled steering.\footnote{32}

Aerojet used the same robust first-stage steel casing for its nearly thirteen-foot long second stage, which experienced the most acute bending forces following launch. A polyurethane propellant binder with ammonium perchlorate and aluminum powder provided sufficient specific impulse and effectively managed the burning rate. A slow-burning outer grain and fast-burning inner grain combined to transform the original star-shaped cavity into a more cylindrical chamber that ensured all elements of the propellant burned and contributed to the missile’s overall thrust.\footnote{33}

Just under seven feet in length, the Hercules third stage used different case material for the motor and a different propellant. A filament-wound fiberglass case proved extremely strong and provided a significant weight reduction. The third stage used a double-base grain propellant consisting of two components, one of which included a high-explosive additive for greater energy than ammonium perchlorate could provide. The third stage also housed four aluminum tubes coated in phenolic resin that would be blown out the side ports for thrust termination. For the deployed missile, General Electric AVCO’s Mark 5 reentry vehicle housed a W-59, 1-megaton yield warhead. The Autonetics inertial guidance system relied on a stable platform with two G6B4 gyroscopes to measure velocity and one VM4A accelerometer to determine
General Samuel C. Phillips played a prominent role in America’s early space and missile programs. Born in Springerville, Arizona, on 19 February 1921, Phillips graduated from the University of Wyoming with a degree in electrical engineering in 1942. During World War II, Phillips was assigned to the 364th Fighter Squadron of Eighth Air Force, where he flew P-38s and P-51s in the European theater, earning two Distinguished Flying Crosses, eight Air Medals and the French Croix de Guerre.

Phillips earned a Master’s degree in electrical engineering at the University of Michigan in 1950. This was followed by his participation in atomic tests in the Pacific, and work on the B-52, Falcon and BOMARC weapon systems. As Director of Materiel for Strategic Air Command’s 7th Air Division from 1956 to 1959, Phillips was instrumental in arranging forward-basing for the Thor Intermediate Range Ballistic Missile in Great Britain.

From 1959 to 1963 Phillips was Director of the Minuteman program, completing Minuteman’s development and transitioning it to operational use. His work on the Minuteman included overseeing the development of the reliable integrated circuit technology which serves as the foundation of many of today’s electronic systems. He then served briefly as the Vice Commander of Ballistic Systems Division at Norton Air Force Base, California.

In 1964 the National Aeronautics and Space Administration “borrowed” him from the Air Force for NASA’s most important mission of the 1960s—the Apollo Manned Lunar Landing program. General Phillips, Deputy Director of the Apollo program in NASA’s Office of Manned Spaceflight, led a government-industry team of more than 400,000 people through the Apollo 11 mission that put the first men on the moon on 20 July 1969. Recognizing this outstanding achievement, the Smithsonian Institution awarded General Phillips the Langley Medal. As the fourteenth recipient, General Phillips entered the select company of such aerospace luminaries as the Wright brothers and rocket pioneer Robert Goddard. Dr. Wernher von Braun, director of NASA’s Marshall Space Flight Center, credited General Phillips with pulling together the many pieces of the Apollo program and making it work.

Returning to the Air Force, General Phillips served as the commander of the Space and Missile Systems Organization from 1969 to 1972 where he led the studies that defined the follow-on to the Minuteman program as well as began implementation of the Air Force’s participation in the Shuttle program. In 1971 he was elected to the National Academy of Engineering in recognition of his continuing leadership of advanced technological programs. He received the 1972 General Thomas D. White Space Trophy as the Air Force member making the most outstanding contribution to U.S. progress in aerospace. After heading the National Security Agency where he focused his attention on reinvigorating the organization’s research and development programs, General Phillips became commander of Air Force Systems Command in 1973. There he managed the development of many Air Force weapon systems including the F-15 and F-16 fighters, the B-1 bomber, the AWACS, and the Peacekeeper Intercontinental Ballistic Missile.

After his retirement from the Air Force in 1975, General Phillips went to work in private industry, managing the Defense Systems Group of TRW. He served as a management consultant to NASA during the 1986 investigation of the Challenger disaster. At the time of his death in 1990, Phillips was a member of the National Research Council’s Committee for the Human Exploration of Space.

In addition to his election to the National Academy of Engineering, General Phillips was honored as a fellow of the American Institute of Aeronautics and Astronautics, and his achievements were recognized by the Institute of Electrical and Electronic Engineers and the American Astronautical Association. In addition, the University of Wyoming honored him with the presentation of an Honorary Doctor of Laws degree. General Phillips died on 31 January 1990.
acceleration. In its electronics, the Minuteman I used semiconductors and mirrored Polaris in relying on a digital computer. With a combined thrust of 305,000 pounds, the Minuteman Ia could deliver its warhead to within 1.5 miles of its target at a distance of between 4,780 to 4,950 nautical miles.\(^{34}\)

In preparation for the first all-up test flight of the Minuteman in 1960, the Ballistic Missile Division and its contractors relied on data acquired during the missile’s test program. In early 1958, Air Force and Ramo-Woolridge engineers had implemented a three-phase program to test the viability of firing a missile from a silo. The first two phases involved subscale models of Minuteman at both Edwards Air Force Base in California’s Mojave Desert and Boeing’s Seattle, Washington, wind tunnel facility. With successful completion of the first two phases in the fall of 1959, engineers began phase three, a series of eighteen full-scale launches from silos at Edwards. In January 1960, tests of flight-weight missiles that were suspended approximately eighteen feet above the bottom of the eighty-five-foot deep silos showed that the Minuteman missile could be successfully launched from a silo measuring only twelve feet in diameter. The test program, which ended in May, provided a wealth of information for designing launch test facilities at the Atlantic Missile Range and on the performance of processing methods used in fabricating the missile’s three stages.\(^{35}\)

As the mid-December target date for the launch at Cape Canaveral approached, planners realized they needed more time to check out the new equipment and postponed the flight to late January. Then, guidance and control subsystem problems delayed the flight an additional week, to Monday, 30 January 1961. Ed Hall, now a civilian working for United Aircraft Corporation, had flown down from New York to join a large contingent of Air Force, contractor, and press spectators for the launch. Unfortunately, problematic nose cone telemetry readings convinced program director Colonel Phillips to scrub the flight. Two days later, however, on 1 February, Minuteman missile 401 made history with a 4,000 nautical mile flight in which all stages and systems performed perfectly, with its reentry vehicle landing just two miles beyond the target impact point. Additional Minuteman flights from Cape Canaveral in 1961, including the first successful all-up missile launch from a silo on 17 November, convinced the Air Force of the missile’s viability as it pressed ahead with deployment plans.\(^{36}\)

Deploying the Minuteman I
The Air Force decided to establish six Minuteman missile wings in five states in the central part of the country.\(^*\) As a cost-saving measure, 150 launchers were to be located in a single area. Each buried launch control center monitored a flight of ten missiles housed in unmanned, underground, hardened launch facilities dispersed at least three miles from each other and the control center. Five flights of fifty missiles comprised a squadron, with either three or four squadrons assigned to a missile wing.\(^{†}\)

---

\(^*\) See Appendix iv-2.
\(^†\) See Appendix iv-3.
Criteria for the Minuteman sites proved similar to that for Atlas and Titan. Most importantly, the Minuteman’s range and its distance from potential enemy targets compelled planners to focus largely on the northern-tier states. The missile field locations also needed to be far enough inland to avoid seaborne missile threats, close to an existing Air Force base, and near a community of at least 50,000 people for support. Preferably, the launchers and control facilities could be constructed on government-owned land that would be relatively easy to acquire.38

As with earlier missile site selection, the process began when the site selection team, consisting of Air Force and Army personnel, conducted field inspections and provided sketches to the real estate branch of the appropriate Army Corps of Engineers district office. The real estate office then worked with government authorities and local property owners to obtain right-of-entry for initial surveys to assess the soil, terrain, and ground water conditions for facility construction. During subsequent negotiations for permanent easements and land purchase, the government offered what it considered fair market value and agreed to compensate landowners for any damage done to their property.39

Once the initial land arrangements had been made, the Corps of Engineers Ballistic Missile Construction Office Area Engineer solicited construction bids based on the designs the Air Force Ballistic Missile Division acquired under contract from the Ralph M. Parsons Company, which also had designed the Titan II launch facilities. Construction then proceeded under the joint management of the Air Force Site Activation Task Force commander and the Army Area Engineer. Corps personnel supervised construction and installation of the missile’s fuel and servicing equipment, while the Air Force and its missile contractors handled missile assembly and checkout responsibilities.40

Compared to the complex liquid-propellant missile programs, the Minuteman construction experience proved far less difficult. By eliminating the propellant loading system and silo elevator required for the Atlas and Titan I, the smaller Minuteman missile needed a silo only eighty feet deep and twelve feet in diameter. This represented a fourth of the width and half the depth of the Atlas and Titan silos. Minuteman construction teams also benefited significantly from lessons learned during the Atlas and Titan I construction. The Minuteman Configuration Control Board, for example, helped minimize design changes and ensured that the Minuteman team received standardized installation plans and procedures for the silos and launch control centers.41

Minuteman construction teams also used assembly line techniques to produce prefabricated components for rapid installation. To make the operation more efficient, specialized crews normally went from one silo site to the next, performing the same specific tasks. While the large number and wide dispersal of Minuteman sites created significant logistics and management challenges, they also facilitated a rapid, routine, uniform, and cost-effective construction process that promoted “identicality” from site to site. The speed of the Corps of Engineers Ballistic Missile Construction Office
project, which involved building one thousand silos by 1966, is reflected in the astonishing figure of one silo completed every 1.8 days.\(^{42}\)

A review of the site selection, construction and deployment experience at Malmstrom Air Force Base illustrates the efficiency of the operation as well as the importance of sound management and effective teamwork. In December 1959, the Air Force selected Malmstrom as the first operational Minuteman wing because its far north location and 3,500 foot elevation meant that the Minuteman 1A could reach its targets despite its range limitation. To ensure that the first missiles would be ready by 1962, planners had been compelled to freeze the first-stage motor design in mid-1960, even though it could not achieve its programmed range of 5,500 nautical miles. Along with satisfying the missile range requirements, Malmstrom was situated adjacent to the city of Great Falls, and could provide base support to a proposed 20,000 square mile missile field containing large tracts of public land and an established 1,384-mile road network.\(^{43}\)

The Corps of Engineers Seattle District office handled the initial survey work as well as easement and land acquisition that involved 1,378 owners of nearly 5,200 parcels of land. Each launch control center and launch site required four acres for equipment storage during construction, with two of the four acres purchased by the government following construction. The Corps also needed to negotiate with nearly 7,500 individual property owners for 2,500 miles of permanent right-of-way easements 16 1/2 feet wide for the underground intersite communications cable. The fact that the government acquired less than 3 percent of the land by condemnation reflected the patriotism of the landowners and their appreciation for the expected economic benefits the community likely would receive.\(^{44}\)

Air Force Colonel Harry E. Goldsworthy arrived at Malmstrom to assume his responsibilities as Site Activation Task Force commander for the “Montana” Minuteman in September 1960, shortly after Army representatives had completed the land acquisition and easement phase. That December the Air Force rejected construction bids from the four competing contractors, because the lowest bid of $79 million was $21 million more than the Air Force expected. While the parties negotiated over the next two months, Colonel Charles C. Lutman, the Malmstrom Air Force Ballistic Missile Division engineer, took the time to identify each critical point at which equipment supplied by the Air Force needed to interface with construction contractor facilities. Colonel Goldsworthy considered the “Interface Handbook” Lutman published a particularly “valuable tool for the Corps.” Goldsworthy also lauded Colonel Arthur H. Lahlum, his Corps of Engineers counterpart and deputy for construction. Describing him as a dedicated, experienced engineer who did not let bureaucratic red tape impede the project, he asserted, “Our relationship could not have been better.” Goldsworthy believed that the work of Colonels Lutman and Lahlum enabled his Site Activation Task Force team to avoid the type of friction between BMD engineers and Corps representatives that affected other missile bases.\(^{45}\)

After contractors resubmitted their bids, the Corps of Engineers Ballistic Missile Construction Office awarded a fixed-price-incentive contract to the team of George
A. Fuller Company and Del E. Webb Corporation for the low bid of $61.7 million. The first of its kind for a Corps construction project, the fixed-price-incentive contract established target cost and profit, together with a ceiling price and formula for the government and contractor to determine final price and final profit. The contractor had the incentive to maximize efficiency, thereby increasing profits and avoiding paying 25 percent of excess costs. In effect, the government and contractor functioned as partners, sharing all risks, expenses, and savings. With this type of contract, the government sought to control the costs of unplanned design modifications that had plagued the Atlas and Titan construction experience. Groundbreaking ceremonies took place at Malmstrom’s base theater on 16 March 1961, when, at the appointed time, political, military, contractor, and labor representatives detonated explosives in the missile fields.46

Malmstrom engineers established the standard procedure for silo excavation. It began with a circular cut to a depth of 34 feet, the level of the foundation for the equipment room surrounding the buried upper third of the 3/8 inch steel plate silo liner. While this crew of engineers moved on to the next site to perform the same initial cut, a second crew used drilling augers, blasting, and clamshell buckets to sink a 15-foot shaft an additional 60 feet. Then, steel contractors lowered a prefabricated, 25-ton, 84-foot long silo liner “can” into the shaft and placed it on the deflector plate. The launcher tube’s reinforced concrete walls were lined with steel plate, with rebar welded to the outside. After orienting the liner, workers added aggregate and pumped in mortar to form the outer silo wall. Crews then completed the equipment and support structures and backfilled the excavation. A three-point pulley system, attached to shock absorbers mounted on the silo floor, suspended the missile in its tube. Colonel Lahlum’s team needed nineteen days to emplace the first silo liner at Silo A-2, but that experience enabled his crews eventually to complete the process every two days.47*

The two-story equipment room was also constructed of heavily reinforced concrete and lined with steel. Measuring 25 feet long, 16 feet wide, and 11 feet deep, it accommodated diesel generators for electricity and gas generators to operate the eighty-six-ton silo closure door, as well as heating and cooling equipment, surge protectors to shield electronic equipment from potential electromagnetic pulse effects caused by nuclear detonations, and communications equipment that linked the launcher to the control center. Above ground, the most prominent features included the nearby launch facility support building and two cylindrical concrete azimuth markers located about 1,000 feet from the launcher to help align the missile’s guidance system. Each of the dispersed launch facilities served, in effect, as a long-term storage area protected with humidity and temperature controls.48†

Construction of the launch control facilities was also rapid and efficient. Workers began with a circular cut to the depth of the reinforced concrete ellipsoidal capsule,

* See Appendix iv-4.
† See Appendix iv-5.
approximately 54 feet long and 29 feet in diameter. Depth could vary substantially depending on the slope of the terrain. At Malmstrom, for example, capsule depth varied from a minimum of 37 feet at site M-1 to a maximum of 51 feet at site B-1, while the excavated area measured 100 feet wide and 200 feet long. Often referred to as a Thermos bottle on its side, the capsule's outer structure consisted of a 4-foot reinforced concrete wall with a ¼-inch steel plate lining. Suspended within was a 12-foot high, 28-foot long rectangular room housing the two-person crew and the equipment needed to monitor the system and launch the missiles. The inner room rested on a steel-framed platform, suspended by specialized shock isolation cylinders that allowed the enclosure to be bounced up to two feet in any direction without significant damage. After reinforcing the prefabricated steel liner for the launch control facility, crews erected forms and poured the concrete. A tunnel connected the capsule to a concrete elevator access tower that workers built at the same time near the capsule entrance. When completed, backfilling restored the original ground level, and crews then constructed the launch control facility support building over the buried control center.

The one-story, wood-frame support building, measuring 128 feet long and 33 feet wide, accommodated the two-person control facility crew; a security police detail; dining, sleeping, and recreation facilities; and at the Malmstrom sites, the underground control center’s environmental support equipment. To access the control center capsule, the crew passed through a security police checkpoint before climbing down the nearly 40-foot ladder in the reinforced concrete corridor to the reinforced concrete vestibule. At the end of the vestibule, an eight-ton blast door secured the capsule. Typically, planners located the launch control facility on four to six acres of land and surrounded it with an outer, three-wire farm fence to identify the property and discourage animals from entering the site. An inner, chain-link security fence, topped with barbed wire, encircled the launch control facility support building and an adjacent series of hardened and survivable communications antennas.

As with construction at the other Minuteman I sites, the Malmstrom team had its share of problems and schedule delays. Design changes, for example, required 243 modifications, while a twelve-day electricians’ strike in November 1961 and spring floods in 1962 also affected progress. Although the site had the services of a federal labor mediator, Colonels Goldsworthy and Lahlum spent much of their time dealing with problems involving hiring practices and jurisdictional disputes. At one point, when the head of the steelworkers union pulled his workers off the job over a minor issue with the electricians’ union, the two colonels traveled to his headquarters and spent the night “pleading with him to get back on the job.” They succeeded.

Landowner issues also required the attention of Goldsworthy and his area engineer. Emplacing nearly 2,500 miles of hardened intersite cable proved especially disruptive. Destroyed crops, broken fences, and interrupted water and power supplies meant real inconveniences to the wheat and cattle farmers, while livestock wandered too

* See Appendix iv-6.
often into the open trenches on the sites. Goldsworthy noted that he and Art Lahlum promptly responded to complaints, paid for any damages, and eased the concerns of many by traveling the state giving a well-received slide presentation on the Malmstrom Minuteman program, from construction to installation, to various organizations and communities.52

Despite the challenges, the work at Malmstrom moved forward rapidly. In a brief ceremony on 14 November 1961, Colonel Lahlum accepted the first completed launcher silo, A-2, from Boeing representatives and turned it over to Colonel Goldsworthy. A month later, crews completed the last of the initial flight of ten silos and made preparations to receive the missiles. The first missile arrived from Hill Air Force Base by train in late July 1962, and was emplaced at the A-9 launch site. Then technicians from Boeing, the system integrator, began assembly and check-out work, first testing individual components, then groups of components, and finally the interrelated subsystems. Only then did they install the missile and test the complete system with a series of simulated missile launches.53

Assembly and check-out of the Alpha flight missile facilities continued into the fall of 1962, and during the Cuban Missile Crisis the flight of ten Minuteman missiles went on alert. Following President Kennedy’s address to the nation on 22 October, Major General Gordon T. Gould, Jr., chief of the Communications-Electronics Division at SAC headquarters, called Colonel Goldsworthy from the SAC command post and asked him when A Flight could be operational. Goldsworthy told him he had been trying to transfer A Flight to SAC for several days, but SAC inspectors kept finding “clean up” items. General Gould directed him to have the warheads installed immediately. Two days later SAC accepted the flight, and the first Minuteman went on alert on 26 October.54

On 3 July 1963, Malmstrom’s 341st Strategic Missile Wing became fully operational when all 150 of its Minuteman IA missiles stood alert. The challenging three-year construction effort had been completed on schedule, for a final contract price of $79,284,385, or $3,544,385 over the final target price. Colonel Goldsworthy left the following month, justly proud of the work he and his Site Activation Task Force team had accomplished.55

Construction of the Minuteman fields at the remaining five bases also progressed at a breakneck pace. Beginning with Wing II at Ellsworth Air Force Base, South Dakota, the next four missile wings received the Minuteman IB. Because the remaining Minuteman wings would be located farther south, missiles deployed in those locations would require improvements to increase their range. While Boeing proceeded to manufacture the Minuteman IA, the Air Force issued an operational requirement in March 1961 for upgrades that included adding more propellant to the aft dome of the first stage and contouring the first-stage exit cones to provide more efficient nozzles. For the second stage, engineers provided lighter nozzles and changed the motor case from steel to much lighter titanium. Those modifications increased the range to the original requirement of 5,500 nautical miles, while the Minuteman
team also replaced the A model warhead with the more powerful 1.2-megaton Mark 11, W-56 weapon. The Air Force designated the modified Minuteman I the Minuteman IB (LGM-30B).56

Construction began on the Ellsworth Minuteman IB facilities on 21 August 1961, and the Site Activation Task Force team transferred the 44th Strategic Missile Wing’s operational missile force to SAC just over two years later, on 23 October 1963. Construction of the remaining Minuteman I sites was just as rapid, with Wing V at F. E. Warren Air Force Base, Wyoming, which housed the only four-squadron Minuteman wing, achieving operational status on 15 June 1965. Its completion brought the total number of Minuteman I ICBMs to 800. Wing VI, the 321st Strategic Missile Wing at Grand Forks, North Dakota, became the first to receive the much improved Minuteman II; its 150 missiles went on alert in December 1966. Finally, when SAC accepted the 564th Strategic Missile Squadron’s Minuteman IIs at Malmstrom in May 1967, the Minuteman force reached 1,000 missiles on alert, in the incredibly short span of five years.57

The deployment of the initial Minuteman force in five years represented a remarkable achievement, especially when compared with its predecessors. A Minuteman silo needed just 15 percent of the excavation, 20 percent of the steel, and 15 percent of the concrete required to construct an Atlas F launch facility. Moreover, with its fewer modifications, simpler design, and excellent management, the Minuteman program lowered construction costs significantly. At Minot Air Force Base, North Dakota, for example, the Corps of Engineers estimated the cost per silo at $400,000, compared to the Atlas and Titan figure of $2 million per silo. The cost of the 150 Minuteman silos at Ellsworth totaled slightly over $75.7 million, whereas construction of just nine Titan I launch facilities at the base had required $64 million. Moreover, while the Air Force spent $1 million annually to maintain the older Titan and Atlas missiles, the Minuteman would cost just one-tenth of that figure.58 Yet, while deploying the Minuteman IA and IB, the Air Force was already looking forward to a much more capable version of the missile.

From Minuteman I to Minuteman II and Minuteman III, 1962–1975

The improvements made to the Minuteman, beginning with the B model first deployed to Ellsworth, reflected the major change in defense strategy that occurred with the Kennedy administration. The Kennedy team sought to develop strategy options for decision makers that went beyond the Eisenhower administration’s overwhelming reliance on nuclear weapons in its strategy of massive retaliation. In what came to be known as “flexible response,” military planners were to prepare a range of conventional or nuclear force options for any threat. With weapons now designed to be more controllable, survivable, and selective in their use, deterrence would be enhanced. Expanding and upgrading the nation’s second-strike ICBM force became a particular focus of the McNamara Defense Department and served to revitalize the Minuteman program and improve the missile’s capabilities.59
Impressed with the first successful Minuteman flight on 1 February 1961 and his visit the following month to the Air Force Ballistic Missile Division headquarters in Inglewood, California, McNamara became increasingly convinced the Minuteman should become the principal strategic weapon for providing the operational control required to support flexible response. At the end of March, he decided to defer development and deployment of three mobile squadrons and to add, instead, three more hardened and dispersed silo-based ICBM squadrons. Despite Air Force arguments in favor of restarting the mobile program, OSD terminated mobile Minuteman on 14 December 1961 and directed that the cost savings be applied to the fixed-based Minuteman. In explaining his decision, Secretary McNamara cited the shortage of technical personnel needed to staff both Minuteman programs simultaneously and, especially, the expense of a mobile system he thought would be “several times the cost of the fixed base version.” Less public were his concerns about the mobile missile’s limited accuracy, susceptibility to sabotage, proximity to population centers, and the prospect of nuclear detonations in case of rail-related accidents. Although the mobile Minuteman would not be reinstated, Operation Big Star provided a legacy that would fuel efforts twenty years later to realize a mobile version of the Peacekeeper, called Peacekeeper Rail Garrison.60

Determined to enhance the flexibility of Minuteman, McNamara and his OSD staff focused on performance modifications. In late spring 1961 he directed Air Force Secretary Eugene M. Zuckert to examine ways to increase Minuteman flexibility. The secretary established a committee chaired by James C. Fletcher, systems vice president of Aerojet-General. Its report that September strongly favored implementing three modifications that had been under discussion late in the Eisenhower era: selective launch, multi-targeting, and “stop” launch capabilities. That fall the defense secretary directed the Air Force to proceed with all three modifications.61

Under Ed Hall’s concept, all fifty missiles in a squadron could be launched in succession or in salvo. Under selective launch, however, the control center would be able to launch missiles individually or in groups, while withholding others. The “stop” launch safety feature involved a continuous tone activated in the launch control center that prevented the ten missiles of a flight from being launched inadvertently. The tone had to be stopped before the missiles could be enabled, then launched only when the control center received a valid launch signal. The modified or “stop” launch control system to prevent inadvertent missile launch would be added, along with a selective launch mechanism, beginning with the Malmstrom wing.62

The second, and subsequent, Minuteman 1B wings also would possess dual targeting, the ability to shift from one predetermined target to another. The original Minuteman concept called for massive attacks against a single, preprogrammed target; retargeting required at least nine hours of tedious work. The modification now allowed the crews to shift from one preset target to another by sending a coded signal to the missile. At the same time, the Air Force began modification efforts needed to enable each Minuteman to launch against any one of eight preselected targets. Finally, the modifications for enhanced flexibility compelled planners to focus on greater sur-
vivability of the Minuteman force. Beginning with the third wing at Minot Air Force Base, technicians would harden the above-ground emergency power generators at both the launch control centers and launch facilities to 300 and 25 pounds per square inch, respectively.63

The effort to enhance Minuteman flexibility eventually led to the much improved Minuteman II model F (SM80/LGM-30F), first deployed to Wing VI at Grand Forks Air Force Base in 1965. Work on the Minuteman II officially began in March 1962, when the Air Force contracted Boeing to plan for and test a more advanced version of the Minuteman. The major changes occurred with Aerojet-General’s second-stage motor and propellant, and also in the missile’s guidance system. The new motor used a propellant consisting of ammonium perchlorate, aluminum, and recently developed carboxy-terminated polybutadiene that resulted in better fuel values, a longer shelf life, and a higher specific impulse than the Minuteman I second stages’s propellant. Aerojet also replaced the four swivel nozzles with a single nozzle that featured a liquid thrust vector control. With the second-stage improvements, the missile’s range increased from 5,500 to 6,600 nautical miles, and it could support the heavier Mark 11C reentry system with the 2-megaton W-56 warhead. The Mark 11C would also contain a new penetration aid consisting of heavy chaff, material designed as a radar countermeasure, that would be deployed at 15-nautical-mile intervals down to 200,000 feet.64*

To meet the Minuteman II’s retargeting requirement for engaging eight preprogrammed targets, Minuteman engineers introduced miniaturized electronics in a new, lighter, more powerful computer and replaced the Minuteman I accelerometer with a pendulous integrating gyro accelerometer from MIT. The improved guidance system made Minuteman II three times more accurate than Minuteman I and capable of striking enemy missiles in their silos.65 In September 1964, Boeing’s first Minuteman II test missile completed a successful flight from Cape Canaveral, and by May 1966, the first Minuteman II squadron, the 447th Strategic Missile Squadron at Grand Forks, North Dakota, went on alert. By the time the Minuteman wings reached their programmed figure of one thousand ICBMs in the spring of 1967, the force consisted of two hundred Minuteman II and eight hundred Minuteman I missiles.66

Impressed by the ICBM’s new features, Secretary McNamara, in December 1964, directed the Air Force to implement the Minuteman Force Modernization Program, which called for replacing the Minuteman IA and IB missiles with either the Minuteman II or a more advanced version, later designated Minuteman III. Strategic Air Command proceeded to replace the Minuteman I missiles wing by wing, beginning at Whiteman Air Force Base, Missouri, in May 1966. The Whiteman, Malmstrom, and Ellsworth wings received what the Air Force termed the Modernized Minuteman II WS 133A-M system, while the Minuteman II deployed to the Grand Forks wing and Malmstrom’s 20th Strategic Missile Squadron received the Improved Minuteman II.67†

* See Appendices IV-7 and IV-8.
† See Appendix IV-6.
The ws 133A-M designation reflected the hardware and ground equipment changes required at Minuteman I silos and launch control centers. For the silos, changes included lowering the missile support ring, improving missile suspension devices, lengthening the umbilical cords and modifying their retraction gear, and shifting the coolant for the guidance and control system. In the launch control centers, force modernization involved installing a series of more sophisticated electronic systems for the launch-enable execute system to prevent accidental launches and a new launch verification panel for selecting any of the eight preset targets. A new squadron-wide status reporting system permitted launch control officers to monitor all squadron launch facilities and missiles instead of just the ten in their flight. Additional launch control center upgrades involved a “missile away time prediction” in order to determine target arrival time and help assess missile bomb damage as well as a “time on target control” system to permit missiles to arrive at their designated targets at a preset time.68

In an effort to improve survivability, the Air Force also decided in 1964 to provide airborne launch control centers to ensure Minuteman missiles could be launched if ground launch control centers were destroyed. By early 1968, SAC had modified thirty-two aircraft for emergency operations. A silo upgrade program also helped ensure survival of the launch facility and its missile by increased hardening to protect the guidance and control system, electronic racks, and the closure system against the effects of electromagnetic pulse.69

Crews removed the last Minuteman IAs from their Malmstrom silos in February 1969 and completed the Minuteman II conversion there in June. By that time, the Minuteman force comprised five hundred Minuteman IB and five hundred Minuteman II missiles. Minuteman IB conversion would continue until 1975, by which time the Minuteman III had joined the force.70

Development of the Minuteman III (LGM-30G) had begun in July 1965, when the Air Force authorized Boeing to undertake research and development on a more advanced missile, whose third stage would include the Mark 12 multiple independently targetable reentry vehicle (MIRV) system with three warheads. The Minuteman III deployed two different versions of the warhead. The Mark 12 deployed the W-62, 170-kiloton warhead, while the newer Mark 12A housed the W-78, 375-kiloton warhead. Using the Minuteman II’s first and second stages, the Minuteman III featured a larger, more powerful third stage and, in effect, a fourth liquid stage to deploy the three reentry vehicles. For the third stage, Aerojet-General used a fiberglass motor case, the same propellant as in its second-stage motor; a single, fixed nozzle; a liquid-injection vector control system; and a thrust termination system. With the third stage able to produce more than double the specific impulse of its Minuteman II predecessor, the Minuteman III’s range improved to eight thousand nautical miles.71*

After the fourth stage’s liquid-propellant, post-boost propulsion “system” guided the Mark 12 or Mark 12A carrier missile into position, thrust termination occurred when

* See Appendix IV-9.
six circular charges detonated, venting the combustion chamber pressure. This created negative thrust that enabled the post-boost maneuvering platform, or “bus,” that carried the three Mark 12/w-62, 170-kiloton or Mark 12A/w-78, 375-kiloton warheads to separate from the third stage, deploy up to sixteen chaff clouds and ten radar decoys, and deliver the warheads to three different targets within an elliptical-shaped section that extended two hundred miles downrange and fifty miles across. The upgraded electronics of the guidance system improved warhead accuracy to nearly 1,500 feet.72*

On 16 August 1968 the first Minuteman III test missile, launched from a silo at Cape Canaveral, completed a successful five thousand-mile flight. In April 1969, the first test missile launched from Vandenberg successfully impacted near the Marshall Islands in the Pacific. Encouraged by the positive results of the test program, planners expected to have Minuteman III missiles operational by July 1969. Yet, budget shortfalls and the tedious process of refurbishing the Minuteman IIB launchers and control centers delayed emplacement of the first Minuteman III into a silo at Minot Air Force Base until April 1970. That December, however, Minot’s 741st Strategic Missile Squadron became the first Minuteman III squadron to stand alert. The Minuteman III phase of force modernization continued to 1975, when Boeing turned over to SAC the final flight of Minuteman IIs to F. E. Warren Air Force Base’s 90th Strategic Missile Wing in January, and Malmstrom’s 20th Strategic Missile Squadron (later redesignated the 564th Strategic Missile Squadron) upgraded to the Minuteman III in July. With completion of the nine-year force modernization program, the Minuteman force now consisted of 450 Minuteman II and 550 Minuteman III ICBMs.73

The Minuteman Combat Crew Experience
Like their Titan II counterparts, officers entering the Minuteman missile career field needed to pass a physical examination, acquire a Top Secret security clearance, and most important of all, complete the Personnel Reliability Program that screened all potential missileers for medical or psychological problems that might hinder their ability to handle nuclear weapons. Missile officers were to be emotionally sound, thoroughly loyal, and reliable. Once selected, all missileer candidates underwent three levels of formal training before being allowed to stand alert. For Minuteman candidates, initial individual familiarization training occurred at Chanute Air Force Base, Illinois, where they received approximately twenty-five days of classroom instruction. During three six-hour shifts, instruction at the Chanute Technical Training Center embraced courses on general Minuteman orientation and on its particular systems and subsystems.74

From Chanute, the potential crewmember joined the 4315th Combat Crew Training Squadron at Vandenberg for a four-week advanced operational training course, referred to as initial qualification training, that included emergency war order (EWO) procedures, plus launch and maintenance techniques using the Minuteman proce-

* See Appendix IV-10.
dures simulator. During training at Vandenberg, supervisors paired up the trainees for subsequent operational assignments. The third level of formal training occurred at the crewmember’s wing of assignment, and consisted of twelve to seventeen days of unit upgrade training dealing with SAC directives, technical data changes, codes, EWO procedures, and situations particular to that unit. Following a successful EWO certification briefing to the wing commander or his representative, his squadron assigned the officer to a flight and scheduled him for alert duty as a deputy commander. Each flight required six crews, as well as one instructor crew and one standardization and evaluation, or standboard, crew.75

Along with the considerable self-study expected of crewmembers, SAC also required its missile officers to participate in monthly training and evaluations dealing with war orders and the weapon system. These included “rides” in the Missile Procedures Trainer, or launch control center simulator, that occurred once or twice a month and lasted 1 to 2½ hours. All training focused on preparing the Minuteman crewmember for alert duty. As the SAC directive on missile duty stated, “The primary function of a missile combat crew is to monitor missile alert status, properly react to authentic execution orders and perform EWO [emergency war order] launches as directed.”76

A typical alert scenario began with crewmembers meeting at the base for a predeparture briefing that covered intelligence information, weather reports, and any change in EWO status. Then, a bus took the crew to the motor pool, where they picked up an assigned crew vehicle for the drive to the launch control facility, which could be as much as 150 miles distant. For safety and security, before leaving the base, each crew phoned in their departure time, the assigned launch center, and expected time of arrival.77

Upon reaching the launch control facility, the topside facility manager checked in the crewmembers at the gate and turned them over to the flight security controller, who examined their identification before the on-duty missile crew began authentication procedures. Having cleared security, the new crew took the elevator down to the control center, known also as the “no-lone zone” in reference to SAC’s policy prohibiting anyone entering the capsule alone. After the on-duty and replacement crews exchanged “greetings,” the eight-ton blast door slowly opened for the new crew to enter the capsule and start “changeover.” This formal procedure started with a ten-minute briefing on missile status, call signs, weather, the daily war plan, inventory of classified documents, and any special interest items, after which each crewmember placed his padlock on the red metal box that housed the launch keys. The process concluded with the departing crew commander and his deputy turning over to their counterparts the following items: the metal framed, plastic-encased card that depicted the code to decipher that day’s SAC messages; the console keys that crewmembers inserted and turned to launch the missiles; and a holstered .38-caliber pistol for additional protection against potential infiltrators.78

Once the departing crew left the capsule and the blast door closed, the new crew reviewed the maintenance logs and, using a 246-step checklist, conducted a compre-
On Alert

hensive inspection of all equipment in the capsule. During the remainder of the shift, the crew reviewed procedures in preparation for possible Operational Readiness Inspections, observed the status of the missiles, communicated frequently with the SAC command post, monitored scheduled maintenance during weekdays, and responded to indications of maintenance problems or security breaches in the launch control facility’s outer zone. Given the sensitivity of the security system at the launch facility and launch site, security alert teams responded frequently to false alarms, often triggered by squirrels or rabbits. Assigned topside, a missile rations cook provided crews in the capsule hot meals that had been prepared elsewhere and frozen. Crews seldom had direct, on-site contact with the launch facilities they monitored.79

The crew commander took his seat at his console, directly opposite the entrance at the east end of the capsule. The console’s illuminated panel continually provided the current security and operational status of the flight’s ten missiles. To help ensure the missiles could not be fired by one crewmember inserting and turning both keys, the deputy commander’s communications control console, with its variety of radio and telephone equipment, was located against the south wall, twelve feet from the commander’s console. A small launch control panel on the side of each console housed inputs for codes and the key-operated launch switch.80

A missile launch sequence began with radio transmission of an EWO from SAC and a message for the launch crew to authenticate. Each crewmember then unlocked his padlock on the red metal box and removed the launch keys and preset authenticators. After validating the message, the crewmembers buckled themselves into their seats. The commander initiated the countdown, while the deputy commander flipped the “arming” switches for the flight’s ten missiles. Each crewmember then opened his launch control panel and inserted his key into the appropriate switch. Before turning their keys, however, they participated in a conference call with the wing command post on the operational status of the other capsules. When the crew received the command post’s “launch on your count” directive, they turned their keys in unison. Even then, one or more of the ten missiles could be fired only if a second launch control center verified the launch command.81

Once the keys started the automatic launch sequence, the “closure” door would be blown aside, and within a minute, the missile blasted out of its silo, preceded by a smoke ring. The Minuteman rapidly rose skyward in contrast to the large, slow-moving, liquid-propellant Atlas and Titan ICBMs; it began a gradual turn toward the target just three seconds after launch. The first stage separated after a minute at 15 miles altitude, the second stage just under two minutes, and the third just over three minutes later, when the missile was 11 miles high and moving 23,000 feet per second. At the apogee of its flight envelope, the reentry vehicle had attained 710 miles altitude.82*

Prior to 1977, crews pulled alert tours of 36 to 40 hours, on an average of five times a month. This meant having two crews at the launch facility at the same time, on

* See Appendix IV-11.
shifts of 8 to 12 hours in the capsule. For a 36-hour tour, for example, the crew arriving at the launch control facility would begin its 12-hour alert shift in the capsule, while the second crew awaited its turn topside. Once the second crew replaced the first, the latter rested or slept for 12 hours before returning to the capsule for another 12 hours on alert. The replacement crew, also on a 36-hour tour, then went topside for its 12 hours of sleep or rest. Crews on 8-hour shifts would spend three shifts in the capsule and two topside. As one veteran complained, “The forty-hour alert system was really draining physiologically, just difficult because your schedule was all crazy.” With the tour’s last eight hours spent on the night shift, the crewmember’s “body clock was all off and then you had to be alert enough to drive home,” which might mean a 3-hour trip back to base.83

The 36 to 40-hour alert tour and the frequency of the tours each month proved to be major irritants, affecting the morale of the Minuteman missile force. The issue went public in August 1971 when the wives of thirty missile officers stationed at Ellsworth wrote to President Nixon and several congressmen about their concerns. Citing poor management of the South Dakota missile force, they complained that their husbands often had nine or ten of the lengthy alert tours per month, while back-to-back tours were not uncommon. In fact, SAC headquarters and Fifteenth Air Force already had begun addressing low morale and motivation among missileers when the wives’ letter appeared. In March 1971, SAC issued the results of a survey on the problem of “historical irritants” affecting missile duty. This led the command to establish a Missile Management Working Group to address the problem. That August, the Missile Commanders’ Seminar meeting at March Air Force Base, California, had “equality of missile combat crew workload” as its theme. Although the commanders declined to change alert policy, they did agree to promote greater equality in scheduling alert tours and to restrict Minuteman I, and Titan II, tours to a maximum of eight 24-hour tours per month and Minuteman II tours to an average of 5½ per month. They also decided to avoid scheduling consecutive tours except under exceptional circumstances. The seminar participants argued these changes would create a more regular work schedule, which would please the wives and improve study opportunities for crewmembers in the Minuteman’s formal education program.84

The issue reemerged in June 1972, when Fifteenth Air Force commander Lieutenant General Paul K. Carlton proposed allowing one of the Minuteman crewmembers to sleep while on duty. With SAC having “to do more, with less resources” during the austere budget climate of the 1970s, General Carlton offered his proposal more as a cost-saving measure than as a means of improving crew morale. Air Force headquarters agreed, and by the summer of 1974 had developed Project Rivet Save, a modification that called for reducing the Minuteman combat crew force by one-third, from nine hundred to six hundred combat crews, which enabled SAC to eliminate six hundred individual crew authorizations and save $12.3 million annually. The new policy included a 24-hour alert tour and allowed one crewmember at a time to rest in the capsule. The modification also included installation of isolation curtains for crewmember bunks.
to help black out light and diminish sound in the noisy control center. Strategic Air Command scheduled July 1976 for Rivet Save's initial operational capability.85

That October, however, the Nuclear Weapons System Safety Group decided the modification would not meet nuclear safety standards unless it also included tamper-detection devices as a deterrent against an unauthorized launch. While technicians at Ogden Air Logistics Center (Air Force Logistics Command) and the Space and Missile Systems Office (Air Force Systems Command) in Los Angeles worked to develop the required devices, SAC postponed the operational date for Rivet Save to July 1977. The tamper-detection modification involved a simple circuitry adjustment, whereby both crewmembers now dialed “unlock” codes included in the Emergency Action Message from the national command authorities directly into the Launch Enable Control Group panel. There, new thumbwheel switches combined preset data and the message codes to produce only one squadron launch enable code. The two-man crew now could turn their keys and fire one to fifty missiles. Technicians began implementing the Rivet Save modification in the spring of 1977, and by 1 July had completed the upgrade at all of SAC's one hundred launch control facilities.86

While the new 24-hour alert policy and a more regular work schedule improved morale in the late 1970s, SAC continued to wrestle with ways to motivate a much younger and inexperienced Minuteman crew force. In the early years of missile operations, SAC had filled its missile crew positions with experienced career officer volunteers from all elements of the Air Force community. From 1963 to 1965, for example, as much as 40 percent of the force consisted of pilots and navigators; many non-rated officers (neither pilots nor navigators) who were selected had completed at least one assignment in another field. Most were officers above the rank of captain. Beginning in 1966, the Vietnam buildup drew most rated officers from missile assignments to serve in Southeast Asia. Consequently, SAC felt compelled to turn to non-volunteer, non-rated second lieutenants coming directly from the Reserve Officer Training Corps and Officer Training School. By 1969, SAC required six hundred new Minuteman crewmembers per year, with force inputs reflecting 25 percent captains and 75 percent lieutenants averaging 1.66 years in missiles. Volunteers made up only 14 percent of crew replacements. Although SAC addressed the problem of retaining experienced crewmembers during the 1970s, the end of the decade still found 75 percent of the Minuteman force consisting of lieutenants with less than two years of service. Moreover, even with the reduced manning requirements from Rivet Save changes, low retention rates meant SAC needed nine hundred new replacements per year for both the Minuteman and Titan II weapon systems.87

Strategic Air Command attributed retention difficulties to problems with missile duty that had been present since the first decade of ICBM operations. The adverse elements reflected the paradox of missile combat crew duty. Given the formidable responsibility of handling nuclear weapons, the Air Force needed to recruit officers who met high educational, physical, and psychological standards. Yet, crew duty generally proved to be repetitive, highly regimented, and standardized. As a result, too many

124
bright young officers experienced little job satisfaction and often chose to transfer to another field once they completed the required four-year tour, or they simply left the service. The four-year tour requirement remained a source of criticism, even though many officers left the field before the four-year point. The problem became more serious for SAC in the 1970s, when there was a large influx of well-educated, but inexperienced, lieutenants on their first assignments.88

While both Minuteman and Titan II crewmembers expressed dissatisfaction with the monotony and boredom of missile duty, the Minuteman missile officer confronted challenges the Titan officer did not. The widely dispersed control centers and launchers spread across the northern tier of states contributed to the general isolation of Minuteman crew duty. Minot Air Force Base, for example, was situated thirteen miles north of Minot, a city of 32,843 people in 1980, and 120 miles north of Interstate 94. While the harsh winters and lack of “distractions” promoted a sense of camaraderie, the remoteness also contributed to the retention problem for both junior officers and enlisted service members. The largely automated Minuteman system also meant that the launch crew monitored the missile’s status but without the Titan crew’s “closeness to the missile.” Unlike the Titan crewmember’s more “hands-on” approach, Minuteman officers had fewer tasks to perform, had little contact with their missiles, and spent more time “sitting and waiting.” As one crewmember stated, the alert experience could be described as “hundreds of hours of monotony interrupted by a few hours of stark terror.”89

Along with addressing specific crewmember complaints, SAC relied on pride and professionalism to motivate its missile force. This approach embraced programs like Giant Pace, Glory Trip, and Olympic Arena.90 Nicknamed Giant Pace, the Simulated Electronic Launch-Minuteman (SELM) program tested the missile’s ability to launch; provided launch reliability data for SIOP planning and Ogden Air Logistic Center’s bench test program; and identified ground equipment malfunctions. For both airborne and ground test phases, special test equipment electronically isolated one flight plus one additional launch facility and control center. The designated missiles had their reentry vehicles removed, and crews and technicians proceeded to monitor critical launch events from key turn to simulated launch. The wing supplied several project officers for the testing, and participating crews received considerable training in safety directives and test procedures. When the program began in the early 1970s, SAC conducted four tests per year, but raised the number to two Minuteman II and three Minuteman III events in the early 1980s. By the end of the decade, however, the imminent deactivation of the Minuteman II as well as budget constraints and the availability of sufficient data convinced SAC to reduce to two the number of SELM tests each year.91

Crews also participated in Glory Trips as part of SAC’s Operational Test and Evaluation program. Every year, each Minuteman wing selected several crews to launch one of their missiles from Vandenberg on a 4,400-mile flight into the Kwajalein Missile Range in the Marshall Islands. Although planning started from the time SAC issued
a launch forecast eighteen months before the event, the wing task force, made up of a commander, maintenance element, and at least three combat crews, did not form until thirty days before the command chose the missile. On the day SAC selected a missile and related launch facility elements the missile began undergoing a series of tests. If successful, maintenance crews removed the ICBM from the silo and transported it to Vandenberg without its nuclear components. There, the task force emplaced the missile and monitored its status from strategic alert to the actual launch by the 1st Strategic Aerospace Division countdown team when authorized by SAC headquarters. The test launch not only provided SAC with missile reliability and accuracy data, wing participants usually found the launch experience exhilarating and the month of “pressure free” alerts in California enjoyable.92

The yearly three-day Olympic Arena Missile Combat Competition provided another chance for crewmembers to demonstrate their competence and professionalism, this time in friendly competition at Vandenberg against teams from other Minuteman and Titan II bases. Apart from adjustments to ensure parity between Minuteman and Titan II competitors, the Minuteman crewmember’s experience dealing with the same assigned EWO script proved similar to that of his Titan counterpart discussed in the previous chapter. One competitor described the event as like an “old time roundup,” in which the “best in the wing(s)” met in a “spirit of fun competition to improve the procedures for all.” For many competitors, Olympic Arena represented the premier missile event of the year and the most enjoyable, professional experience of their careers.93

Despite the opportunities accorded missileers to demonstrate individual, team, and unit competence and professionalism, the monotony of crew duty remained a morale issue that demanded SAC’s attention. SAC had long sought to combat the boredom of Minuteman crew duty and motivate its officers by offering them the opportunity to earn advanced degrees through its Minuteman Education Program.

**SAC’s Minuteman Education Program Initiative**

First proposed in 1961, well before the Minuteman force became operational, SAC initiated the Minuteman Education Program at Malmstrom Air Force Base in 1963 after SAC Commander-in-Chief General Power decided to offer a cost-free MA degree program to attract volunteers to missile duty and, by extension, help to relieve the monotony of alert duty. Participants would be able to study while on alert and attend classes on base taught by contracted civilian education institutions “as an authorized and integral part of missile LCO [Launch Control Officer] duty.” To be eligible, officers needed a BA degree in any subject and had to meet the prerequisites of the particular university. Graduates incurred a two-year commitment, to run concurrently, and SAC expected most officers to complete their MAS before their four-year tour ended because of “ample” time to study. The other five bases soon followed Malmstrom’s lead by offering four MA programs in a variety of subjects. Over the next four years enrollment averaged 60 percent of Minuteman crewmembers.94
Even so, the Minuteman Education Program experienced a rocky decade. Air Force headquarters, concerned about costs, had decided in 1965 to end its support following completion of the initial cycle of base programs. SAC countered by emphasizing the original goal of higher education as a motivator for recruitment and the fact that study time did not affect unit alert status. The command also argued that the $673,700 in development costs represented a one-time capital investment and suggested prorating the development cost to reduce funding for future cycles. Although Air Force headquarters relented, by 1969 the Minuteman Education Program again was in serious trouble. Decreased participation and increasing costs became the focus of an official audit by the Air Force comptroller. The critical report noted that, while the six hundred students enrolled in the program represented 60 percent of the launch control officer force, it reflected only 45 percent of officers in the missile career field and just 55 percent of students called for under contract terms. Most officer complaints centered on the poor study environment of the alert tour, during which noise, fatigue, and frequent interruptions made it hard to concentrate, and the necessity for considerable study during their limited off-duty time. At one point it seemed likely SAC would terminate the program. The auditors recommended that SAC provide night classes and close missile base programs with low enrollment. SAC demurred, however, arguing that these changes would defeat the very purpose of the program.95

Strategic Air Command made the Minuteman Education Program a part of its larger agenda of addressing the criticisms of crew duty from missileers, and the command’s attention seemed to be reflected in a steady rise in enrollment that once again reached 60 percent of the missile force by 1976. This proved to be the peak year. Enrollment declined every year thereafter until it bottomed out at 31 percent, or 402 crewmembers, in 1985. Also alarming, class attendance figures at the end of 1985 indicated that only 17 percent, or just over half of the number of enrolled students, actually attended classes.96

Although by 1980 more than 2,000 Minuteman crewmembers had earned advanced degrees, SAC had become increasingly alarmed at the troubling enrollment figures and high costs of the program. In 1984, SAC surveyed officers on crew to determine the reasons for declining participation. Most responses cited duty requirements, too many course prerequisites, too much time required to complete the program, and especially the lack of choice among the MA degrees offered. In the late 1970s, the Minuteman Education Program offered only a Masters in Business Administration; most officers surveyed stated they simply did not want an MBA degree. Indeed, 19 percent of the 1,300 crewmember force elected to pursue other on-base graduate programs even though they were not tuition free and participants did not benefit from having their class schedules coordinated with duty requirements.97

Strategic Air Command’s assessment of the Minuteman Education Program compelled the command to revise it, both in name and substance. By 1988, SAC had renamed the initiative the Missile Crewmember Education Program and offered enrollees their choice of “any locally available, regionally accredited graduate pro-
gram,” with tuition and books paid for by SAC. In the late 1980s SAC still considered its Minuteman education initiative a good incentive for entering the missile career field and coping with the constraints of alert duty.98

Women Join Minuteman Crews
Startegic Air Command faced a different type of morale and motivation issue when it decided to integrate women into the Minuteman crew force. The impending deactivation of the Titan II ICBM in the early 1980s compelled the Air Force to reexamine its policy, generally referred to as “Titan Yes, Minuteman No,” prohibiting women from serving on Minuteman and future Peacekeeper crews. SAC’s opposition continued to center on the confined nature of the Minuteman capsule with its modest privacy accommodations. Women on crew, the command asserted, would generate spousal concerns and become a morale problem. The question surfaced in August 1984 when a team directed by Major General Robert C. Oaks, director of personnel plans at Air Force headquarters, assessed women’s roles throughout the Air Force. Secretary of the Air Force Verne Orr became very interested in reviewing the policy when planners decided to base the Peacekeeper in Minuteman silos without making major modifications to the launch control centers. As General Oaks noted, “There is concern that women will be excluded from the Peacekeeper and, as the Titan is deactivated, will eventually be excluded from all ICBM launch crew positions.” Responding to a request from General Oaks to examine the issue thoroughly, SAC Chief of Staff Major General John A. Brashear appointed a committee to provide an assessment that would be part of the Air Force’s report to Congress on women in the service.99

For the study, SAC’s committee surveyed 1,400 SAC missile officers for their views on having women on crew at Minuteman and Peacekeeper sites. While the respondents reaffirmed the negative attitudes about mixed crews that had appeared in a similar survey in 1980, the report SAC submitted in late January 1985 asserted that “the concept of gender-specific [all female] crew implementation in Minuteman/Peacekeeper is feasible.” At the same time, the report predicted that gender-specific crews would create scheduling, career progression, inexperience, and morale problems. On 4 February 1985, SAC Commander-in-Chief General General Bennie Davis announced that women would be allowed to serve on Minuteman and Peacekeeper crews and charged his command to prepare an implementation plan. Completed in April, the plan called for women to join the Minuteman force, one wing at a time, starting with the 351st Strategic Missile Wing at Whiteman Air Force Base. No modifications for privacy were to be made to toilet and sleeping facilities in the capsule. To provide the needed experience in the crew commander position, Titan II female crewmembers would command the first all-female Minuteman crews.100

After reviewing the records of twenty volunteers with Titan II experience, SAC selected the first ten women for Minuteman based on their officer effectiveness reports, professional military education, and civilian academic achievements. The selectees averaged 2.75 years in the Titan program as instructors or as members of
standardization and evaluation boards. The first six officers began their fourteen-week initial qualification training with Vandenberg’s 4315th Combat Crew Training Squadron at the end of October 1985, with the remaining four to follow in December. SAC expected its first gender-specific Minuteman crews to pull alert at Whiteman in March 1986.101

Captain Linda S. Aldrich vividly recalled her experience as one of the first six Titan II veterans selected for Minuteman duty. Speaking for the other “pioneers,” she declared, “It’s a tremendous honor to be selected in the first cadre of women because of the trust SAC is placing in us to bring about a smooth transition.” She always considered herself a mentor for the women to follow. Less positive, however, was the decidedly unpleasant response she received from the spouses of male crewmembers who seemed jealous of the female missileers’ high visibility with the public and concerned about “hanky-panky” occurring in the confined space of the Minuteman capsule. Captain Aldrich recounted numerous instances of nasty treatment, such as “we don’t want you here” notes on her windshield after alert, wives in the Officers Club moving to another table to avoid her presence, and taunting of her daughter at school by other children, which she found especially objectionable. Having never before encountered “such vicious and malicious comments and behavior,” she considered spiteful actions from spouse “trouble-makers” at Whiteman “the lowest point in my life.”102

Captain Aldrich contrasted the disagreeable actions of the wives with the treatment from male officers, who, for the most part, made her and her female colleagues feel welcome. The women overcame the initial hostility by relying on their ability and professionalism. Aldrich had completed initial qualification training at Vandenberg as a distinguished graduate, and received similar accolades for her upgrade training at Whiteman. Indeed, on 25 March 1986, Captain Aldrich and fellow “pioneer” Captain Nancy K. Dean became the first all-female crew to stand alert at Whiteman. That November, the wing tapped Aldrich to be the first woman instructor in the training division, and three months later, Dean became the first female to join the evaluations division. While the appointments reflected their outstanding performance, their move to wing duty also created more difficulty for schedulers dealing with the gender-specific policy.103

The excellent results of the Whiteman program convinced SAC to introduce gender-specific crews at Malmstrom in October 1987 and to plan implementation of the policy at the remaining wings by early 1989. The Air Force projected that women needed to comprise 20 percent of the Minuteman combat crew force to permit scheduling flexibility. By the close of 1987, women comprised 40 of Whiteman’s 188 combat crewmembers and 8 of Malmstrom’s 282 missile crewmembers. At this point, however, SAC had exhausted its pool of experienced Titan II female missileers and would need three years to develop an experienced female contingent from other career fields or commissioning sources. Although Whiteman had surpassed its 20 percent goal with 36 assigned female crewmembers, the command also realized it could not achieve a 20 percent female crew force by relying on volunteers. Rather than turn to
involuntary acquisitions, SAC decided to retain the 20 percent goal and postpone the gender-specific crew policy at the remaining four Minuteman wings.\textsuperscript{104}

Meanwhile, at a missile airmanship seminar held at F. E. Warren Air Force Base in November 1987, both male and female attendees complained about alert scheduling under the all-female crew policy. When a female crewmember could not pull her scheduled alert, for whatever reason, the limited number of qualified women missileers meant that the schedulers often called on an all-male replacement crew. Then, too, male deputy crew commanders believed the women became crew commanders faster than men because of a relative shortage of female competition. The normal 2-year wait to upgrade to commander now was extended to 2½, or more, years for male deputies. Without upgrading the women, however, there would not be a sufficient number of gender-specific crews available. Arguing that these practices adversely affected proficiency and morale, the seminar participants recommended adoption of a gender-inclusive crew policy as soon as possible.\textsuperscript{105}

Ironically, Whiteman Air Force Base senior officers had believed from the beginning of integration that mixed crews were necessary because of the problems with scheduling and career progression. Then, too, in September 1986, SAC staff officers had prepared a proposal for Whiteman to use mixed crews, but they declined to present it to then SAC Commander-in-Chief General Larry D. Welch after a news story broke describing the forthcoming court martial of a former Titan female officer on charges of adultery and fraternization. When his successor, General John T. Chain, received the airmanship seminar’s proposal at the end of November 1987, the general promptly had his staff develop a mixed-crew policy initiative for Minuteman and Peacekeeper crews. The new policy became effective on 1 January 1988, but crewmembers who preferred to serve on a gender-specific crew could petition their commanders to do so.\textsuperscript{106}

The new plan had not addressed how a pregnant crewmember should be treated. On 11 February 1988, the SAC surgeon general determined that crewmembers who became pregnant would be assigned to Duty Not Involving Alert. Waivers to pull alert could be granted to a pregnant volunteer if both her doctor and her commander concurred. If approved, she could not stand alert beyond the twenty-fourth week of pregnancy. Male supervisors viewed pregnancy as a scheduling and morale problem, and, partly to offset the belief among some males that pregnancy was a deliberate act to avoid alert, usually encouraged the women to request waivers to continue pulling alerts.\textsuperscript{107}

On balance, the integration of women on crew proved successful, and mixed-gender crews increasingly became the preferred option. By the end of 1988, for example, two-thirds of the fifty-eight female crewmembers had chosen mixed crews over the gender-specific option. A year later, the number of mixed crews had risen from thirty-five to sixty-seven, while gender-specific crews had declined from sixteen to ten. At the conclusion of the decade, the gender-specific option remained squadron dependent, with growing sentiment to disregard spousal concerns and end that option.\textsuperscript{108}
The advent of mixed-gender crews helped compel SAC to upgrade the launch control center facilities. The 1987 missile airmanship seminar, in fact, had developed what became a long-overdue launch control center quality of life renovation project to deal with noise, heating, and other quality of life issues. The renovation program, referred to as Glowing Patriot, also included refurbishing the latrines, adding modular bed storage units, replacing launch control chairs, adding coffee pots and microwave ovens, installing satellite dish receivers, and providing missileers a new uniform. In July 1989, crewmembers began receiving the new one-piece blue uniform, much like the flight suit, to replace the traditional two-piece uniform.109


By 1985 the Minuteman II and Minuteman III had served well beyond their ten-year design life. The Minuteman II surpassed its life expectancy in 1975, as did the Minuteman III five years later. Growing degradation of the weapon system and the shortage of spare parts compelled SAC to initiate several programs to extend the service life of both missiles beyond the year 2000. Most important proved to be the Minuteman Long Range Plan, the Rivet Minuteman Integrated Life Extension program, and the Rapid Execution and Combat Targeting modification effort.110

In late 1985 SAC, the Ballistic Missile Office, and Ogden Air Logistics Center issued the Minuteman Long Range Plan, designed to maintain stable Minuteman effectiveness and high alert rates through its projected service life. Working groups assessed logistics requirements, mission objectives, and systems options in preparing a Twenty Year Technical Plan that established an integrated course of action to extend the operational life of the Minuteman. By the end of the decade, the program had shown that “Minuteman [III] life is extendable beyond the year 2010,” and, despite the need to redesign and refabricate replacement equipment, the system remained “affordable compared to replacement ICBMs.”111

Also in 1985, SAC and Air Force Logistics Command implemented the Rivet Minuteman Integrated Life Extension (MILE) program, a comprehensive plan of programmed depot maintenance to maintain the Minuteman through the year 2000. Ogden arranged for the establishment of depot facilities at all six missile bases, and in July 1985, working with local contractors, initiated the first of three, three-year cycles of full-scale depot maintenance at each Minuteman launch control center and each launch facility at all six missile wings simultaneously. Maintenance activity focused on hardness deficiencies, corrosion and water leaks, and hardware problems beyond the control of the local units. Efforts included not only replacing silo liners and repairing damage to silo doors and fuel lines, but also relining and refueling second-stage motors, improving standby power systems, and adding an upgraded physical security system to reduce the inner and outer security zone nuisance alarm rates. In order to keep SIOP commitments, only one launch control center and four launch facilities at each wing would be off alert at any one time. Workers needed twenty days at each launch facility and forty-five days at each launch control center to complete Rivet MILE requirements.
the end of the decade, Rivet MILE maintenance teams had completed over half of the modifications in the second three-year cycle, and SAC considered that Rivet MILE had already proven “invaluable in extending the life of the Minuteman missile.”

In 1988, SAC initiated Rapid Execution and Combat Targeting (REACT), a third major effort to improve the Minuteman’s long-term effectiveness. This upgrade focused on modernizing the launch control center’s equipment and improving its survivability. Confronted with increasing failure rates of the central computer, the brain of the control center, its limited memory capacity, and the difficulty of acquiring spare parts, SAC planners predicted the system would be unsupportable by the mid-1990s.

The Air Force had completed a major modification effort in the 1970s to improve the targeting capability of both the Minuteman II and Minuteman III. This involved the Command Data Buffer for the Minuteman III NS-20 Guidance System and the Improved Launch Control System for the Minuteman II NS-17 Guidance System. Although both used a Weapons System Controller and Memory Controller Group drawer, similar to a computer’s operating system and hard drive, respectively, the Command Data Buffer system had far greater memory processing capability. Consequently, it could store targeting data, overwrite target routines, transmit to the guidance sections at individual launch facilities, and change target data for the missile remotely. Because the NS-17’s Missile Guidance Computer (D-37) lacked the NS-20’s processing capability, targeting teams needed to preload target data and routines at the launch facility. The Command Data Buffer modification began in June 1970 and ended in August 1977 with completion of the upgrade at Malmstrom’s Squadron 20. Ogden Air Logistics Center completed the Improved Launch Control System upgrade at the Minuteman II wings by January 1980.

By the mid-1980s, however, the system’s growing obsolescence compelled SAC to plan further upgrades. REACT had its genesis in March 1986, when SAC issued an “ICBM Rapid Message Processing and Retargeting” statement of need. It followed with another, “ICBM Launch Control Center Integration,” in November 1987. Both were incorporated into the Rapid Execution and Combat Targeting requirements document, issued on 20 December 1988. It brought together five related programs in a single coordinated effort. The most important element of REACT involved replacing the aging weapon system controller with a state-of-the-art computer system that would automate manual functions and reduce by two-thirds the time crews needed to execute the SIOP. REACT also would upgrade the system’s retargeting capability, promising to reduce by 50 percent the time required to insert new targets in the missile. Another program modification focused on improving and consolidating the control center’s communications equipment to enhance the center’s nuclear hardness and speed up message processing. Finally, REACT would modernize the training simulators by replacing the computer in the missile procedures trainers. The most visible sign of the integrated modernization effort in the launch control center would be the new single, integrated, dual-workstation console that enabled either crewmember to perform most functions from one workstation.
In April 1989, the Air Force awarded REACT development contracts to Loral Command and Control Systems for the new central computer system, rapid retargeting upgrade, missile trainer computer, and crewmember console, and to GTE Corporation for the message processing equipment and communications system. The contractors were to work closely from the outset with operational crews as well as maintenance and communications technicians to determine requirements and to ensure the program’s realism and effectiveness. Expected to be completed in 1995, REACT “was considered by many the most important modernization program in the history of the Minuteman weapon system.”

Operational test flight failures of both the Minuteman II and Minuteman III in 1987 highlighted existing system deficiencies and provided added support for modification and modernization programs. When three of the seven Minuteman III test flights failed in 1987, that November Air Force Chief of Staff General Welch directed a multi-command assessment of the Minuteman III’s reliability. Although the investigation noted several potential age-related problems with the missile’s third-stage propulsion motor and its guidance system, the study concluded that these problems did not contribute to the test failures and that Minuteman III’s reliability remained within acceptable limits. Assessment of the Minuteman III precipitated a similar evaluation of the Minuteman II, which had failed on two of its four test flights in 1987.

Issued in March 1988, the Minuteman II assessment revealed a seriously aging weapon system, whose guidance system and third-stage propulsion motor required particular attention. When Ogden Air Logistics Center confirmed major problems with the D-37C missile guidance set, SAC Commander-in-Chief General Chain that August halted all Minuteman II operational test flights. Minuteman II’s reliability, in fact, had long been a source of concern. SAC’s annual flight test program required seven flights per year for each Minuteman model. While the Minuteman III usually met this stipulation, Minuteman II flight tests had totaled only eleven of the fifty-six necessary at the time of their cancellation because of the shortage of missiles and missile components. Moreover, in order to demonstrate warhead effectiveness, six Minuteman III and two Minuteman II test flight missiles required Department of Energy-configured test reentry vehicles. Because of limited testing, Department of Energy officials could not certify that the Minuteman II’s warhead would perform as programmed.

Strategic Air Command had implemented several programs to address age-related deterioration of Minuteman components. In 1979, Ogden Air Logistics Center started a program to replace the silo liner and propellant in all Minuteman second-stage motors. At the end of the decade, Minuteman II motors had been replaced, and changeout of Minuteman III motors, which had experienced less deterioration, was scheduled to be finished in 1993. Minuteman II’s third-stage motor, however, indicated seven potential failure nodes during the 1987 assessment. Because of flight test limitations, only one, a defective thrust termination port, had been properly evaluated; by December 1989, that part had been refurbished for all but seventy-five of the deployed missiles.
In 1984, a missile guidance set and flight control examination had revealed degraded electrical components in some Minuteman II guidance systems. The following year, SAC responded with an accuracy, reliability, and supportability improvement program to upgrade the electronics and enhance the software to improve accuracy. More alarming proved to be the degraded missile guidance computer identified in the 1987 Minuteman II assessment. The Air Force planned to replace the Minuteman II’s guidance computers and third-stage motors, but these and other proposed modifications remained unrealized at the end of the 1980s, when the fate of the missile itself became the central issue. In January 1990, Secretary of Defense Richard B. Cheney declared the Minuteman II force would be retired, beginning in 1992, if the Soviet Union and the United States reached a Strategic Arms Reduction Talks agreement. At the time of the defense secretary’s announcement, the Air Force already had begun planning the missile’s deactivation. Along with arms control developments, the Minuteman II’s fate had been sealed by age-related deterioration of its key subsystems, the high cost to operate and support the old system, and the inability to conduct adequate ground and flight-testing to reestablish confidence in its operational capabilities. Deactivation of the Minuteman II also seemed more palatable given the advent of the Peacekeeper ICBM in 1988 and the continuing viability of the Minuteman III.

On 31 July 1991, American President George H. W. Bush and Soviet President Mikhail S. Gorbachev signed the first Strategic Arms Reduction Treaty, committing both countries to a gradual reduction of strategic nuclear weapons during the next decade. Two months later, on 27 September, President Bush directed the Air Force to remove all 450 Minuteman II ICBMS from alert; the service complied seventy-two hours later. The Minuteman II era at Malmstrom, Ellsworth, and Whiteman had come to an end. For the South Dakota and Missouri bases, which hosted only Minuteman II ICBMS, the president’s decision represented the end of the missile age. The Minuteman had served as the backbone of the Triad’s land-based nuclear deterrent forces for over twenty-five years. Modifications and upgrades enabled the Minuteman II and the Minuteman III to remain operational far past their predicted design and service life spans. While the Minuteman II had succumbed to age and policy changes at the close of the Cold War, the 500 Minuteman III ICBMS remained fully operational, and programs like Rivet Minuteman Integrated Life Extension and Rapid Execution and Combat Targeting promised to keep the Minuteman the nation’s “ace in the hole,” well beyond the turn of the century as it adjusted to new post Cold War realities. This would be especially important because of the uncertain fate of the Peacekeeper ICBM.
First launch of the Minuteman I, Cape Canaveral, Florida, 1 February 1961. Photo courtesy of the Space and Missle Systems Center History Office archive.
A Minuteman I capsule is emplaced at Malmstrom Air Force Base, Montana, ca. 1961. Photo courtesy of the Malmstrom Air Force Base Heritage Center.

The hardened intersite cable system is emplaced during deployment of the Minuteman I at Malmstrom Air Force Base, Montana, ca. 1961. Photo courtesy of the Malmstrom Air Force Base Heritage Center.
Colonel Harry E. Goldsworthy, Minuteman I Site Activation Task Force Commander, accepts the symbol of the first silo completed, Alpha-2, from Army Area Engineer Colonel Arthur H. Lahlum on 17 November 1960. Also pictured are Mr. D.G. “Bud” Hall, Fuller-Webb team representative (far left) and Mr. Clair Popejoy of the Boeing Company (far right). Photo courtesy of Lieutenant General Harry E. Goldsworthy, USAF (Ret.).
Colonel Goldsworthy accepts the symbolic key to Flight A from Army Area Engineer Colonel Arthur H. Lahlum. Flight A missiles were the first Minuteman ICBMs to become operational, on 24 October 1962 during the Cuban Missile Crisis. Also pictured are Mr. D.G. “Bud” Hall, Fuller-Webb team representative (far left) and Mr. Clair Popejoy of the Boeing Company (far right). Photo courtesy of Lieutenant General Harry E. Goldsworthy, USAF (Ret.).
A Minuteman Transporter-Erector lowers a Minuteman I ICBM into a silo at Malmstrom Air Force Base, Montana, ca. 1962. Photo courtesy of Lieutenant General Harry E. Goldsworthy, USAF (Ret.).
Crews use a Minuteman Transporter-Erector to place a Minuteman I ICBM into a silo at Malmstrom Air Force Base, Montana. Source: From Snark to Peacekeeper, 1 May 1990, p. 36.
The heat ascent shroud is lowered over the three Minuteman III reentry vehicles prior to a test launch. 
Source: *From Snark to Peacekeeper*, 1 May 1990, p. 35.
Tecnicians mate a Minuteman III nose cone to its missile in the silo, 1968. Photo courtesy of the Space and Missile Systems Center History Office archive.

In an assessment of the mobile Minuteman concept, Operation Big Star, a test train rolls through the mountains of Utah in 1960. Source: From Snark to Peacekeeper, 1 May 1990, p. 33.
A Missile Alert Facility over one of the 341st Missile Wing’s control centers provides support for Minuteman operations and for security police personnel. Photo courtesy of the Malmstrom Air Force Base Heritage Center.

The Delta-01 launch control center, now part of the Minuteman Missile National Historic Site, Ellsworth Air Force Base, South Dakota. Photo courtesy of the Warren ICBM and Heritage Museum.
Minuteman II missile combat crew on alert in the Delta-01 launch control center, Ellsworth Air Force Base, South Dakota. Photo courtesy of the Warren ICBM and Heritage Museum.

A colorful depiction of blast door artwork at a Minuteman II launch control center. Photo courtesy of the Warren ICBM and Heritage Museum.

Captain Linda S. Aldrich, one of the first female missileers to join the Minuteman force, operates a Minuteman II console at Whiteman Air Force Base, Missouri, ca. 1987. Photo courtesy of Colonel Linda S. Aldrich, USAF, (Ret.).
An Air Force security policeman uses a Missile Electronic Encryption Device to gain access to a 341st Missile Wing Minuteman launch control facility. Photo courtesy of the Malmstrom Air Force Base Heritage Center.

An Air Force security police unit provides security for a 341st Missile Wing Minuteman missile convoy. Photo courtesy of the Malmstrom Air Force Base Heritage Center.

The first 90th Strategic Missile Wing Peacekeeper launches from Vandenberg Air Force Base, California, 17 June 1983. Photo courtesy of the Warren ICBM and Heritage Museum.
A 90th Strategic Missile Wing Peacekeeper launches from Vandenberg Air Force Base, California, 23 August 1985. Photo courtesy of the 90th Missile Wing History Office.

The heat ascent shroud is lowered over the Peacekeeper reentry vehicles prior to a test launch. Photo courtesy of the 90th Missile Wing History Office.

A Peacekeeper missile crew conducts a checklist countdown, November 1993. Photo courtesy of the 90th Missile Wing History Office.
A union Pacific GP-5 Rail Garrison mock-up performs a test run, ca. 1988. Photo courtesy of the 90th Missile Wing History Office.

On 18 October 2002, Air Force leaders gathered at launch facility Sierra-07, near Hawk Springs, Wyoming, to observe a F. E. Warren Air Force Base maintenance crew begin removing the first of the fifty Peacekeeper ICBMs programmed for deactivation. Speaking in recognition of this event, Secretary of the Air Force Dr. James G. Roche declared, “It’s a momentous point in history. It’s a reflection of how the world has changed and how we are adapting to a new era. This [Peacekeeper] is the most accurate ballistic missile that was ever designed and fielded. And it did its job.” From 1986 until 2005, the Peacekeeper ICBM represented the most powerful, most technically sophisticated, and, as the Air Force secretary affirmed, the most accurate ballistic missile in the nation’s strategic nuclear arsenal. Indeed, capable of delivering warheads with more than twice the accuracy of the Minuteman III, the Peacekeeper force provided the primary threat to Soviet and Russian hardened strategic targets throughout its nineteen-year operational lifespan.1

While the Peacekeeper demonstrated a major advance in accuracy, payload, and launch capability, it also became the focus of intense congressional and public scrutiny and the centerpiece in a contentious debate over the nation’s strategic direction and arms control priorities. For many, the value of the Peacekeeper came less from its hard target “kill” capability than from its importance as an arms negotiator’s bargaining chip. In both cases, protecting the missile became the paramount concern. The major point at issue centered on how best to base the Peacekeeper force to insure its survivability against increasingly capable Soviet ICBMs. At one point in the early 1980s, the basing dilemma threatened to scuttle the entire program. Then, in 1991
and 1993, only a few years after the missile achieved full operational capability, arms control agreements gave the Peacekeeper its “death sentence.” Consequently, with deactivation looming on the horizon, it continued its role as bargaining chip and received only modest system improvements over the course of the next decade. Even so, Peacekeeper continued to perform effectively as the nation’s ultimate deterrent weapon system.

An MX Advanced ICBM Project Takes Shape

From its inception the Peacekeeper had been envisioned as a replacement for the Minuteman. On 23 October 1963, even before development of the Minuteman III, Strategic Air Command (SAC) headquarters issued a requirement for an “Advanced ICBM” with a large payload, improved guidance, high-energy propellants, and a “cold launch” capability then used by the Navy in its ballistic missile submarines. The latter technique involved using the so-called “air elevator” of compressed gases to eject the missile from its silo before first-stage ignition. Air Force technicians successfully demonstrated a cold launch on 25 June 1965 when they ejected a tethered 300,000-pound dummy missile from a Minuteman silo at Edwards Air Force Base, California. Using this method meant that the missile could fill nearly all the space within the silo rather than having to allow room for the gases expelled by the first stage’s burning propellant. Engineers also made progress with an inertial guidance system that could be instantly activated with no loss of accuracy after lying dormant for lengthy periods.2

By the summer of 1966, the Air Force had called for the Advanced ICBM, now designated WS-120A, to be capable of delivering a 7,000-pound payload a distance of 5,500 nautical miles (later increased to 6,500 nautical miles), with a circular error probable (CEP) of 0.2 nautical miles. The Office of the Secretary of Defense (OSD), however, refused to authorize contract definition, the first stage in an official development program, without the Air Force first selecting a basing concept that would guarantee survivability if attacked by Soviet nuclear multiple reentry vehicles. After assessing both mobile and hardened silo options, Air Force Secretary Harold Brown and Chief of Staff General John P. McConnell chose hardened silos, referred to as “hard rock” silos, capable of resisting overpressures of 3,000 pounds per square inch. In the spring of 1968, the Air Force proposed immediate WS-120A development to achieve a 10-missile initial operational capability in fiscal year 1975 and to deploy a total contingent of 280 missiles by the end of June 1977. Yet, defense officials also became interested in using the hard rock silos for the Minuteman III as well as the Advanced ICBM. Although the Air Force proceeded to plan for the WS-120A missiles to replace the Minuteman III at the rate of 140 per year, OSD continued to block development of the Advanced ICBM in favor of enhancing Minuteman survivability.3

Meanwhile, when the budget-conscious Nixon administration took office in 1969, it reduced funding that December to design studies only for the hard rock silo program, which compelled the Air Force to pursue a silo upgrade program that would increase
Minuteman silo hardness from 300 psi to 1,000 psi. The Advanced ICBM effort would remain dormant for the next two years. During that time concerns grew that Soviet advances in missile accuracy with its SS-16, SS-18, and SS-19 ICBMs could very well threaten the survivability of the fixed-based Minuteman. On 2 November 1971, the Air Force responded to the potential threat with a report that identified the need for a new ICBM with improved survivability and range, greater accuracy, variable-yield warheads, and multiple independently targetable reentry vehicles (MIRV) capability. Approval of the report in February 1972 officially initiated the Advanced ICBM program, which the Air Force, on 4 April of that year, designated Missile-x (for experimental), or MX, and assigned responsibility for its development to Air Force Systems Command’s Space and Missile Systems Organization. Directed by the Air Force only to emphasize air- and ground-mobile basing, planners also studied all types of missiles, both large or small, and single or multiple warheads, along with various potential basing concepts.4

From the start of the MX saga, the missile faced two constraints. One proved to be lukewarm interest from an Air Force community that preferred a new bomber rather than a new missile system. The second involved deploying the new missile in such a manner that it did not create more problems than it resolved. The first issue revolved around the prospect of having a new bomber, the B-1, which would first be cancelled by President James E. “Jimmy” Carter, Jr., then reinstated in the administration of President Ronald W. Reagan. The second constraint would prove far more difficult to overcome. Indeed, the basing challenge was to bedevil the program throughout its developmental and operational lifespan.5

As part of the effort to select a basing mode that would ensure survivability, the Air Force experimented in late 1974 with the first air launch of an ICBM. After dropping seven pallets, each loaded to simulate a missile’s weight, in September a C-5A “Galaxy” transport aircraft successfully launched three inert Minuteman I missiles over the Western Test Range off the California coast. During the third and most impressive flight, on 24 October 1974, two thirty-two-foot drogue parachutes extracted the missile from the aircraft, after which the Minuteman I fell from 20,000 to 8,000 feet, stabilized by three additional parachutes. At that point, the first-stage motor fired for thirty seconds, with the upward thrust lofting the missile more than 20,000 feet before it dropped into the ocean twenty miles from the coast. Despite the success of the airmobile feasibility demonstration, the Air Force ended testing of the airmobile basing system in May of 1975 because OSD officials considered the aircraft bases vulnerable to surprise attack.6

As for a land-mobile option, the Air Force had been studying various ground mobile concepts since the late 1960s and had determined that a mobile system could approximate that of a silo system in terms of reaction time, accuracy, and post-attack endurance. By late 1973, SAC had fifteen different mobile basing concepts under study, and in 1975 it selected a basing plan labeled “deep trench.” Under this concept, transporters would move the missiles in horizontal position through a network
of tunnels five feet below the surface and be prepared to stop at designated points in the tube to erect and fire the missiles. Tests at Luke Air Force Base, Arizona, in 1977, however, showed that transporter movement of this kind disturbed the earth’s surface, which would allow the enemy to detect the missile locations, whereas a deep-trench basing system also would likely prevent required verification by satellite under future arms control agreements.7

In the meantime, the Air Force had not given up on initially basing the MX in Minuteman or Titan II silos, then later deploying them in a ground-mobile system. Although Soviet accuracy, timing, and use of multiple reentry vehicles could weaken the survivability of the silo-based system, silo basing also provided better performance at lower cost if retrofitted with larger missiles. Using an advanced shock isolation system and the cold launch method, for example, the Minuteman III silo could house a much larger ICBM. In 1974, the Minuteman program office contracted Westinghouse Electric Corporation to develop a canister shock isolation system that would both protect and guide the missile as it emerged from the silo. Since launch and protection requirements were similar for both silo and land mobile operations, the canister could serve both basing alternatives. The Air Force saw no reason to forego fixed silos, the easiest and cheapest solution.8

During the first three months of 1976, the MX program transitioned from conceptual design to test component fabrication, and in 1977 planners established the missile’s size and general configuration as a large, four-stage, solid-propellant ICBM capable of launching from a Minuteman silo. As prescribed by the 1972 requirement, the MX would be more accurate, possess greater target flexibility, be more resistant to nuclear blasts than the Minuteman, and be fully capable of destroying the hardest of Soviet targets.9

The Carter Administration Commits to A Basing Strategy

When President Jimmy Carter took office in January 1977, the MX basing issue remained unresolved. Particularly concerned with the inability of deep-trench basing to meet arms control requirements, the president eliminated funding for the trench configuration that very month. Meanwhile, Congress continued to worry that silo basing would not provide the required survivability. The previous July it had refused to fund fixed, or silo basing, and in April 1977 it chose to delay full-scale development for a year to allow more time to select a mobile basing system.10

That June President Carter, at considerable political cost, cancelled the B-1 bomber program in favor of ICBMs, SLBMs, and air launched cruise missiles on B-52s. Denied the weapon system they wanted, unhappy Air Force leaders now turned to the MX as the only available new strategic program and initiated a concerted effort to decide on an acceptable basing scheme for the ICBM. Over the next two years, momentum continued to build for the MX. During this period, defense analysts believed that a new guidance package the Soviets tested for their SS-18 gave it potential first-strike capability. Were they to retrofit their three hundred SS-18s with up to fourteen warheads
Ivan A. Getting

Dr. Ivan A. Getting was the founding President of the Aerospace Corporation, serving in that position from 1960 to 1977. The Aerospace Corporation was established in 1960 as a non-profit organization at the request of the Secretary of the Air Force. It was founded to apply "the full resources of modern science and technology to the problem of achieving those continued advances in ballistic missiles and space systems, which are basic to national security."

Dr. Ivan Getting was born in 1912 in New York City. He attended the Massachusetts Institute of Technology as an Edison Scholar, receiving his Bachelor of Science in 1933. Following his undergraduate study at MIT, Dr. Getting was a Graduate Rhodes scholar at Oxford University. He was awarded a Ph.D. in Astrophysics in 1935. Dr. Getting was a Junior Fellow at Harvard University from 1935-1940. In 1940 he joined the staff at Massachusetts Institute of Technology radiation laboratory. He became an associate professor in electrical engineering at MIT in 1945, and a professor in 1946. During World War II he was a special consultant to Secretary of War Henry L. Stimson on the Army's use of radar. In 1950 he left MIT for a position as the Assistant for Development Planning, Deputy Chief of Staff, United States Air Force.

In 1951 Dr. Getting became the vice president for engineering and research at the Raytheon Corporation. The first three-dimensional, time-difference-of-arrival position-finding system was suggested by Raytheon Corporation in response to an Air Force requirement for a guidance system to be used with a proposed ICBM that would achieve mobility by traveling on a railroad system. When Dr. Getting left Raytheon in 1960, this proposed technique was among the most advanced forms of navigational technology in the world, and its concepts were crucial stepping stones in the development of the Global Positioning System (GPS). Under Dr. Getting's direction Aerospace engineers and scientists studied the use of satellites as the basis for a navigation system for vehicles moving rapidly in three dimensions, ultimately developing the concept essential to GPS. Among the many other projects undertaken at The Aerospace Corporation under Dr. Getting's direction were planning for new ballistic missile systems, oversight of space launch systems, and the development of high-powered chemical lasers.

Dr. Getting also was a founding member of the Air Force Scientific Advisory Group, later renamed the Scientific Advisory Board, which provides a link between the Air Force and the nation's scientific community, promoting the exchange of scientific and technical information to enhance the effectiveness of Air Force mission performance. As chairman of the board's Electronics Panel, Dr. Getting oversaw implementation of the Quick Reaction Capability for Electronic Counter-Measures and helped establish the SHAPE (Supreme Headquarters Allied Powers, Europe) Laboratory at the Hague, both of which enabled the Air Force to deal with increased Soviet radar capabilities. He also played a role in the deployment of a critical U.S. air defense capability called the Semi-Automatic Ground Environment (radar) system. Dr. Getting directed studies on MX missile basing and long-range combat aircraft and became a strong advocate for the Global Positioning System. Dr. Getting also provided technical analysis and suggestions on the design of a long-range supersonic bomber capable of reaching the former Soviet Union and returning without refueling. His work resulted in the reinstatement of the B-1 bomber funding by Congress.

Following his retirement in 1977 Dr. Getting served as a consultant to and board member of various companies. He remained associated with the Aerospace Corporation with the title President Emeritus. Recognized on numerous occasions for his contributions and achievements, Dr. Getting has received the President's Medal of Merit, the Naval Ordnance Development Award, the Kitty Hawk Award, and the Institute of Electrical and Electronic Engineer's Pioneer Award and Founders Medal. In 1997 he received the Department of Defense Medal for Distinguished Public Service and the following year the John Fritz Medal, one of the nation's highest engineering awards. Dr. Getting died on 11 October 2003.
each, the pessimists who for years had been decrying Minuteman’s vulnerability might very well be vindicated. Although later assessments determined that the ss-18 threat had been overblown, the early tests proved alarming and accorded well with the phrase, “the window of vulnerability,” coined by OSD analyst James P. Wade in 1979. Wade’s description referred to that dangerous period between deployment of the more accurate ss-18s and the time the United States could field an appropriate missile to counter the threat. As one author argued, “The mx became the great beneficiary of the window of vulnerability.”

By the spring of 1979, the Air Force had examined more than forty basing modes for the mx. That June President Carter authorized full-scale engineering development of the mx, but deferred a decision on basing pending more study. Three months later, on 7 September, the president selected Multiple Protective Shelters (mps) as the preferred basing mode. Under this scheme each of the two hundred mx missiles was to be shuttled randomly in its separate oval, underground railway or road cluster of twelve non-hardened horizontal protective shelters that were to be spread over remote sections of Utah and Nevada. Advocates of the shelter concept argued that the Soviets would have to target all 2,400 shelters because they could not determine which structures contained a real missile and which a dummy. This meant that over half of available Soviet warheads would be directed at the mx shelters, leaving them unable to strike all of the remaining military targets, especially the Minuteman silos. Above all, the concept offered the key advantage of deception, or what Air Force basing planners referred to as “preservation of location uncertainty.”

By the spring of 1980, the Air Force had determined that with each new Soviet ss-18 carrying ten mirved warheads and ss-19s configured with six, the Soviet Union could deploy more warheads than originally estimated. Consequently, the Air Force increased the number of shelters to 4,600, with each of the two hundred missiles moving among 23 shelters. At the same time, planners replaced the oval racetrack clusters with a linear road network, which required less area for deployment and saved $2 billion. With doubling the size of the system, they also adopted the split-basing concept, whereby mx shelter networks would be deployed to two or more areas to reduce the environmental impact and dampen political opposition. Even so, critics, led by those in the deployment states of Utah and Nevada, attacked the plan from the outset, citing the high cost, which grew to more than $37 billion in fiscal year 1980 dollars, and the large amount of land required. The enormous linear-cluster project would involve 8,500 miles of road, 400,000 tons of steel, 1.5 million tons of concrete, as well as 19,000 construction workers. The basing system also would require 6,000 technicians for check-out and assembly, and 13,000 Department of Defense (DoD) personnel to operate the network.

Sensitive to public opinion, political leaders in one of the proposed deployment areas, the Nevada-Utah border, complained about the area’s proximity to civilian population centers and, as one Utah congressman declared, “This system is going to make Utah a red dot on the Soviets’ target list and, as a result, the entire state could be
Opposition also came from environmental groups concerned about the threat to wildlife and from the Bureau of Indian Affairs and Church of Jesus Christ of Latter-day Saints. Other critics pointed out the difficulty of providing future verification by the Soviet Union, despite a system design element that could allow orbiting satellites to observe a set number of MX missiles. Meanwhile, during the 1980 presidential election campaign, Republican candidate Ronald Reagan declared that, while he strongly supported fielding the MX, he opposed MPS as wasteful and ineffective. He promised to cancel it if elected.14

The Reagan Administration Pursues Another MX Basing Strategy

President Reagan entered office determined to upgrade all three legs of the strategic Triad under his strategic modernization program. For the land-based ICBM leg, the future of the MX became the administration’s major focus. In February 1981, the president initiated a comprehensive review of MX basing by appointing a fifteen-member panel of prominent defense experts, headed by Nobel Prize-winning physicist Charles H. Townes. The committee’s report, issued that summer, found the members divided between deep underground basing and continuous aircraft patrol, but unanimous in recommending that one hundred MX missiles be based in hardened silos until a permanent solution could be found.15

In October 1981, President Reagan carried out his campaign promise and cancelled the multiple protective shelter basing system. In its place he proposed a two-phase alternative, whereby the MX missile would be deployed initially in “super hardened” Titan II or Minuteman silos, but later in a more survivable system. This would end what he termed “the decade-long pattern of postponement, vacillation, and delay” in modernizing the nation’s strategic arsenal. By early 1982, an Air Force program directive that sanctioned continued full-scale development also called for deploying forty missiles in Minuteman silos, with the first ten to achieve initial operational capability by late 1986. Geological assessments determined that F.E. Warren Air Force Base or Davis-Monthan Air Force Base would be the best support base candidate. The Air Force chose F.E. Warren over Davis-Monthan because the Minuteman base could deploy up to two hundred MX missiles, while the Titan II base could house only eighteen.16

Congress reacted to silo basing just as it had in 1976. In March 1982 it rejected the president’s plan and directed DoD to accelerate efforts to determine a suitable, permanent basing scheme. The administration responded by charging the Air Force to provide a technical analysis of four basing options that included the MX in Minuteman silos, in widely-spaced silos, in closely-spaced capsules, or in a deep-basing configuration. It also authorized a site selection team to recommend a basing site. While deploying MX in Minuteman silos remained a contingency plan, the Air Force centered primarily on “Defendable Modular Array Basing” or, as it became better known, “Closely Spaced Basing.” On 22 November 1982, Secretary of Defense Caspar W. Weinberger announced the choice of Closely Spaced Basing, known to the public...
as “dense pack,” and F. E. Warren as the deployment base. On that same date, the president officially renamed the MX, the Peacekeeper.\textsuperscript{17}

Under the dense pack scheme, a trapezoidal array of one hundred Peacekeeper ICBMs would be located just 1,800 feet apart, and emplaced in super-hard silos designed to withstand blasts of 60,000 to 70,000 psi, or the effects of a 27-megaton strike from a Soviet SS-18. Supporters of this idea argued that during a full nuclear attack the enemy’s first detonation of warheads over the closely-spaced missile sites would pre-detone the next wave of incoming warheads, creating a chain reaction that would protect most sites by means of “nuclear fratricide.” The dense pack scheme also called for an anti-ballistic missile (ABM) defense system, despite the United States having abandoned the single Safeguard ABM site in North Dakota shortly after declaring it operational in April 1975. Because a dense pack system could be constructed within a fifteen to twenty square mile area, it would be entirely situated within government owned land, thereby avoiding the political uproar that helped destroy MPS basing.\textsuperscript{18}

Congress, however, had no interest in dense pack basing, either. A majority of its members considered the scheme to have too many unanswered technical questions and fielding an ABM system too destabilizing to the strategic balance in an already tense American-Soviet relationship. In December 1982 Congress voted to withhold funds for initial Peacekeeper procurement and prohibited flight-testing until both houses agreed on an appropriate basing scheme proposed by the White House. Congress also pressed the administration to authorize a comprehensive technical evaluation of the MX, alternative ICBM programs, and basing options. At this point Congress even considered scrapping the MX ICBM altogether in favor of upgrading the Minuteman force.\textsuperscript{19}

\textbf{The Scowcroft Commission Establishes an Agenda}

With closely spaced basing rejected and the entire Peacekeeper program in jeopardy without an acceptable basing option, President Reagan, on 3 January 1983, appointed a prestigious bipartisan Commission on Strategic Forces, chaired by retired Air Force Lieutenant General Brent Scowcroft. The president directed the commission to assess strategic modernization with special emphasis on the Peacekeeper ICBM and how best to deploy the new missiles. At the same time, Reagan also directed Air Force headquarters to prepare a comprehensive technical assessment of the Peacekeeper weapon system that encompassed nine basing options and four ICBM modernization alternatives. Although the Scowcroft Commission called 203 witnesses and spent nearly 48,000 hours in its three-month effort, the Air Force technical assessment served as its primary source of information.\textsuperscript{20}

Released on 6 April 1983, the Scowcroft Report argued that arms control and strategic forces modernization remained mutually reinforcing and the basis for international stability. Modernization of the ICBM, it asserted, proved to be a “particularly

\* See Appendix V-1.
The “Ultimate Deterrent”

important” means of convincing the Soviets to negotiate “stabilizing” arms control measures and to redress the “perceived” United States disadvantage in strategic-force capabilities. The report took direct aim at silo-basing the Peacekeeper. For an increasingly endangered ICBM force, it argued, deploying the small Peacekeeper force in vulnerable launch sites at a single base would not lessen the possibility of nuclear conflict between the United States and the Soviet Union. On the contrary, with one Soviet reentry vehicle capable of destroying ten Peacekeeper reentry vehicles, Soviet planners might feel confident about eliminating the whole United States ICBM force while holding back enough weapons to blunt attacks from the other two elements in the U.S. strategic Triad.21

The commission recommended a three-part approach. First, to address the long-term threat, the nation should develop a new, small, single-warhead ICBM in hardened shelters, either in silos or on hardened mobile launchers. With its reduced target value, a fleet of small ICBMs would, it argued, stabilize the strategic balance by requiring the Soviets to use an increased number of warheads to destroy a single U.S. reentry vehicle. Ultimately, the “Small ICBM” also would replace the MIRVed Minuteman and Peacekeeper force. Second, the commission strongly recommended that the United States undertake a major examination of all basing alternatives, but especially the option of hardened land vehicles for both the Small ICBM and Peacekeeper.22

Third, the United States should immediately deploy one hundred Peacekeeper missiles in Minuteman silos to demonstrate national will, give the nation a credible capability against hardened targets, and convince the Soviets to negotiate new arms control agreements. This action would be the fastest way to correct the strategic nuclear imbalance as well as compensate for the deactivation of the powerful Titan II. The megatonnage of the one hundred Peacekeeper force approximated that of the fifty-four Titans being retired as well as the one hundred Minuteman ICBMs that would be replaced. Although OSD and Air Force officials had preferred a more survivable mode, they now embraced basing the Peacekeeper in Minuteman silos, realizing that it represented both the quickest and the cheapest basing option. They also could argue that deploying Peacekeepers in Minuteman silos represented only an interim basing solution. On 19 April President Reagan approved the Scowcroft Committee’s recommendations, and Congress followed suit on 24 and 25 May. For the very first time, Congress had endorsed silo basing for the MX/Peacekeeper ICBM. By the end of 1983, it also had authorized production of the first twenty-one Peacekeeper missiles.23

The Peacekeeper ICBM Takes Shape
In spite of the programmatic turbulence caused by the MX basing dilemma, the new missile’s development proceeded on schedule. Technological problems proved few and relatively easy to overcome. The Ballistic Missile Office, successor to the missile portion of the Space and Missile Systems Organization, remained responsible for program management and testing, with the Arnold Engineering Development Center at Arnold Air Force Station near Tullahoma, Tennessee, handling motor testing under
conditions simulating sea level, altitude, and pre-ignition states. The mx program benefited significantly from seasoned program managers and engineers and a contract structure involving over twelve associate contractors nationwide with a wealth of experience in the solid-propellant Minuteman and Polaris programs. Veteran advisor Thompson Ramo Wooldridge, Inc. (TRW) provided systems engineering and technical advice for the program.24

When the Space and Missile Systems Organization had begun the component-testing phase for the mx in the spring of 1976, it could rely on aerospace contractors with proven track records in solid-rocket development. Morton Thiokol Company, for example, the contractor for the first stage, also had manufactured the first stage of the Minuteman I, II, and III. Likewise, second-stage contractor Aerojet had produced the second stage of all three versions of the Minuteman, as well the third stage of the Minuteman III. Hercules Corporation, which received the contract for the mx’s third stage, had built the third stage of the Minuteman I and II. Both Aerojet and Hercules also had worked on the Navy’s Polaris IRBM. By May 1978, the Space and Missile Systems Organization had awarded propulsion contracts to Thiokol for the mx first stage, Aerojet for the second, and Hercules for the third.25

To achieve the performance capabilities of the mx, designers and engineers used a number of innovative missile technology concepts for the first time in an ICBM. For example, all three propulsion contractors used Kevlar fibers in place of aluminum for the solid-motor casings. The Kevlar epoxy and resin-coated shell reduced the missile’s overall weight, thereby increasing its range and, also, making it sufficiently light and sufficiently strong for deployment in some type of future mobile basing system. A second innovation involved the use of extendable nozzles for the second- and third-stage motors. After staging, the solid-propellant motor’s exit cone, which had remained folded within the rocket, telescoped outward for extra power. Through this method, the mx could achieve the range and payload of a longer missile while remaining short enough to be deployed in a Minuteman silo.26

In a third major advance, planners adopted the canister, or cold launch technique rather than the hot launch method used by the Titan II and Minuteman ICBMs. Steam produced by a gas generator at the base of the canister ejected the missile from the silo to approximately 110 feet at a velocity of approximately eighty miles per hour, whereupon the first stage ignited, launching the missile on its journey. Cold launch caused little damage to the silo, making the launcher reusable in a matter of a few days.27

When completely assembled, the missile included three solid-propellant booster stages and a liquid-propelled fourth stage. The mx/Peacekeeper measured seventy-one feet high and ninety-two inches in diameter. When fully loaded, it weighed 195,000 pounds, or 2½ times the weight of the Minuteman III including reentry vehicles. The mx was designed to deliver ten reentry vehicles to within four hundred feet of each separate target more than six thousand miles distant.28*

---

* See Appendix V-2.
Both the first- and second-stage motors used different proportions of the same propellant mixture, based on synthetic rubber and consisting of aluminum powder, ammonium perchlorate, and hydroxyl-terminated polybutadiene. The missile’s first stage measured twenty-seven feet six inches in length, seven feet six inches in diameter, and weighed nearly 108,000 pounds, or more than the entire weight of the Minuteman III missile. Using a single movable nozzle to provide steering, the first-stage motor boosted the missile to nearly 75,000 feet, whereupon, following first-stage burnout and release, the seventeen-foot, six-inch long, 60,000 pound second stage ignited and propelled the missile to approximately 300,000 feet before it burned out and dropped away. Both the second and third stages used the extendable exit cones that permitted the motor nozzles to remain folded until ignition of the stage in flight. Once extended, the larger diameter of the exit cone produced increased thrust, thereby adding up to 118 nautical miles to the missile’s range.

Among the four stages, the second caused the most difficulty during testing, because the motor case tended to rupture following the rapid pressure increase after ignition. Even though the motor performed satisfactorily during flight testing, it required frequent redesign and retesting, with a focus on problems of insulation thickness on the forward dome, inadequate liner material, and poor performance of the extendable nozzle exit cone. While technicians worked to solve these problems, the second stage received special attention when a catastrophic failure occurred on 17 November 1982 during a high-altitude, high-temperature ground test at the Arnold Engineering Development Center. The engine exploded in its test cell, spilling 55,000 pounds of solid propellant on the floor, which accidently ignited ten days later, killing four workers who were cleaning the silo. Aerojet subsequently redesigned the engine, removing 300 pounds of propellant, and static tests confirmed its reliability.

For the third-stage propellant, Hercules used a synthetic polymer plastic matrix of the nitrate ester plasticized polyether family, consisting of cyclotetramethylene tetranitramine and nitroglycerine with aluminum powder and ammonium perchlorate additives. Measuring seven feet seven inches long and weighing 18,000 pounds, the third stage raised the missile an additional 500,000 feet before it, too, burned out and separated.

The smaller, liquid-propellant fourth stage, built by Rocketdyne, measured just three feet five inches long and weighed 3,000 pounds. Also referred to as the postboost vehicle, its propulsion system consisted of two tanks of hypergolic liquid bipropellants for the axial engine and eight attitude control system engines, along with a thrust vector actuation system. Only a liquid-propellant motor could offer the multiple engine restarts and recycling required for precise maneuvering to ensure correct ballistic trajectories for each of the Peacekeeper reentry vehicles. The fourth stage also housed the missile’s “brain,” the Missile Guidance and Control System (MGCS), another key MX/Peacekeeper innovation.

Smaller and more accurate than any other missile guidance system, the Rockwell Autonetics-built MGCS fit into a fourth-stage “drawer.” Within the MGCS, the Missile
Electronics and Computer Assembly housed the on-board computer with several types of memory and most of the electrical signaling equipment. Northrop Electronics Division manufactured the critically important inertial measurement unit (IMU) within the MGCS to provide the precise velocity and attitude measurements throughout the flight, thereby ensuring correct reentry vehicle trajectories. Especially innovative was the IMU’s Advanced Inertial Reference Sphere, a neutrally buoyant “flotated-sphere” that consisted of three gyros to stabilize the whole system, three force-integrating receivers to sense the velocity of the missile, and three turbo pumps to maintain constant fluid flow in the sphere. An in-flight cooling subsystem, air-borne power supply, missile interconnection cables, and missile ordnance arm switch completed the MGCS inventory of components.33

General Electric AVCO’s fifteen-foot long Mark 21 reentry system, sitting atop the fourth stage, housed the General Electric W-87, 300-kiloton yield warhead, the deployment module, and the shroud. Initially, the Peacekeeper development plan called for using AVCO’s Mark 12A reentry system, with W-78, 350-kiloton yield warheads, but in 1982 OSD chose to use the cheaper, safer, and more accurate Mark 21/W-87 weapon set. The titanium shroud, which protected the reentry vehicles during the flight through the atmosphere, contained a forty-pound tractor motor in its nose cap that separated the shroud from the fourth stage. The deployment module provided the structural support for the attached reentry vehicles and housed the electronics required to activate and deploy them. The post-boost vehicle maneuvered to designated positions in space where it released the reentry vehicles in sequence on their intended ballistic flight paths.34*

In January 1981, Hercules successfully tested its third-stage motor at the Arnold Engineering Development Center, and the next month Morton Thiokol followed suit at its Utah plant with its 105,000-pound, first-stage prototype engine. By year’s end contractors had successfully tested all four stages, and technicians had subjected the design and fabrication of the missile and its launch canister to an integrated system evaluation. In January 1982, a full-scale, weight-simulated MX shell rose over three hundred feet in the air from its protective canister in the first of five tests of the cold launch system at the Indian Springs, Nevada, test site. Even though flight-testing would not officially begin before mid-1983, following congressional approval of the Scowcroft Commission recommendations, testing of the system elements using wind tunnels, vacuum chambers, ovens, and acceleration devices had convinced managers that the Peacekeeper would perform as expected.35

Meanwhile, by April 1982, contractors at Vandenberg had completed their three-year project to construct fifteen major Peacekeeper flight test facilities. These included a missile assembly building, payload assembly building, integrated test facility, installation and checkout structure, and mechanical maintenance site. Only the discovery of Native American artifacts on Vandenberg’s grounds slowed the construction

* See Appendix V-3.
process, because each discovery meant delays while the location was evaluated to determine whether it should be designated an archeologically sensitive site. During the first six months of 1983, Vandenberg technicians prepared a test pad, measuring 130 feet by 270 feet, and an underground launch support equipment building to support the first Peacekeeper flight.  

Flight-testing began at Vandenberg on 17 June 1983, with the successful cold launch of the first Peacekeeper missile from Test Pad-01 for a 4,190-mile flight to the Kwajalein Missile Range in the Marshall Islands. It delivered six inert test reentry vehicles within the target area. The first phase of the research and development (R&D) flight test program included four more missile launches, each designed to test subsystem performance. All flights used an instrumentation and flight safety system provided by a network of tracking stations that monitored the missile’s performance. The final flight on 15 June 1984 involved the first test of the Mark 21 reentry system. The seven flights in phase two, from October 1984 to May 1986, evaluated operational performance under a variety of ranges and conditions using different payloads. Full Mark 21 integration and silo operations received particular attention. The first eight flight tests used above-ground canisters, while subsequent Peacekeeper test missiles launched from three reconfigured Minuteman silos.

The Ballistic Missile Office originally had planned to conduct twenty R&D flights before deployment of the initial ten operational missiles in December 1986. As it turned out, the first flight was postponed six months, to 17 June 1983, because of congressional concerns about Peacekeeper basing. The delay resulted in completion of fifteen flights by the initial operational capability deadline. Two more test flights occurred before the full Peacekeeper force went on alert in December 1988. All seventeen R&D test flights were successful, giving the Peacekeeper flight program a record unequaled by any other U.S. ICBM.

The Air Force Selects F. E. Warren Air Force Base, Wyoming, for the Peacekeeper’s Home

On 14 June 1983, three days before the first Peacekeeper R&D flight at Vandenberg, Air Force headquarters directed the Ballistic Missile Office to begin full-scale development of the basing mode with Peacekeepers deployed in Minuteman silos at F. E. Warren. The selection of F. E. Warren as the Peacekeeper base came as no surprise. It had been the administration’s choice for both its proposed hardened-silo basing scheme of early 1982 and the closely spaced basing mode later that year. The same selection criteria of geology, cost, environmental impact, and compatibility with future command, control, and communications systems proved applicable in 1983. Assessments also determined that the Peacekeeper force would likely receive the same strong support and acceptance that Cheyenne city leaders and Wyoming residents previously accorded the Atlas and Minuteman contingents.

As a result of its Minuteman mission, F. E. Warren also possessed important support facilities and an organizational infrastructure readily adaptable to Peacekeeper
operations. Most importantly, unlike Grand Forks and Malmstrom, F. E. Warren possessed Minuteman silos eighty-seven feet deep, a depth sufficient to install equipment without significant modifications. Also, in contrast to Malmstrom and Grand Forks, the Wyoming wing’s Minuteman carried the Mark 12 rather than the more capable M12A reentry system. Consequently, removing 90th Strategic Missile Wing Minuteman IIs, with their less powerful reentry vehicles, would minimize the impact on the overall deployed Minuteman force. Finally, Lieutenant General George D. Miller, SAC vice commander-in-chief, explained, “A major factor in the decision to deploy the new Peacekeeper missile near Cheyenne…is that it is farther north than other areas that were considered.”

Even though the Peacekeeper would be deployed on federal sites already occupied by the Minuteman missiles, U.S. law required comprehensive environmental analyses before deployment. Following publication of the initial draft environmental impact statement in October 1983, the Air Force held seven public hearings in different affected locations before issuing the final environmental impact statement in Cheyenne on 31 January 1984. In the area of natural resources, the investigation addressed probable effects of the missile system on water, biological and geological resources, air quality, and visual and noise pollution. In every area, it concluded the Peacekeeper’s impact would be largely benign.

With respect to the impact on the community, the assessment examined long- and short-term consequences for local housing, employment, public finance, and a variety of public services. The study forecasted positive short- and long-term effects on the employment situation in Cheyenne and surrounding areas. Of an estimated 3,000 new jobs, over half would be filled by local residents, with peak immigration of 3,200 people occurring in 1987. F. E. Warren would need an additional 500 workers to support the new ICBM system beginning in 1991. The population increase would boost the housing market and produce higher property values. Despite some variation from area to area, the study concluded that the Peacekeeper’s impact would be moderate, if “locally significant,” in the near term but low and insubstantial in the long term. Schools and other public services were predicted to experience similar results.

In order to help minimize the impact of Peacekeeper deployment on local communities, the Department of Defense signed an agreement on 7 May 1984 that pledged federal support of local and state government officials to ensure contractors fulfilled their commitments to the wider community. Generally, the concerns of local residents and officials proved minimal; the new missile went into a region whose residents had long ago become comfortable with strategic nuclear weapons in their midst.

At the same time, the Air Force needed to acquire land or restrictive easements from civilian landowners in the affected area. To install additional cable for the hardened inter-site communications network, crews needed access to the property of fifty-two landowners. Expansion of the explosive safety zone surrounding the launch facilities proved to be more challenging. The Minuteman’s current safety zone of 1,200 feet for inhabited buildings and 750 feet for public access roads had to be enlarged to 1,750
feet for buildings and 1,050 for access roads to accommodate the heavier Peacekeeper. This meant acquiring restrictive easements at ten launch sites for 117 additional acres, involving three hundred parcels of property. The parcel owners could continue farming or grazing livestock up to the perimeter of the silo, but they could not construct habitable buildings on the designated land. It turned out that seventeen landowners had dwellings on property identified for the explosive safety zones. The Air Force gave the property owners the option of moving the buildings, selling them to the Air Force, or possibly continuing to maintain them under an exception granted by the secretary of the Air Force. By the end of 1985, nine had sold their property to the Air Force, one had submitted a waiver request, and the remaining seven continued negotiations to sell.\textsuperscript{44}

While Air Force lawyers dealt with landowner issues, the service also faced two lawsuits filed in 1984 to block Peacekeeper deployment. One, Western Solidarity v. Reagan, claimed the Peacekeeper project violated aspects of constitutional and international law; the other, Lamm v. Weinberger, found Colorado’s Governor Richard D. Lamm arguing that the final environmental impact statement did not address the impact on Colorado of potential environmental, social, health, and safety consequences. On 20 February 1986, after two years of litigation, a federal district court judge in Lincoln, Nebraska, dismissed the lawsuits, finding that since missile deployment involved major questions of foreign policy and national defense strategy, it was the responsibility of the national government’s executive and legislative branches. The plaintiffs appealed the decision, however, and litigation stretched into the fall of 1991, when the Air Force effectively ended the process by issuing a final supplemental environmental impact statement that December. Meanwhile, Peacekeeper deployment had continued as scheduled.\textsuperscript{45}

Peacekeeper protesters proved equally unable to delay or forestall the missile’s deployment. While the Peacekeeper drew consistent opposition from the nation’s vocal antiwar and anti-nuclear groups, the existence of other strategic nuclear weapon systems, such as various cruise missiles and the Navy’s Trident SLBM, weakened the case against a particular system, like the Peacekeeper. Most demonstrations at F. E. Warren’s main gate or individual missile sites consisted of a handful of people who often only conducted silent prayer vigils. Typical was the anti-nuclear protest that occurred on 20 April 1984, when fourteen people arrived at Juliett-01 launch control facility with crosses and proceeded to pray around the site for the day without violating the twenty-five-foot clear zone. Protest groups became particularly active as the Peacekeeper’s IOC date approached. During a two-week period beginning on 13 August 1986, Western Solidarity, a loose coalition of anti-nuclear activists from eight western states, started a “Nuke Watch” to observe and follow the movement of missile convoys to and from the missile field. On 31 August and 1 September, the group drove from Cheyenne to two launch facilities and made statements to the press before dispersing. One of the largest incidents occurred on 7 June 1987, when 150 protesters congregated at F. E. Warren’s main gate to climax a weekend Faith and Resistance Retreat. Nearly 100 of the demonstrators violated federal property restrictions and were detained.
briefly, prompting authorities to issue letters restricting them from the base for two years. Significantly, only seven of those detained hailed from Wyoming, which corroborated missile opposition groups’ criticism that most Cheyenne residents strongly supported having the Peacekeeper based nearby. Neither anti-missile protests, landowner issues, nor litigation, however, could derail Peacekeeper deployment.46

The Site Activation Task Force Deploys Peacekeeper Missiles in Minuteman Silos

The three-year deployment plan called for the first fifty Peacekeeper ICBMs to replace the fifty Minuteman missiles of the 400th Strategic Missile Squadron, beginning in January 1986, with the next contingent of fifty to replace the Minuteman IIIs of the 319th Strategic Missile Squadron. The initial operational capability date for having the first ten Peacekeepers on alert remained December 1986. On 7 January 1983, well before the Scowcroft Commission recommendations received congressional approval, SAC activated BMO’s Site Activation Task Force (SATAF) under Colonel Warren W. Hickman, who led the joint Air Force, Army Corps of Engineers, and contractor effort at F. E. Warren.47*

After considerable preparation, the physical conversion process to accommodate Peacekeeper began on 30 December 1985 at launch facility Quebec-02, when SAC “depostured” the missile from alert. In this process, the 90th Strategic Missile Wing team removed the reentry system and missile guidance set, while Boeing and Ogden Air Logistics Center technicians helped extract the Minuteman missile stages from the silo and prepared them for shipment to the Ogden facility. Once the missile had been removed, crews disassembled the mechanical and facility hardware, modified some for Peacekeeper use, and returned the remainder to the Minuteman inventory. Strategic Air Command teams worked one unit at a time, leaving each Minuteman site on alert until depostured.48

Modifications to the silo included removing internal protuberances, adding launch tube attachments for the new canister shock isolation system suspension cables, relocating umbilical elements to support the canisterized missile, and removing six feet of tube liner at the top of the silo for maintenance access and debris control inside the launcher. Launch facilities also received new guidance and cooling systems, new 96-volt DC power supplies, AC/DC converters, and lead acid batteries for emergency power. Topside, workers graded more area to support the heavier missile and its installation equipment.49

Unlike the Minuteman missile, which arrived from Ogden with three stages already assembled, the size and weight of the Peacekeeper required the SATAF team to assemble the entire missile, one stage at a time, at the F. E. Warren launch facility. First they installed the 68.2-foot canister by lowering it into the silo with a 90-foot crane. The canister protected the missile from shock, electromagnetic pulse, and corrosion.

* See Appendix V-4.
Next, crews combined the missile air elevator, launch-eject gas generator, and longitudinal support assembly, and used the crane to lower the equipment inside the canister. Each booster section then was roll-transferred in sequence into the emplacer, erected, and placed in the canister. Once the three solid stages had been mated, the air elevator lowered the entire assembly. Crews then installed the missile guidance and control system using the access area in the canister and launch tube liner. Attaching the umbilical and installing a reentry system simulator completed the process.50*

With the missile largely in place, the Sataf team integrated the various systems, mated the missile to its own launch facility, and validated the communications connections between launch facilities and launch control facilities. Crews followed with operational performance demonstrations before initiating “posturing,” the final element in the deployment sequence. This called for SAC and Ogden personnel to remove equipment that had supported assembly and check-out, reconstitute operational elements, add communications security equipment, and install the Mark 21 reentry system and debris collar. When SAC had verified the weapon system's operational and maintenance capabilities, it assumed custody of the site and put it on alert.51†

On 4 April 1986, the first Minuteman launch control center underwent Peacekeeper conversion. The modest facility modifications included a new commercial power filter and electrical surge arrestors, together with computer hardware and software to support Peacekeeper operations. An ultra high-frequency (UHF) transmitter-receiver provided missile control by the Airborne Launch Control System's EC-135 aircraft, the alternative method of launching the missiles. While the conversion process continued at the launch sites and launch control facilities, workers also buried five additional cables for the hardened intersite communications system, and construction crews pressed ahead building support facilities at F. E. Warren. In fact, back in July 1984, SAC and Army engineers had begun the construction or renovation of more than twenty-five major Peacekeeper support facilities at the base, including those for reentry system storage, weapon system assembly, and surveillance and inspection requirements. Despite one- to two-week delays occasioned by heavy rains in August 1985, all projects remained on schedule except the maintenance launch facility trainer, which had been slowed by weather problems and substandard contractor performance.52

The Peacekeeper Becomes Operational

For the 400th Strategic Missile Squadron conversion, SAC planned to complete ten missile sites and achieve initial operational capability in December 1986, finish thirty launch facilities in 1987, and complete the last ten launch facilities by December 1988, the target for full operational capability of the fifty Peacekeeper missile force. For each silo conversion, Boeing planned to allow forty-seven workdays: three for deposturing, three for removing the old Minuteman equipment, twenty-six for necessary struc-

* See Appendix v-5.
† See Appendix v-6
tural changes, and fifteen to install the Peacekeeper system and conduct assembly and check-out procedures. Understandably, the sataf crews needed more time for the first launch facility (LF). Quebec-02, in fact, did not receive its canister until 20 April 1986, 111 days after deposturing commenced and, even in October, had not yet become operational. On the whole, however, Boeing averaged only about 1½ days behind schedule for each site. The sataf team turned over the first increment of four Peacekeepers to sac on 13 September 1986, with the first missile placed on alert on 17 October. Progressing rapidly, technicians had eight more missiles on alert by the end of November, with the final Peacekeeper operational by 20 December, on schedule. As with the Minuteman force, the Peacekeeper squadron would operate with five launch control centers managing fifty missiles round robin, on a sequenced, time-sharing arrangement.53

The impressive achievement of Colonel Hickman's sataf team can best be appreciated by assessing the challenges presented by the transition process itself and especially the intra-squadron command and control issue. Of the 400th Strategic Missile Squadron's five launch control centers (LCCs), crews converted two LCCs to Peacekeeper configuration before bringing any Peacekeeper missiles to alert status. The 400th now operated as two mini-squadrons, with two LCCs monitoring converted Peacekeeper launch facilities and two managing the remaining Minuteman missiles and launch facilities. This alignment permitted the sataf to have the fifth, Boeing-maintained LCC coordinate the transition of normally four missiles at a time from Minuteman to Peacekeeper.54

Problems developed for Air Force and contractor crews when a malfunction periodically shut down one of the launch control facilities. Because only two LCCs monitored the missiles, a failure experienced by one forced the Peacekeeper or Minuteman mini-squadron into single flight operations. In accordance with safety procedures, the crew on duty in the operational LCC had to eliminate, or “dissipate,” their launch and enable codes and immediately “safe” all launch facilities not properly supervised. A second crew then had to bring new launch codes to the site; both crews needed to stay awake, monitor the new codes, and be able to return the LCC with dissipated codes to operational status once the “downed” control center had been repaired. During the conversion process at F. E. Warren, malfunctions shut down LCCs a total of fifty times, on both Peacekeeper and Minuteman sides of the squadron.55

Moreover, all of the control centers and missiles functioned on different codes and time sequences and had to be isolated from one another. Redundancy required every launch facility and launch control facility in a Minuteman and Peacekeeper squadron to be interconnected with a minimum of five other facilities by means of the buried, hardened intersite cable system. Since both missile systems shared the same cable network, their LFS needed to be isolated in order for Minuteman and Peacekeeper elements to communicate only with their own components. During the missile transition move, the timing requirements of the interrogation and response cycle often would be disrupted, producing a “status out” launch facility, and requiring maintenance crews and security teams to respond.56
Another challenge during the transition phase involved putting the missile on alert. When a new missile transitioned to the Peacekeeper side, it took six to eight weeks of maintenance, including attaching the Mark 21/w-87 weapon set, and many tests before the missile could attain alert status. As a result, maintenance continued at many sites simultaneously, creating a tracking "nightmare" for crews able to speak to the maintenance teams only over radio.

The most significant threat to the deployment timetable came from Missile Guidance and Control Set delays and failures. By early 1986 Northrop Aerospace's IMU deliveries averaged four instead of the six per month stipulated in its contract, while unit acceptance tests revealed an unacceptably high failure rate. With the December initial operational capability (IOC) date looming, the Air Force became concerned and, in July, awarded a second source IMU contract to Rockwell's Autonetics Division. Between October and the December IOC date, maintenance crews replaced eight IMUs, seven the result of a faulty third-generation gyro. As the wing historian asserted, "Maintenance personnel spent as much time posturing MGCSs for the new missile as they spent replacing failed ones."

Although the wing had gained a sufficient number of sets to provide critical spare parts in support of the December 1986 IOC, the excessive MGCS failure rate continued into 1987. By April 1987, tardy IMU deliveries and need to stock enough spare guidance sets for the missiles already on alert had resulted in delaying alert status for all seventeen Peacekeepers currently in silos. By this point, Northrop had been sued by two former employees, who charged the company knowingly had manufactured and supplied defective Peacekeeper parts. In May 1987 their suit led to further investigation of alleged misconduct, as concerns over IMU reliability and production precipitated investigations by two subcommittees of the House Armed Services Committee, the FBI, several Air Force agencies, and the U.S. Attorney for the Central District of California. The public scrutiny also brought unwanted criticism about the value of continuing the Peacekeeper deployment.

In July 1987, the Air Force suspended all progress payments to Northrop, because the company had delivered only forty-four of the sixty-three required IMUs. Air Force inspectors also found that the installed systems did not receive routine maintenance and repairs. By the end of the year, SAC had documented sixty-three MGCS failures, fifty-four resulting from IMU deficiencies. Consequently, SAC had only eighteen Peacekeepers on alert. At year's end, however, Northrop and the Air Force had a recovery program in place that centered on improved acquisition quality control. Public criticism gradually subsided.

By the start of 1988, forty-one silos had been depostured, with thirty-two sites converted from Minuteman to Peacekeeper operations. Crews reached another milestone on 4 April when they removed the fiftieth and last 400th Strategic Missile Squadron Minuteman from alert. Although problems with IMUs in the field continued, repaired units started arriving from Rockwell Autonetics, and Peacekeeper deployment remained on schedule. Even a December 1987 explosion at the Morton Thiokol plant
that slowed deliveries of first-stage motors did not seriously affect the road to full operational capability. Neither did the incident at launch facility Quebec-10 in June 1988, when a first-stage bonding skirt supporting the missile in the silo failed, causing the missile to slide eight inches in the canister. Six other missiles needed repair when investigators discovered the same defect. Nevertheless, by December, these problems had been overcome, and the Air Force had on hand a sufficient number MGCSs to support all fifty missiles, including fifteen spares and nine IMU spares undergoing reliability tests. On 30 December 1988, one day ahead of schedule and within cost, SAC declared its fifty-missile Peacekeeper force “alert capable and operationally sustainable.”

The Air Force Adopts Peacekeeper Rail Garrison Mobility

Although Congress had approved basing the first fifty Peacekeepers in Minuteman silos in May 1983, congressional concerns about the missile’s survivability continued. In early 1985, opposition to basing Peacekeeper in Minuteman silos had gained renewed momentum in Congress as a decision neared on deploying the second increment of fifty missiles in F. E. Warren’s 319th Strategic Missile Squadron’s Minuteman silos. In his 4 March 1985 message to Congress, President Reagan attempted to quell the criticism and renew support for the additional missiles requested in the 1985 Department of Defense Authorization Act. The president argued that “Peacekeeper is an essential element of our arms control strategy” to compel an equitable agreement from the Soviets to lower nuclear arsenals. “Should Congress delay or eliminate the Peacekeeper program, it would send an unmistakable signal…that we do not possess the resolve required, nor the continuity of purpose, to maintain a viable strategic triad and the policy of deterrence the triad represents.” To ensure an equitable treaty in forthcoming negotiations, he reasoned that “procurement of one hundred Peacekeeper missiles must continue.” The report also argued that continued Soviet expansion of their nuclear forces increased the military need for the Peacekeeper. It concluded, “Peacekeeper deployment in existing silos is essential to enhance deterrence and to maintain crucial options for restoring the survivability of land-based ICBMs in a cost-effective manner in the years ahead.”

Congress, however, expressed alarm that the interim “quick fix” silo-basing scheme might become permanent and continue to expose the Peacekeeper to Soviet ICBMs, given the latter’s greater accuracy and hard-target kill capabilities. That spring, influential Senator Samuel A. “Sam” Nunn declared, “I am now at the end of the line on the MX as long as it is being deployed in fixed Minuteman silos.” He insisted that the Air Force consider deception and mobility as priorities in basing the second contingent of fifty missiles. Congress agreed and chose, in July 1985, to cancel the second increment “unless a different basing mode is proposed by the President and agreed to by Congress.”

Congressional concerns signaled the need for more basing assessments. That spring the Air Force, led by SAC and BMO, initiated the first in a series of basing studies that would continue over the next eighteen months. By August 1986, the options had
been narrowed to four candidates that had been considered more than once in the long and convoluted MX basing history. The four contenders consisted of super-hard shelters, with or without a deceptive element; mobile encapsulated hardness, referred to as “carry hard”; shallow tunnel, or “hard trench”; and rail garrison, which had been chosen from a number of mobile rail alternatives. Ironically, the Ballistic Missile Office had eliminated rail garrison from consideration the previous year because of what it considered problems associated with nuclear safety, security, and excessive public visibility. On 19 December 1986, three days before the Peacekeeper achieved IOC, President Reagan selected rail garrison as the basing choice for the additional fifty missiles because, he argued, it would make the missiles almost impervious to strategic attack and provide the most flexibility at minimum cost.64

Peacekeeper Rail Garrison basing evoked memories of SAC’s feasibility studies in 1960 with Operation Big Star, the precedent-setting rail version of the Minuteman. Under the new rail-basing concept, each of twenty-five military trains would consist of two missile launch cars with one missile each, two security cars, and one launch control car, pulled by a single locomotive. Each designated SAC “garrison” base would house two to four trains, which would remain on alert, capable of firing from the base, until dispersed into the commercial railroad network. While on the base, the trains would remain in secure, designated garrison areas of approximately 150 acres surrounded by a 1,400-acre clear zone. Each train would be parked inside igloo-appearing shelters that would provide environmental protection, limit explosion damage, and “mask the train’s appearance and configuration.” Out on the rails they would use move-park-move maneuvers, random in distance and direction, to enhance survivability.65

Strategic Air Command chose F.E. Warren as the main operating base for rail garrison in order to take advantage of its current Peacekeeper support facilities in making it responsible for intermediate level maintenance and team training. From ten additional garrison base candidates, SAC chose Barksdale Air Force Base, Louisiana; Dyess Air Force Base, Texas; Fairchild Air Force Base, Washington; Grand Forks Air Force Base, North Dakota; Little Rock Air Force Base, Arkansas; and Wurtsmith Air Force Base, Michigan. Planners expected this geographic dispersion to provide the system a range of options and require the Soviets to use the entire warhead capability of their SS-18 and SS-19 ICBMs to successfully attack the rail garrison trains, if the trains had four hours to deploy. The Air Force planned to begin development in 1987, with initial operational capability scheduled for December 1991.66

Strategic Air Command did not have to change the missile’s hardware significantly, but Boeing, which received the contract, implemented several innovations to the launch and launch-control systems. The launch car housed the missile, canister, and trunnion, supported by a chassis framework secured to two eight-axle rail trucks. During operations, gas-driven activators would erect the missile canister for launch, after which the empty canister would be lowered to allow the train to resume mobility. Planners programmed the system to have the same command, control, and
communications capabilities as the silo-based missiles, and sufficient redundancies at
the base eliminated the requirement for in-garrison, airborne launch control center
backup.⁶⁷*

In 1988, SAC tested the feasibility of the rail garrison concept by conducting three
progressively more complex train exercises, without nuclear weapons on board. The
third, completely under SAC’s control, proved especially useful. The two-day jour-
ney began 22 June on the Burlington Northern Railroad that extended from Grand
Forks to Minneapolis and allowed the thirty Air Force personnel and twenty other
participants to test rail garrison procedures, garrison maneuvering, dispersal opera-
tions, and measures involving alignment of the train with landmarks, or pre-surveyed
benchmarks, for missile launch. Although the exercise tested concept, not equipment,
it made the simple point that train movements took more time than expected, and
that the pre-surveyed benchmark alignment process dominated mission planning and
restricted mobility. The practice run also called for revised tactics and procedures,
because railroad officials in effect compromised deployment security by scheduling
operations well ahead of time to reduce traffic volume.⁶⁸

The successful rail trips helped convince Secretary of Defense Frank Carlucci to au-
thorize the Air Force to proceed with full-scale development in May 1988. Peacekeeper
Rail Garrison experienced a major program change the following April when the
president, responding to congressional reluctance to fund the second increment of fifty
missiles, directed the Air Force to redeploy the 400th Strategic Missile Squadron’s silo-
based missiles to the rail garrison trains. That November, Secretary of the Air Force
Edward C. “Pete” Aldridge, Jr., issued a “record of decision,” justifying the choice of
the six rail garrison bases, confirming the environmental impact statement’s “minimal
impact” conclusion, and corroborating the decision to use the fifty siloed Peacekeeper
missiles. Congress responded by signing the record of decision, thereby giving final
approval for Peacekeeper rail garrison basing. By this point, the system’s IOC date had
slipped to December 1991, with final operational capability scheduled for June 1994.⁶⁹

Despite the program’s design successes and initial production of the missile car, the
canister erector and launch systems, and the proven “rail-worthiness” of the rail cars,
political events overtook rail garrison basing for Peacekeeper. By 1990, support for the
mobile missile system eroded in the wake of tighter military budgets and a weaken-
ing congressional mandate, a crumbling Warsaw Pact and a Soviet Union in disarray,
and progress in arms control. In response, the Air Force completely restructured the
program. By the end of 1990, it had gone from a fully funded to a minimally funded
development program. The restructured program was to conduct a missile launch
from a train, perform mobility tests, and assess a variety of rail operational and secu-
ry procedures.⁷⁰

By the fall of 1991, however, momentum developed to end rail garrison basing for
Peacekeeper entirely. On 26 September the Senate decisively voted to end funding

* See Appendix v-7.
and terminate the program. Two days later Secretary of Defense Richard Cheney described a presidential memorandum directing that it be ended “as soon as possible.” The Air Force immediately began termination procedures with its contractors, a process that would continue for the next two years. Peacekeeper rail garrison basing, like its rail mobile Minuteman predecessor, succumbed not to technical or operational deficiencies but to funding and altered political realities.

The demise of rail garrison for Peacekeeper also ended the Small ICBM development program the Scowcroft Commission had recommended. With this second mobile ICBM program intended to replace the silo-based Peacekeeper eventually, the latter’s production had been linked to Small ICBM developmental milestones. When President Reagan announced his decision in favor of Peacekeeper Rail Garrison on 19 December 1986, he also called for full-scale development of the Small ICBM. Congress endorsed the president’s request on 7 January 1987.

Planners designed the Boeing Small ICBM to be effective against hardened targets and to be small and sufficiently light to be mobile. The three-stage, solid-propellant missile measured fifty-three feet long, forty-six inches in diameter, and weighed only about 37,000 pounds. It used the same inertial measurement unit, reentry system, and warhead carried by the Peacekeeper. Like the larger missile, it adopted the cold launch method. After considering several basing modes, the Air Force selected the hard mobile launcher, consisting of a launcher-trailer pulled by a manned tractor. The system would rely on a main operating base and supporting facilities in the southwestern states.

The Small ICBM experienced even more program uncertainty than did Peacekeeper Rail Garrison. Several times during 1987 both the Air Force chief of staff and SAC leaders recommended cancellation. Growing economic retrenchment brought criticism of two expensive mobile ICBM systems, and Air Force leaders, if forced to choose, favored the rail garrison alternative. Although terminated at one point, the program survived and, by 1990, was in active development. Then, like Peacekeeper Rail Garrison, it, too, entered a period of uncertainty in the wake of rapidly changing international events, budget shortfalls, and the strategic arms reduction talks.

In May 1989, the missile underwent the first of sixteen scheduled test flights that would lead to deployment. Its second, however, on 18 April 1991, would be its last. When the secretary of defense announced the cancellation of Peacekeeper Rail Garrison on 27 September 1991, his memo also provided for removing the Minuteman II force from alert and immediately terminating the hard mobile launcher portion of the Small ICBM program. During his State of the Union speech on 20 January 1992, President George H. W. Bush said the Small ICBM program would be cancelled in its entirety. Two days later, the secretary of the Air Force directed the immediate termination of all contracts, rather than allow them to run their course. Like its mobile counterpart, the Small ICBM had proven worthy technically and operationally, but it could not survive in the new post-Cold War strategic environment.

* See Appendix v-8.
Arms Control Agreements Set the Course for the Peacekeeper

The silo-based Peacekeeper force also found itself directly affected by the new world order and arms control developments. The initial Strategic Arms Reduction Treaty (START I), signed on 31 July 1991, called for a major drawdown in delivery vehicles and warheads between the United States and Russia, together with the former Soviet republics of Ukraine, Belarus, and Kazakhstan. By 4 December 2001, the parties were to have reduced their arsenals to 1,600 delivery vehicles and 6,000 warheads, with 4,900 limited to ICBMs and SLBMs. The treaty, which the signatories ratified on 5 December 1994, also included implementation of a treaty verification inspection process. The treaty more directly affected Peacekeeper with language asserting that the parties could take credit for reducing their MIRVed ICBMs by as many as four warheads.76

In September 1991, when the U.S. secretary of defense had declared that the Minuteman II would be taken off alert and the Peacekeeper Rail Garrison and the mobile portion of the Small ICBM programs cancelled, he also called for the United States and the Soviet Union to agree mutually to eliminate their multiple independently targetable reentry vehicles as early as possible. During his State of the Union address on 20 January 1992, Bush reiterated his desire to see all MIRVed missiles removed from the strategic inventories. That same month he also halted the last annual purchase of twelve Peacekeeper missiles and terminated the production line.77

The second Strategic Arms Reduction Treaty, signed on 3 January 1993, not only set a target of 3,000 to 3,500 warheads for both sides, it directly prohibited the use of MIRVs on all ICBMs. The treaty also identified the Russian SS-18 for elimination and prevented the Peacekeeper, unlike the Minuteman III, from being reconfigured to a single warhead. Although the treaty would never enter into force, both sides fully expected their respective legislatures to ratify it and pledged, at the time, to abide by its terms even though it “has not entered into force.” Indeed, the Air Force expected to begin removing the Peacekeeper in 1994, when OSD started planning its deactivation and the Air Force budgeted necessary funds.78

START II, in effect, gave Peacekeeper its death sentence. Following the treaty’s signing, Peacekeeper would enter a “holding pattern,” funded year-to-year for operations and maintenance support, but without programming for long-term sustainment of the system after 1996. As one official summarized the Peacekeeper dilemma, “We are shutting down, so let’s do what we need to with the least amount of expense to keep operating until that time.” From the time Peacekeeper became operational, it had benefited from SAC’s policy of integrated Minuteman and Peacekeeper logistical support and application of upgrades to both missiles. Most modifications to Peacekeeper in the 1990s occurred primarily in the early part of the decade and were modest. In 1994, for example, Rivet MILE workers removed hazardous lithium batteries, and munitions personnel replaced some reentry vehicle nose tips.79
On the other hand, the nation’s most modern missile continued to operate with command and control technology dating from the 1960s. By the end of the 1990s, for instance, Peacekeeper launch control centers had to be shut down for sixty days to remove and replace program control panels, processor verifier drawers, and other faulty, but necessary, equipment. At one point, lack of funding and anticipated deactivation meant the Peacekeeper missile procedures trainer did not receive the necessary modification to incorporate the Milstar satellite communications system. As a result, crews could not train with this essential equipment, yet they were tested on it at the launch sites. Maintenance crews experienced frequent breakdowns of Peacekeeper transport vehicles, which meant using “extra” vehicles when available, prolonging the time required to finish projects, increasing costs, and reducing the time available for maintenance teams to deal with other problems.  

Although these deficiencies might have seemed minimal, planners realized their potential for constraining operations. Peacekeeper combat crews stood alert in converted Minuteman III launch control centers that had received only modest upgrades. With their aging command and control systems, crews required thirty to forty minutes to retarget sorties using the Command Data Buffer, and they needed considerable time to run tests to verify weapon system status and keep it in prime operating condition. Minuteman crews, on the other hand, benefited from the Rapid Execution and Combat Targeting (react) system upgrade that SAC introduced at F. E. Warren in 1994 and 1995. react, with upgraded communications equipment, and an integrated dual-workstation console promoted speedy decision making. Crew-members operating a state-of-the-art computer system needed only minutes to take action.

While react clearly would have enhanced Peacekeeper operations, the upgrade seems never to have been seriously considered. In the late 1980s, when the 400th Strategic Missile Squadron became operational, the Command Data Buffer targeting system in the converted Minuteman III launch capsules seemed adequate for a missile with ten MIRVed reentry vehicles. Later, after START II had been signed, it made little sense to introduce the expensive react upgrade to a system facing deactivation and, in doing so, raise Russian concerns about America’s intention to comply with START II provisions. Minuteman, however, continued to receive important upgrades to ensure its viability well into the twenty-first century.

The Peacekeeper Combat Crew Experience

For members of F. E. Warren’s 400th Missile Squadron, the challenge became one of keeping the nation’s most capable ICBM operating at maximum efficiency without the benefit of long-term sustainment modifications. By all accounts, Peacekeeper missile deficiencies seem to have had little direct impact at the operational level, and the Peacekeeper assignment consistently attracted outstanding personnel.

The first Peacekeeper missile crews had been handpicked during the deployment period in 1985, a year before the missile’s IOC date. Applying stringent selection standards...
criteria, SAC required prospective Peacekeeper crewmembers to be volunteers, have current ICBM experience, be qualified on the Minuteman III, and possess the highest possible officer effectiveness ratings. Crewmembers from F.E. Warren and Minot began screening the records of potential selectees in late 1984. A Fifteenth Air Force five-officer selection committee then met in the summer of 1985 to choose the initial line crews from among thirty-two candidates. By the end of October 1985, the committee had selected an initial cadre of nine two-person combat missile crews consisting of three captains, ten first lieutenants and five second lieutenants, with a second cadre of eighteen crewmembers joining the force in 1986.83

The first six crew members selected—three commanders and three deputy commanders—received their initial qualification training from Boeing personnel, and together they prepared lesson plans and developed the missile crew trainer. They then trained designated instructor and evaluator crews. By November 1985, F.E. Warren had five instructor and standardization board crews available for duty. The majority of the new Peacekeeper crewmembers came from F.E. Warren, where two to four officers per month transitioned from Minuteman to Peacekeeper. By the time the first ten Peacekeeper ICBMs went on alert in December 1986, initial qualification training had begun at Vandenberg. Once that pipeline started sending officers to F.E. Warren, the 90th Strategic Missile Wing ended its own training program. By 1988 the Peacekeeper force consisted of thirty-six authorized combat crews. Although by the late 1980s SAC no longer handpicked its Peacekeeper crew members, selection criteria remained stringent and Peacekeeper duty continued to attract highly motivated and qualified men and women.84

Minuteman missileers transitioned into the Peacekeeper program with relative ease, since crew duty for both was remarkably similar. In the two missile systems, a two-person crew of commander and deputy commander pulled a 24-hour alert tour in essentially the same launch facility, where they each controlled a flight of ten missiles. During emergencies, however, two Peacekeeper crews, like their Minuteman counterparts, could control all fifty missiles.85

Peacekeeper crew training was also very similar to that for Minuteman crews, despite the different missile systems and support equipment at the launch facilities. In fact, one former Peacekeeper crewmember remembered that instructors at Vandenberg taught emergency war order (EWO) procedures to Minuteman and Peacekeeper students in the same classroom. Following six months of initial qualification training at Vandenberg, Peacekeeper crewmembers also underwent continuous monthly training at their operational bases. The first phase of training involved two days of classroom instruction that focused on regulations for handling cryptographic codes and the crewmember’s ability to receive and properly process and execute EWOs. Each crewmember needed to score at least 90 percent on codes and EWO tests to remain qualified. Periodic training on security responses and weapon system operating procedures also made up the classroom curriculum.86
The second training phase involved practical experience in the missile procedures trainer, where crewmembers practiced simulated routine, emergency, and launch procedures. At the end of this phase came the EWO certification briefing before the wing commander or his representative. During the third phase of instruction, the wing’s standardization and evaluation (stan/eval) teams arrived at alert sites to assess how well crewmembers performed required operational procedures and to conduct no-notice technical inspections. For the combat crew on alert, the long list of inspectable items made the launch control facility’s configuration checks especially demanding. For a deputy crew commander to become a commander, a missileer needed to complete a significant number of alerts and a qualification evaluation before entering upgrade training. The latter required three rides in the missile procedures trainer and an evaluated trainer ride, in addition to prescribed classroom training and the certification briefing.87

Strategic Air Command’s operational training for Peacekeeper combat crews, like that for their Minuteman counterparts, included Nuclear Surety Inspections, Operational Readiness Inspections every eighteen months, and periodic 3901st Strategic Missile Evaluation Squadron assessments of training programs, compliance with technical orders, and squadron maintenance requirements. Operational testing also involved exercises to verify alert readiness, yearly tests of the system’s responsiveness to prelaunch and launch commands, and trips to Vandenberg to evaluate squadron missile launch and flight performance.88

Despite the similarities in crew duty and training, operational procedures differed for Minuteman and Peacekeeper. Calibration for the Minuteman, for example, occurred weekly and monthly, and none of the three different calibrations, which lasted only a couple of hours, took the missile off alert. Peacekeeper, on the other hand, notified crews when it needed calibration, required twenty-four hours to finish the procedures, and remained off alert the entire time. Furthermore, unlike the Minuteman, the Peacekeeper could not be launched while undergoing calibration. The Peacekeeper force also operated with new or modified ground equipment at the launch site, which meant learning new ground maintenance responses; different launch facility code components also meant having to master their particular functions and handling requirements. For missileers moving from Minuteman to Peacekeeper, transition training normally took from four to six weeks.89

The major difference for Peacekeeper crews, however, came with targeting, which was far more complex for Peacekeeper personnel, from planners at the wing level, to squadron EWO officers who validated the requirements, to crewmembers who entered the data and sent it to the missile. Having ten rather than three warheads per missile meant Peacekeeper missileers dealt with considerably more data. The much more capable W-87 warhead also offered an array of fusing options that made targeting and particularly retargeting more exacting.90

Conventional wisdom might suggest that Peacekeeper personnel suffered from low morale brought on by concerns about duty with a weapon system identified for
elimination. On the contrary, morale appears to have been generally high throughout the operational life of the missile. Officers who volunteered for Peacekeeper crew duty during the initial operational period at F. E. Warren realized they had been chosen from among the best missileers in SAC to operate the most capable and lethal ICBM in the arsenal. Later, members of the 400th Missile Squadron and the overall Peacekeeper force continued to take satisfaction from the camaraderie generated by being part of a small, tight-knit community that operated a unique weapon system. Peacekeeper veterans also noted that their squadron schedulers experienced fewer problems scheduling their relatively small contingent compared to the much larger three-squadron Minuteman force. At the same time, the relatively small size of the force helped alleviate inter-squadron issues and improve management of the deputy commander upgrade process. With a dedicated missile procedures trainer, Peacekeeper crews had an easier time scheduling training and evaluation activities than on the “react side.” As for the react upgrade, Peacekeeper crews often preferred their targeting system that demanded more understanding of the system and higher crew coordination. Indeed, as one veteran explained, react did so much thinking for the crewmember that, unfortunately, “students/crewmembers/instructors were able to become complacent in their weapon system knowledge.”

The performance of the Peacekeeper force also suggests high morale and professionalism. The monthly alert rates for the Peacekeeper during the 1990s consistently reflected ready rates well above 95 percent. This figure compared favorably to that for the Minuteman III, despite the high number of hours off alert due to persistent missile guidance and control system failures. Peacekeeper missile and maintenance crews compiled impressive results on codes training tests, and missile combat crews likewise achieved outstanding results for EWO training and yearly qualification evaluations. In the final year of the decade, the 400th Missile Squadron won the coveted General Samuel C. Phillips Award as the operations squadron of the year for 1999. The squadron also led the group in testing, achieving an “outstanding” operations rating, while the performance that year of eight crews during the Nuclear Surety Inspection proved to be the best in the operations group.

By this point, however, the 400th Missile Squadron faced the looming reality of deactivation of its missile, which START I and START II had prescribed early in the decade. The association of Peacekeeper personnel with the arms control agreements occurred primarily with the START I treaty compliance inspections and, for the most part, involved maintenance and weapon specialists.

The treaty inspection regime began for the 90th Space Wing on 17 May 1995 with a two-day baseline inspection. During this first of three types of inspections experienced at F. E. Warren, a team of ten Russian inspectors and nine members of the On-Site Inspection Agency established initial compliance and verified data provided in the memorandum of understanding between the two countries. This involved confirming the number of first-stage boosters, missile emplacers, transporter-erectors,
and inspecting associated facilities. A second type of inspection, referred to as “data
update,” confirmed any changes or updates to the memorandum. F. E. Warren’s first
data update inspection occurred from 22 to 24 October 1996, but its second not for
another five years, on 2 and 3 October 2001.93

The reentry vehicle/on-site inspection represented the third and most frequent
treaty compliance inspection. In this type, teams verified the precise number of
warheads on a missile, ensuring that they did not exceed the number listed in the
memorandum. The inspectors could choose to examine any missile in the force. By
1998, the fourth treaty year, the American and Russian inspectors had performed
eight of these inspections, three on the Minuteman and five on the Peacekeeper. Two
additional inspections of Peacekeeper sites occurred by the end of 2001. While the
team inspected the selected Minuteman III warheads at the particular launch facility,
the much heavier Peacekeeper reentry system had to be removed and transported
to the weapons storage area where the munitions team shrouded parts of the system
before the official viewing.94 The inspections would continue through the three-year
deactivation of the Peacekeeper.

Momentum Builds for Peacekeeper Deactivation
After the start I treaty inspection regime got under way in 1995, Clinton administra-
tion officials intensified their efforts to convince the Senate to approve start II. Ap-
ppearing before the Senate Foreign Relations Committee in March 1995, Secretary of
Defense William J. Perry emphasized the significant role the second arms reduction
treaty played “in our overall effort to prevent the reemergence of a nuclear danger
to the United States … by reducing overall levels of strategic nuclear weapons and by
eliminating the most destabilizing systems.” On 26 January 1996, the Senate ratified
start II by a vote of 87-5, but remained concerned about the slow pace of Russian
treaty deliberations.95

The following year, Congress responded to Russian procrastination with passage of
the “Defend the United States of America Act of 1997,” which prohibited the United
States from reducing its nuclear arsenal unilaterally before start II had entered into
force. Beginning in fiscal year 1998, Congress also inserted a provision into the Na-
tional Defense Appropriation Act that precluded the Defense Department from using
funds to dismantle, retire, or prepare to deactivate the Peacekeeper weapon system.
The Russians, meanwhile, expressed concerns about NATO expansion and American
anti-ballistic missile testing that could require “major revisions” in the treaty.96

At the same time, the Peacekeepers clearly remained on alert, primarily as an
arms control bargaining chip. The two sides already had proposed discussions on
a third start agreement. Protocols signed in New York on 26 September 1997 by
U.S. Secretary of State Madeleine K. Albright and Russian Foreign Minister Yevgeny
Primakov committed the two countries to eliminate their key MIRVed ICBMS, the
Russian SS-18 and SS-24 and the U.S. Peacekeeper during the period 1 January 2003
to 31 December 2007. In his annual report to Congress in 1998, Secretary of Defense
William S. Cohen reiterated that with the ratification of START II, the fifty Peacekeeper ICBMs would be eliminated, and the missiles’ Mark 21 reentry systems would be used on the Minuteman III in order to take advantage of its improved safety features.97

Finally, on 14 April 2000, the Russian Duma ratified START II, but with an addendum requiring operational limits on theater ballistic missile and anti-ballistic missile systems. Although the U.S. Senate refused to accept the addendum, momentum for Peacekeeper deactivation intensified. In June, an amendment to the Senate’s Defense authorization bill permitted cuts below the START I levels, even though START II had yet to become effective. The Senate also authorized funds for Peacekeeper warhead containers and missile stage storage end rings to enable the Air Force to deactivate the weapon system and eliminate the silos.98

Meanwhile, Air Force Space Command headquarters, the 90th Space Wing, and the Environmental Protection Agency updated earlier Peacekeeper deactivation and dismantlement planning. Air Force Space Command had prepared seriously for the Peacekeeper drawdown since early 1997, when it updated a four-phase plan originally formulated in 1994. The plan called for removal of the reentry vehicles, missile guidance systems, and boosters, to begin in 1999, with completion of launch facility destruction and residue cleanup by 2003. With the delay in Russia’s treaty ratification, however, the Peacekeeper elimination plan had remained in limbo, and Air Force Space Command had faced the dilemma of whether to fund minimal sustainment programs such as periodic silo maintenance, warhead alteration, and a modest life extension program to sustain the missile beyond January 2003. At the end of 2000, the Air Force Center for Environmental Excellence issued a final environmental impact statement that outlined a four-phase program to remove the missiles and dismantle related operational and support elements. It also determined that Peacekeeper deactivation and dismantlement would have no significant impact on F.E. Warren Air Force Base and the Cheyenne region. At year’s end, the updated plan called for one missile to be eliminated every three weeks, beginning on 31 December 2003, with the entire process completed in three years.99

The new Bush administration immediately made clear its interest in further reductions in nuclear weapons and its desire to proceed with Peacekeeper deactivation. During the election campaign, candidate George W. Bush expressed his intention to reduce United States nuclear warheads rapidly to the “lowest possible number.” Testifying before the House Armed Services Committee in June and July 2001, Secretary of Defense Donald H. Rumsfeld asserted that the Peacekeeper “is a missile whose time has come and gone,” because senior Air Force leaders had determined that SIOP commitments no longer required this ICBM. The defense secretary also complained that OSD lacked funding after 2003 either to sustain or to eliminate the missile. That fall Congress responded by authorizing funding for Peacekeeper deactivation.100

The most important step in directing deactivation of Peacekeeper was the Nuclear Posture Review that the administration submitted to Congress at the end of Decem-
ber 2001. The previous month President Bush, in a meeting with Russian President Vladimir Putin, had pledged to reduce United States deployed nuclear warheads from 7,000 to between 1,700 and 2,000. The Russian leader responded by declaring a corresponding reduction, from 6,000 to approximately 2,000 warheads. Eliminating the Peacekeeper represented the first step in reducing warheads to the level President Bush promised. Asserting that a nuclear arsenal of 1,700 to 2,200 warheads would meet deterrence requirements, the Nuclear Posture Review identified Peacekeeper elimination as an important first step in achieving this warhead level. Once removed from the missile, the Mark 21 reentry system, with its W-87 warheads, would be reconfigured to replace the older Mark 12/W-62 weapon set for Minuteman III operations.\textsuperscript{101}

The informal agreement between Presidents Bush and Putin set the stage for the Strategic Offensive Reductions Treaty (SORT) that both leaders signed on 24 May 2002. (They exchanged ratified copies on 1 June 2003.) The new treaty also minimized the impact of Russia’s decision to end its START II involvement on 14 June, after the United States refused to ratify the treaty with the Duma’s addendum and its intention to withdraw from the 1972 Anti-ballistic Missile Treaty. In early September 2002, Air Force Chief of Staff General John P. Jumper, citing the reduced strategic threat, the Nuclear Posture Review, SORT, and the views of senior OSD officials, declared, “It is in the best interest of the Department of Defense to retire the Peacekeeper ICBM weapon system.” He directed Air Force Space Command to begin deactivation, effective 1 October 2002. The command’s three-year plan called for deactivating seventeen missiles during each of the first two years and sixteen the third year. All missiles would remain on alert until withdrawn from their silos, while all five launch control centers would retain their nuclear certified status until the final Peacekeeper had been deactivated.\textsuperscript{102}

**The Air Force Deactivates the Peacekeeper**

During deactivation, crews at most sites needed approximately seventeen days and fifty vehicles to remove the 195,000-pound missile and associated equipment. They spent the first nine days extracting the guidance equipment, the four missile stages, launch ejection system, and then erecting the handling equipment to remove the warheads. Work during the remaining eight days involved removing critical components, including ordnance and hazardous fluids. Munitions crews then worked for another ten days at the weapons storage area, to remove, disassemble, inspect, and pack the warheads for shipment to Department of Energy facilities in increments of five. Personnel at the missile processing center also needed ten working days to prepare the missile for shipment to the Ogden Air Logistics Center.\textsuperscript{103}

By the beginning of 2004, 90th Space Wing personnel had removed twenty-three Peacekeepers, with twenty-seven still on alert. By October 2005, they had completed the project, with the final Peacekeeper deactivated on the fourth of that month. In December 2004, workers had dismantled the first two launch control centers, remov-
ing communications equipment, classified material, and shutting down environmental systems. The wing maintained the remaining three control centers on alert until 8 September 2005, when Papa-03, the last Peacekeeper launch facility, was decertified. The formal end to nineteen years of Peacekeeper operations came on 19 September 2005, when F. E. Warren hosted a ceremony to commemorate both the deactivation of the missile and inactivation of the 400th Missile Squadron.104

During the three-year deactivation process, Vandenberg’s 392nd Training Squadron graduated the last Peacekeeper class. On 18 October 2004, General Lance W. Lord, commander of Air Force Space Command, officiated at the graduation of the final six Peacekeeper officers, all second lieutenants. Two months later these officers and other missileers from the 90th Space Wing began retraining at Vandenberg for Minuteman III crew duty. By all accounts, Peacekeeper crew morale remained high; it even increased during the deactivation process. Many in the crew force considered it special to be part of a select group that operated a weapon system that had proven pivotal in ending the Cold War and contributing to a more nuclear-free world. As a former Vandenberg Peacekeeper instructor recalled, “It was significant to see that many of the young Lts [lieutenants] we trained during that time were excited about their opportunity to serve in the Peacekeeper force...even though they knew it would only be a few alerts...before being retrained to react [Minuteman III].”105

Deactivation planning also embraced future uses for Peacekeeper equipment and facilities. In June 2005, Colonel Evan Hoapili, 90th Space Wing commander, declared, “Almost every piece of this system, from the nose cone to the nozzles, including the warhead, is going to get reused/recycled in some way.” For example, in December 2006, the Air Force contracted with Lockheed Martin Space Systems to provide the Safety Enhanced Reentry Vehicle (SERV) modifications needed to replace the Minuteman’s Mark 12 reentry system with the Peacekeeper’s Mark 21. The Air Force expected to upgrade the Minuteman force with at least two hundred of the W-87 warheads, with the remainder placed in reserve. The Air Force elected to retain the Peacekeeper’s launch and missile alert facilities in a 30 percent caretaker status to support potential national missile defense mission requirements or the next land-based ICBM program.106

Peacekeeper components also would be used as space launch vehicles and as targets. Orbital Suborbital Corporation, for example, used three decommissioned Peacekeeper solid stages together with a commercial Star-48v motor fourth stage and various subsystems in its Minotaur IV space launch vehicle. Developed under contract to the Air Force’s Space and Missile Systems Center, the ten-year program experienced its first successful orbital flight on 25 September 2010, when it launched a Space-Based Space Surveillance satellite into a 500-mile, sun-synchronous orbit, where it began detecting debris, spacecraft, and other objects, unaffected by weather or atmospheric interference, as part of the Air Force Space Surveillance Network.107

During the thirty-minute ceremony at F. E. Warren on 19 September 2005 that
marked the close of the Peacekeeper era, Undersecretary of the Air Force Dr. Ronald M. Sega highlighted the missile system’s major contribution to deterrence. “The Peacekeeper,” he said, “was a great stabilizing force in an increasingly unstable world. As the 400th Missile Squadron brought its full complement of Peacekeepers online in 1988, another aspect of the system’s success came to light... [Soviet missiles] weren’t as good as Peacekeeper.” Following the formal ceremony, attendees and others gathered to observe a parade of Peacekeeper vehicles dating back to the missile’s initial deployment. That evening, prominent dignitaries joined General Lance Lord, Air Force Space Command commander, at a special Peacekeeper deactivation dinner at F. E. Warren’s Trail’s End club. General Lord’s closing remarks were titled, appropriately, “One Team—Mission Complete.”108
Chapter VI
The Once and Future Minuteman III, 1991–2011

In the twenty years following the end of the Cold War, Air Force planners repeatedly assessed the capability of the aging Minuteman III intercontinental ballistic missile (ICBM) to remain viable as the nation’s current and future land-based strategic missile. The issue became increasingly important, as the deactivation of the Peacekeeper ICBM in 2005 left Minuteman III as the sole weapon system supporting the land-based ICBM leg of the strategic Triad. Two loosely defined schools of thought on the Minuteman III’s future emerged within the ICBM community. One could be termed the “sustain forever” grouping, represented from late 1997 by TRW and Northrop Grumman, as the prime integration contractor for the Minuteman, and by Air Force “blue suit” missile maintainers, who favored incremental upgrades to extend continually the service life of the missile. The other, the “follow-on” weapon system faction, consisted of key independent contractors and much of the Air Force acquisition community. They preferred to develop a new, more sophisticated replacement ICBM. Proponents of either an upgraded Minuteman or its successor had to contend with a diminishing industrial base, while fending off critics who argued that in the post-Cold War environment the ICBM no longer played a vital role in the nation’s strategic defense posture.

Indeed, in the decade following the end of the Cold War, defense officials focused on reducing the nation’s nuclear arsenal through strategic arms agreements while formulating strategic policy that focused on the challenges of regional conflict and unconventional warfare. With nuclear deterrence becoming less central to American security strategy, the Air Force chose to reduce, reorganize, and decentralize its
nuclear “enterprise” (mission responsibilities). The result proved to be an erosion of nuclear-related expertise, along with fragmented authority and responsibility. After the 11 September 2001 terrorist attacks on the United States, when the Air Force supported two expensive conventional conflicts and the so-called Global War on Terror, focus on and funding for the nuclear mission declined even further.

Against this backdrop of fiscal constraint, arms control priorities, and post-Cold War strategic policy imperatives, Air Force leaders confronted the future role of the nation’s strategic bomber and missile deterrent. Regarding the land-based ICBM force, their assessment continued to center on whether to make incremental improvements to the Minuteman III—first to the year 2020, then 2030, even 2040 and beyond—or to initiate development of an entirely new and considerably more capable ICBM.

Arms Control Agreements Compel Minuteman Force Structure Changes in the 1990s

The first Strategic Arms Reduction Treaty (START I) that American President George H.W. Bush and Soviet President Mikhail Gorbachev signed on 31 July 1991 led to major restructuring of the Minuteman force over the course of the 1990s.

The reshaping of the Minuteman deterrent began with deactivation of the Minuteman II. To help meet the treaty’s requirement for a 35 percent cut in ballistic missile warheads, President Bush decided to eliminate the entire 450 Minuteman II contingent. In January 1990, Secretary of Defense Richard Cheney had anticipated a signed treaty by declaring that the Minuteman II would be deactivated beginning in 1992. On 27 September 1991, two months after the signing of START I, President Bush confirmed the Minuteman II’s fate, directing immediate removal of the missiles from alert. Over the next three days, the Ellsworth, Malmstrom, and Whiteman missile wings took the 150 Minuteman IIs that each possessed off alert. With its aging components, high operational and maintenance costs, and uncertain operational reliability, the Minuteman II system had become a prime arms reduction target.¹*

The Air Force, in fact, had been planning the retirement of the missile since Defense Secretary Cheney’s announcement in early 1990, and in April 1991 the service issued a program directive that called for deactivation of the missile at all three bases and inactivation of the missile units at Ellsworth and Whiteman. The three-year deactivation process began at Ellsworth in October 1991, with Whiteman following in October 1992. Personnel began by removing each launch control center’s launch and enable codes, as well as launch keys and essential documents. Crews then used a safety control switch to “safe” each missile before other Air Force personnel removed the reentry vehicle and the guidance and control sets, followed by the missile boosters and any visible hazardous material. Contractors also checked for remaining hazardous items and ensured that all assets had been withdrawn before imploding the launch facility. At each missile alert facility, Air Force maintenance personnel welded

* See pp. 131–134.
the blast doors shut and contractor crews then filled up the elevator shafts. On 15 December 1997, the Air Force destroyed Whiteman's Hotel-11 silo, located approximately ninety miles southwest of the base near Dederick, Missouri. This proved to be the last remaining Minuteman II silo, and its implosion represented the closing event in the history of the Minuteman II.  

Malmstrom, meanwhile, had been selected to have its Minuteman II silos converted to accommodate Minuteman III missiles. Beginning in October 1992, Ogden Air Logistics Center at Hill Air Force Base, Utah, began shipping the thirty Minuteman IIIA-M weapon system missiles from storage to Malmstrom to join the 564th Missile Squadron's fifty Minuteman IIIB contingent. The conversion process proceeded rapidly, as technicians needed only to adjust the missile's umbilical cable and suspension system and load appropriate Minuteman III software at the launch facility and missile alert facility. By the end of 1993, twenty-six of the twenty-eight silos that had received Minuteman IIIs stood alert. Crews completed installing the initial thirty-missile increment early the next year, but the fate of the remaining silos awaited the decision of the Base Realignment and Closure (BRAC) Commission, established in 1995.  

The previous year, the Clinton administration had issued its 1994 Nuclear Posture Review, which reaffirmed the requirement to maintain the strategic Triad, consisting of sixty-six B-52 and twenty B-2 bombers, fourteen Trident II submarines, and, for the ICBM leg of the Triad, 450-500 single-warhead Minuteman IIIs deployed at three missile wings. Given the decision to maintain three rather than four wings of Minuteman IIIs, the BRAC commissioners needed to identify one missile group or wing for inactivation from among those at Malmstrom, F. E. Warren, Minot, and Grand Forks. If it chose a missile wing or group other than Malmstrom's for elimination, Air Force Space Command (AFSPC), having assumed responsibility for the missile force in July 1993, planned to move 120 missiles from the closed wing or group to Malmstrom.  

After several rounds of meetings and assessments, the commission supported the Air Force position and recommended that the 321st Missile Group at Grand Forks be inactivated and 120 missiles of its Minuteman III force be transferred to Malmstrom's 341st Missile Wing, with the remaining 50 sent back to the Ogden depot. When compared to the other three missile bases, the commission determined that the Grand Forks missile field ranked lowest because of its high water table, which reduced survivability and required more on-site depot support, as well as excessive on-site support costs per silo based on sustainment of the smaller number of B system silos, and a missile alert rate “consistently lower” than Minot's. Efforts by the Grand Forks community to have F. E. Warren or Malmstrom chosen instead proved futile. The Air Force argued that F. E. Warren and Malmstrom should not be eliminated because of their existing Peacekeeper and Minuteman III squadrons, respectively, and the Office of the Secretary of Defense (OSD) concurred. OSD also declared that removing the Grand Forks missiles would not require destroying the existing anti-ballistic missile (ABM) facilities or losing the privilege of retaining an ABM deployment capability in the Grand Forks area. 
Congress agreed with the BRAC decision, and the transfer process got under way. Yet, while crews removed the 341st Missile Wing’s last Minuteman II on 10 August 1995, it would be another three years before the Malmstrom conversion would be completed. Meanwhile, the 341st Missile Wing would carry on, with personnel from its 10th Strategic Missile Squadron and 490th Strategic Missile Squadron performing mock alerts at the non-operational missile alert facilities, while occasionally standing alert at 12th Strategic Missile Squadron sites to maintain emergency war order (EWO) certification. By the spring of 1998, the Minuteman missile force consisted of 500 Minuteman III ICBMS, with 200 deployed to Malmstrom and 150 each to F. E. Warren and Minot.

The arms control treaties also precipitated the reduction of warheads from three to one on each Minuteman III (the Minuteman III Single Reentry Vehicle, or SRV program). The initial START agreement called for the U.S. to reduce its strategic warhead inventory to six thousand by December 2001, without specifying the particular strategic weapon systems. As an incentive to have both sides eliminate all MIRVED ICBMS, President Bush, in January 1992, presented a comprehensive proposal of arms cuts that not only identified the Peacekeeper for elimination but also offered to reduce the number of Minuteman III warheads from three to one. The president’s initiative set the stage for START II, signed on 3 January 1993, which called for both sides to eliminate all multiple independently targeted reentry vehicles by 2003 and specifically required Minuteman III ICBMS to be downgraded from three warheads to one. Were the two sides able to reach a separate agreement by which the United States would help defray the cost of the Russian drawdown, all 500 Minuteman IIIs would be converted to the single reentry vehicle configuration by 31 December 2000. Without an agreement, the target date remained January 2003.

The 1994 Nuclear Posture Review confirmed the de-mirving of the Minuteman III force. According to the original plan, each of the three Minuteman III wings would convert fifty missiles each year, beginning at F. E. Warren in late 1994, when the new single-vehicle platform would be available for installation. Although initially the SRV program supported only the Mark 12 and Mark 12A warheads, Martin Marietta, which received the contract to produce the new bulkhead, agreed to configure the platform in order to attach the more capable Mark 21 warhead. In order to use the Mark 21/w-87 weapon set, however, the Air Force had to finish the planned upgrade to the Minuteman III’s guidance system, not scheduled for completion until 1997.

Although the conversion program for F. E. Warren’s 150 Minuteman IIIs had been scheduled to begin in late 1994, contractors did not have the platforms ready for installation until the fall of 1998. F. E. Warren’s 90th Logistics Group decided to begin with launch facility Alpha-07, which had been functioning only as an exercise training module with its warheads already removed to the weapon storage area. Shortly thereafter, conversion commenced at Golf-08, the first Minuteman III operational site. In order to keep the missile on alert, maintenance crews began by dispatching a

* See Appendix VI-1.
single reentry vehicle spare to Golf-08 to replace the one scheduled for removal. After installing the single RV, crews transported the removed RV to the base weapon storage area, where the munitions team detached the warheads from the MIRV payload bulkhead assembly, replacing it with the new single vehicle platform. Maintenance teams then transported the new reentry system to the next site, while weapons crews proceeded to destroy the MIRV bulkhead. The procedure took nearly a week for each conversion, and the F.E. Warren SRV program remained on schedule and the missile force on alert. In fact, when maintenance crews completed the last Minuteman III conversion at launch facility Charlie-08 on 6 August 2001, they were seventeen weeks ahead of the START I deadline.9

By the time the F.E. Warren conversion began in late 1998, planners had determined that, with START II still awaiting ratification, the Minuteman IIIs of only one of the three wings needed to be downloaded to one warhead each in order for the U.S. to meet its START I target date. Consequently, the Joint Staff directed Air Force Space Command to convert the Minuteman IIIs of F.E. Warren but not those of Minot and Malmstrom. With the removal of two warheads from each of F.E. Warren’s 150 Minuteman missiles, the Minuteman III force at the end of 2001 deployed a total of 1,200 warheads. The Bush administration, however, had signaled its intention to convert the remaining Minuteman IIIs to single reentry vehicle missiles in the near future.10

U.S. Leaders Decide to Extend the Service Life of the Minuteman III

With provisions of the START agreements forecasting the deactivation of the Peacekeeper, the aging Minuteman III would be the sole land-based ICBM remaining in the strategic Triad. In 1992 a memorandum from Secretary of Defense Cheney directed the Air Force to “upgrade and extend Minuteman III service life.” Given the post-Cold War context of weapon reductions, budget constraints, and strategic policy changes, it seemed better to upgrade this relatively low-cost system than to propose a new, expensive land-based strategic deterrent successor. Indeed, the deployment and operation of the ICBM leg of the Triad traditionally represented only 11 percent of the strategic nuclear budget. From the early 1990s, therefore, the Air Force focus for its ICBM mission became how best to ensure the viability of the Minuteman III well into the new century.11

The 1994 Nuclear Posture Review specifically endorsed two upgrade efforts already approved and underway. One, the Rivet Minuteman III Life Extension (MILE) maintenance program had completed, by 1993, two cycles of depot maintenance and modification of operational ground equipment involving five hundred Minuteman IIIs and the associated fifty launch control centers. That October, the Ogden Air Logistics Center introduced Rivet MILE 2010, which established a smaller workforce of twenty to twenty-four personnel at each wing to provide the necessary recurring depot presence and ensure the completion of scheduled modifications to the year 2010.12

A second modification in progress was the Rapid Execution and Combat Targeting (REACT) command and control system, which had been underway since the late
1980s.* With this system, crews would receive better training and be able to retarget the Minuteman III twice as fast compared to the Command Data Buffer system it replaced. Software anomalies had delayed deployment to 1994, but even then crews operating the new equipment soon reported having problems with receipt of correct alarm and display data for outer-zone security status changes. On 6 January 1995, Air Force Space Command ordered deployment suspended until the command had in place a credible test and evaluation program and Loral Systems, the prime contractor, could provide revised software. A very unhappy General Joseph W. Ashy, AFSPC commander, declared, “It’s hard for me to believe that we field a system like this.” By July, however, both conditions had been met and deployment resumed; by August 1996 all missile wings had received their modification except the 321st at Grand Forks, North Dakota, which had been scheduled for deactivation.13†

Air Force leaders realized the Minuteman III system needed more than Rivet MILE maintenance and REACT to remain operational beyond the year 2010. In 1993, they initiated a series of “life extension” modernization programs to replace both the missile guidance electronics and the solid-propellant motors for all three stages. These improvements promised to help extend the missile’s service life to the year 2020.14

The Guidance Replacement Program (GRP) was a two-phase effort to avoid the downward trend in flight reliability and parts degradation that the Minuteman II had experienced in the late 1980s. As outlined in a February 1993 mission needs statement, phase one involved replacing the aging three-decades-old electronics of the NS-20 guidance set. The Air Force expected the new NS-50 guidance system to be more efficient, reliable, and easier to maintain. The second phase called for replacing the inertial measurement unit (IMU) with one capable of achieving the accuracy of the Peacekeeper missile. Progress on the first phase proved slow and contentious. An initial contract dispute and multiple budget cuts produced schedule slippages, which compelled planners to revise delivery dates for the NS-50 guidance sets and extend the initial operational capability (IOC) date from November 1997 to the spring of 2000. The second-phase IMU upgrade remained unfunded.15

The Minuteman III Propulsion Replacement Program (PRP) also experienced funding problems and schedule delays. It was to replace the propellant and liner system in all three solid stages before they exceeded their seventeen-year service life span in 2002 for the first and second stages and in 2004 for the third stage. Already in the early 1990s missile inspections revealed propellant hardening and cracking, motor case insulation debonding, and internal liner degradation. All three stages would be repoured simultaneously so that technicians could minimize logistical costs by removing and transporting the missile only once. The propulsion initiative also permitted the Air Force to replace substances now prohibited by the Environmental Protection Agency with more acceptable materials.16

* See pp. 132-133.
† See Appendix vi-2.
The PRP also proceeded in two phases. In the first “technology insertion” phase, manufacturers intended to validate the remanufacturing process, replace the restricted materials, incorporate updated technology, and start producing motors at the deliberate rate of one per month. Once they had authenticated the process, the program would enter its second phase, which involved full production of eight motors a month, beginning in 2000. Developmental funding cuts and schedule “restructuring,” however, threatened to delay initial production contracts by six months and extend program completion from 2008 to 2016.17

By the end of 1997, slow progress with the guidance and propulsion replacement programs helped convince the Air Force to establish a more focused and centralized approach to long-term Minuteman modernization. In September 1995, the Air Force had closed the Ballistic Missile Office and moved the ICBM System Program Office (SPO) from Norton in California to the 526th ICBM Systems Wing at Hill in Utah. At Hill, the ICBM SPO became responsible for managing over 150 software and hardware missile contracts, along with sustaining engineering support. Over the next two years, Air Force acquisition officials examined other methods of managing Minuteman acquisition and sustainment programs that would reduce the burgeoning costs and manpower requirements. By 1997, Air Force officials had decided to appoint a single prime integrator to manage the entire Minuteman III life modernization program. That December, following an open competition, Ogden Air Logistics Center awarded a fifteen-year ICBM prime integration contract to TRW, whose technical and engineering support for the Air Force ICBM program dated from the early days of the Western Development Division. Working closely with the ICBM SPO, TRW would implement a systems approach in leading a team of first- and second-tier subcontractors in place of the group of associate contractors that previously had reported individually to the SPO. TRW would head the effort until in December 2002, when Northrop Grumman acquired TRW and assumed responsibility for the Minuteman III fifteen-year prime integration contract.18

The Air Force Implements Minuteman III Flight System Modifications
Shortly after TRW received the weapon system integration contract, it acquired management responsibility for the Guidance Replacement Program and the Propulsion Replacement Program, the two major flight system modifications already underway. Later, it would oversee two additional upgrades, the Propulsion System Rocket Engine and the Safety Enhanced Reentry Vehicle programs, as well as a number of ground system modifications. Designed to extend the Minuteman’s operational life span to 2020, the fifteen-year Air Force modernization program amounted to an upgrade of the missile, from nose tip to exhaust nozzle, that it planned to complete by 2012.19

Guidance Replacement Program (GRP)
In March 1998, Hill’s 526th ICBM Systems Wing awarded TRW, with its contract partner Boeing, a low-rate initial production contract for forty NS-50 guidance units, with
delivery to begin in 1999, with final operational capability scheduled for early 2008. In January 2000, five months after Malmstrom Air Force Base took delivery of the first unit and installed the ns-50 at launch facility India-09, the TRW team received a full-rate production contract to manufacture a total of 652 units, with 500 to be installed on the Minuteman III fleet and the remaining 152 to serve as spares or be used for flight tests. The program achieved initial operational capability at Malmstrom on 20 July 2000, having met the criteria of no less than 720 alert operational hours for each of ten guidance sets and four support sets.20*

Malmstrom’s 341st Space Wing became the first to complete the upgrade when launch facility Charlie-10 received its ns-50 missile guidance set on 4 December 2007, with Minot’s 91st Space Wing following, on 18 January 2008. When technicians installed the last of the F. E. Warren sets on 25 February 2008, Twentieth Air Force announced that the modification had been completed and the fleet had achieved full operational capability. Initial tests of production units, however, revealed a number of accuracy problems. Although Boeing had corrected them by 2003, the ns-50 guidance system, despite initial intentions, did not achieve accuracy equal to that of Peacekeeper.21

**Propulsion Replacement Program (PRP)**

A year after TRW received the guidance set replacement contract, the Air Force awarded its propulsion team a low-rate initial production contract for sixty upgraded boosters, consisting of all three stages. When TRW delivered its first refurbished booster to Malmstrom on 15 April 2001, the 341st became the first wing to receive the PRP missile stages, as well as the new missile guidance sets. In October 2001, after tests determined that the new booster met mission requirements, the Air Force sanctioned the first of eight yearly full-production-rate contract options that called for deploying six to seven boosters per month for a total of 607 sets. Soon thereafter, problems developed with the subcontractor, Pratt and Whitney, when twelve second-stage motors and nine third-stage motors at its San Jose, California, motor remanufacturing facility were found to contain small lead pellets from a cracked mallet. The facility then experienced explosions in August and September 2003 that further demonstrated “a lack of adherence to procedures and a lack of commitment to producing quality products.”22

Although the 2003 explosions destroyed the facility for upgrading the third-stage booster, Alliant Techsystems, Inc., which replaced Pratt and Whitney, built a new plant and production resumed in 2005 after a nine-month delay. By July 2006, the new Bacchus facility in Magna, Utah, had remanufactured its hundredth third-stage booster, and the program was back on budget and on schedule. By November 2006 the Hill Air Force Base depot had sent the three missile wings 185 PRP-modified Minuteman III missiles. Two years later the number had risen to 424, with 134 shipped to Malmstrom.

* See Appendix VI-3.
148 to Minot, and 142 to F. E. Warren. In 2009 the wings received their remaining upgraded missiles, and the Air Force declared full operational capability.\textsuperscript{23}

**Propulsion System Rocket Engine (PSRE) Life Extension Program (LEP)**

Two additional Minuteman III flight system modification programs neared completion at the close of this history. One, the Propulsion System Rocket Engine LEP, involved upgrading the single-axial, liquid-propellant, fourth-stage engine that operated during the post-boost phase to maneuver the reentry system correctly and guide the reentry vehicles to their targets once separated from the third stage. The modification called for replacing seven components in a system whose oldest unit in 2000 had been operational nearly thirty-five years, well beyond its programmed ten-year service life.\textsuperscript{24}\textsuperscript{*}

In February 2000, TRW received the initial contract that would ultimately call for the delivery of 589 refurbishment kits to the three missile wings. A successful test flight of a PSRE LEP-equipped Minuteman III in 2000, followed by a number of engine test firings, convinced Ogden Air Logistics Center to authorize low-rate initial production in 2004. The Air Force received the first two modified PSRES from Northrop Grumman in February 2005, and that June deployed the first PSRE-configured Minuteman III to F. E. Warren's launch site Juliet-06. PSRE-equipped missiles attained initial operational capability in November 2006, and by April 2007 eighty stood alert. Funding reductions, high labor costs, and quality control problems at Hill that allowed thirty-nine upgraded PSRES to be deployed in 2008 with faulty P106A actuators threatened to delay the 2012 completion date. By the spring of 2009, however, 220 launch facilities had been upgraded, with delivery of the last of the 589 refurbishment kits scheduled for July 2012.\textsuperscript{25}

**Safety Enhanced Reentry Vehicle (SERV) Program**

The Safety Enhanced Reentry Vehicle Program also remained unfinished in 2011. This program involved installing on the Minuteman III Mark 21/w-87 warhead sets that had been downloaded from deactivated Peacekeeper missiles. Policy and management coordination issues made this flight system modification especially challenging for the TRW/Northrop Grumman consortium.\textsuperscript{†}

Although the large Peacekeeper warhead inventory became available with deactivation of the missile, from 2002 to 2005, interest in converting the Minuteman III’s Mark 12 and Mark 12A reentry systems to the Mark 21 had emerged at the end of the Cold War. In 1990, a three-person panel chaired by Lawrence Livermore National Laboratory’s Dr. Sydney D. Drell provided the House Armed Services Committee a report on nuclear warhead safety that recommended all nuclear weapons be configured with Enhanced Nuclear Detonation Safety systems, insensitive high explosives,

\textsuperscript{*} See Appendix VI-4.

\textsuperscript{†} See Appendix VI-5.
The Once and Future Minuteman III

warhead plutonium encased in fire resistant pits, and propellant that helped prevent dispersal if explosions were to occur. The Drell scientists determined that the Mark 21 reentry vehicle met their criteria, but proposed that the Minuteman III fleet field both the Mark 12A and the Mark 21 reentry vehicles to prevent problems with a single reentry vehicle grounding the whole Minuteman III force. In July 1994, after both the House and Senate armed services committees endorsed the Drell Report's criteria, Air Force Chief of Staff General Merrill A. McPeak approved a mission needs statement that called for the SERV/warhead (SERV/W) to be configured for the Minuteman III. Subsequent analyses confirmed that, although the Mark 12A reentry system would also be fielded, the Mark 21 provided better system accuracy and reentry dispersion, more fuzing options, and improved safety features.26

The program, however, made little progress in the later half of the 1990s. The new requirement to retrofit the guidance replacement sets with Mark 21 software, along with electrical and mechanical interfaces, resulted in higher costs and schedule delays. So, too, did the requirement to provide Minot and Malmstrom the Mark 21 support equipment that F. E. Warren already had available for the Peacekeeper. Furthermore, the Air Force plan to use Peacekeeper warheads depended on the missile's projected deactivation schedule, which remained uncertain without ratification of START II.27

Only in 2004, with Peacekeeper deactivation underway, did the Ogden Air Logistics Center award low-rate production contracts for the initial ninety-nine SERV kits. Test flights from Vandenberg in the summer of 2005 and February 2006 validated hardware and software integration and accuracy using inert warheads. The successful test flights convinced the 526th ICBM Systems Wing, in March 2006, to award Northrop Grumman and its principal teammates, Lockheed Martin and Boeing, the six-year, full-rate production contract to modify the entire Minuteman fleet to carry the Mark 21. It was important to begin deployment of Mark 21-configured Minuteman IIIs by October 2006 in order to achieve full deployment by the time the Department of Energy planned to decertify the older Mark 12 reentry vehicle used by F. E. Warren's and Malmstrom's Minuteman III fleet. The effort also had to be coordinated with the Propulsion Rocket Engine Life Extension upgrade, because the latter required modification kits to permit installation of Mark 21 as well as MIRV-capable Mark 12A reentry systems.28

The SERV conversion began in October 2006 at Warren, with Malmstrom to follow in July 2007 and Minot in July 2008. Air Force leaders had indicated their intention to have a portion of the Minuteman force deploy with more than one warhead. As Twentieth Air Force Commander Major General Thomas Deppe stated in an April 2007 speech, the missiles could be configured with one, two, or three warheads. Three years later, however, the 2010 Nuclear Posture Review, in developing positions for the New START Treaty negotiations, declared that “all U.S. ICBMs will be ‘de-mirved’ to a single warhead each,” in order to “enhance the stability of the nuclear balance by reducing incentives for either side to strike first.” Yet, because the support payload
bulkhead could remain and continue to support the Mark 21 and the Mark 12a, the United States retained its MIRV option should the international security environment change. While only 313 Minuteman had received the SERV upgrade by May of 2011, the Air Force still expected to complete the program in 2012.29

The Minuteman III Receives Ground System Modifications
In addition to the four major flight system modifications, Northrop Grumman directed five ground system life extension programs that the ICBM community also expected to help keep the Minuteman operational to at least 2020. Unlike the flight system programs, not all of the ground system upgrades were scheduled for completion by 2012.

**REACT Service Life Extension Program (SLEP)**
The REACT Service Life Extension Program involved an upgrade to the REACT consoles that had been installed in the Minuteman III launch control centers between 1994 and 1996. In June 2002, the Air Force contracted TRW to undertake this program, which focused on fixing software problems and increasing memory capacity of the Embedded Memory Array Dynamic unit from four to sixteen megabytes so that it could handle the updated software used to incorporate the Safety Enhanced Reentry Vehicle program targeting and fuzing changes. Additionally, in the Head Disk Assembly, flat panel displays would replace cathode ray tube displays and flash random access memory would supersede the electro-mechanical drive, while Console Operations Program software would integrate all elements and allow more rapid retargeting capability. The Air Force completed the four-year deployment effort at all fifty Minuteman III launch control centers, as well as nineteen training units, in August 2006.30*

**Environmental Control System (ECS) Service Life Extension Program (SLEP)**
The ECS program called for installing a modern air conditioning system with digital controls in the launch control centers and launch facilities, as well as the missile alert facilities and trainer sites. The new system would replace outdated air compressors, brine chillers, and pneumatic controls. The upgrade also included a remote monitoring and diagnostic capability to increase maintenance manpower efficiency. The successful testing of a prototype at Hill Air Force Base in the first part of 2005 convinced the Ogden Air Logistics Center to award Northrop Grumman, with its key subcontractor Boeing, a five-year, full-rate production contract in the summer of 2006.31

Malmstrom received the first production unit in October 2006 and, following initial training, wing maintenance personnel installed it that December. By the next December, however, failures attributed to ECS power filters at ten launch sites and

* See Appendix VI-2.
one missile alert facility posed potential fire hazards, which compelled the 526th ICBM Systems Wing to suspend the installation process. Although installation resumed in March 2008, with a newly designed control panel, another suspension occurred in late May when an investigation of a fire concluded that a faulty battery charger in F. E. Warren's launch facility A-06 launcher equipment room produced hydrogen gas that the newly installed ECS did not adequately ventilate from the equipment room. The potential for an explosive atmosphere in other launch facilities compelled the 526th to introduce a comprehensive air quality improvement program to prevent repetition of the incident. When an investigation determined that the missile alert facility ECS configuration was not an issue, the ECS upgrade resumed in early January 2009 at all three missile wings’ missile alert facilities. With the suspensions, the contract officials extended the full operational capability date from September 2011 to the middle of 2012.32

**Minuteman Minimum Essential Emergency Communications Network (MEECN) Program (MMP)**

The MMP represented one element in the overall MEECN program. It involved replacing the legacy Survivable Low Frequency Communications System in the launch control facilities with a more survivable, reliable, and integrated extremely high frequency (EHF) and very low frequency/low frequency (VLF/LF) communications capability. The upgrade would enable crewmembers to receive emergency action messages from the president and secretary of defense over a more efficient network, one better protected against nuclear detonations and jamming.33*

Air Force Space Command had initiated the modernization with a mission needs statement in January 1996. Engineering and prototype development began in 1999, and by early 2002 initial operational testing and evaluation of the VLF/LF and EHF MMP segments had been completed. That June the Air Force awarded the production contract to TRW, with initial operational capability scheduled for March 2004, followed by final deployment and full operational capability by December 2005.34

The Air Force selected Malmstrom’s 341st Space Wing as the first unit to receive the upgrades. In the first part of a two-phase deployment at the missile alert facility, contractors installed an EHF antenna in a 40,000-pound, above ground, reinforced steel shelter on top of a 60,000-pound concrete pedestal. In the second phase, they put in cables linking the VLF antenna to the launch control centers and set up the new EHF and VLF/LF communications equipment in the capsules. Crews completed phase one at Malmstrom’s twenty missile alert facilities in October 2003, and installed phase two communications equipment by December 2004. F. E. Warren’s 90th Space Wing completed the two-stage upgrade on November 2004 and June 2005, respectively; the upgrade team finished Minot’s above-ground antenna installation in June 2005 and the last phase-two modification, at the Oscar-01 facility, on 11 November 2005.

* See Appendix VI-6.
On Alert

With completion of the Minot communications upgrade, the Minuteman Program achieved full operational capability at the three wings on schedule and on budget.35

ICBM Security Modernization Program
Following tests conducted in 2002 and 2003, Air Force Space Command implemented a security modernization program. The three-part initiative consisted of the fast-rising b-plug, the launch facility concrete headworks enhancement, and the remote visual assessment system.*

The fast-rising, secondary, launch site door, or turbo b-plug, would prevent or delay access to intruders through the maintenance portal during maintenance activity. In effect, the b-plug was a piston-type steel security door activated by an electro-mechanical actuator. Unlike the existing system, which could move the plug only 9 inches per minute, the b-plug would rise 100 inches in just fifteen seconds, and within thirty seconds reach a maximum of 145 inches while automatically extending twelve bolts to preclude unauthorized access. Planners designed the system for activation, and rapid reuse, by the local on site maintenance team without significant impact on their maintenance activities.36

Northrop Grumman received a low-rate initial production contract in May 2005 to design, develop, and produce sixty-six fast-rising b-plugs. In 2006 Hill Air Force Base’s 526th ICBM Systems Wing successfully tested a prototype and assessed resources and procedures required to operate the system. Late that year contractors installed b-plug trainers at all three wings, and planned for the first operational fast-rising plug to be operational at Minot Air Force Base in the spring of 2007. Despite a delay due to funding shortfalls, the contractor team subsequently was able to meet the scheduled IOC deployment target of early 2008 but had to extend the full operational capability date. As of December 2010, ninety-four had been completed at Minot, eighty-seven at Malmstrom, and seventy-eight at F. E. Warren, with projected completion rescheduled from 2011 to December 2013.37

A second security enhancement to hinder unauthorized access was the launch site concrete headworks upgrade. This involved installing a steel-reinforced concrete apron nine feet wide and two feet deep outward from the launch facility’s personnel access hatch. The schedule called for the work to begin at Minot in 2004, with all 500 Minuteman III launch facilities to receive the upgrade by the end of 2008. By this point, however, Malmstrom’s 564th Missile Squadron faced inactivation, and headworks installation work ceased after eighteen of the squadron’s fifty launch sites had been upgraded. This meant that a total of 468 launch facilities would receive the concrete headworks modification. The program moved forward rapidly, with contractors completing the upgrade at Minot in the summer of 2007, at F. E. Warren by November 2006, and at Malmstrom in June 2007. On 15 November 2007, Air Force Space

* See Appendix VI-7.
Command announced the program had achieved full operational capability, eighteen months ahead of schedule.\textsuperscript{38}

The third in the trio of Minuteman III security modifications consisted of a pole-mounted, single, closed circuit television surveillance camera situated outside each launch facility. The camera, which had a fixed and pan-tilt-zoom capability, would be linked to the “parent” missile alert facility’s flight security controller and the missile base’s security control center. While the F. E. Warren and Minot systems used commercial satellite feed, Malmstrom relied on terrestrial microwave equipment. In order to save satellite time and money and to receive a better quality picture, the F. E. Warren and Minot sites were being retrofitted for the terrestrial option. Planners expected the all-weather system to provide near-real-time streaming video to operations personnel and to alarm response teams that could remotely access the area and react accordingly, thereby reducing the number of times security teams had to respond to false alarms.\textsuperscript{39}

Minot Air Force Base was the location for a thirteen-site engineering model demonstration of the system in March 2005. Ogden Air Logistics Center planned to have F. E. Warren’s 90th Space Wing use the first fifty units to develop the operational concept for the entire Minuteman III fleet. The Northrop Grumman contract, with subcontractor SuperTel Network, called for a total of 458 units, with IOC scheduled for December 2007 and the system fully operational in 2010. Cost overruns with the concrete headworks upgrade, however, led to work stoppages on the remote visual assessment project. The shutdown compelled Ogden to extend the completion date to 2013.\textsuperscript{40}

**ICBM Cryptology Upgrade**

This upgrade responded to a National Security Agency mandate to replace the aging KI-22 cryptographic device. The latter ensured authentication and encrypted transmission of all message traffic between the launch control centers and the launch control facilities through the hardened inter-site cable system. The newly designed KS-60 replacement equipment possessed important enhancements, such as the future capability of permitting rapid emergency code changes in a matter of hours rather than days. The KS-60, installed in the Wing Codes Processing System, provided digital encryption of the data used to conduct annual code changes provided by the National Security Agency. It also offered the significant future capability to change remotely codes unique to each site, which promised to eliminate the need to open up each launch facility and manually change codes in the field.\textsuperscript{41}

In March 2004, Northrop Grumman received the system design and demonstration contract, and by year’s end had completed successful interface upload demonstrations and harness testing, determined hardware requirements, and conducted preliminary design reviews. Production of 650 KS-60s began in mid-2007, with phase one IOC scheduled for the summer of 2008 and final operational capability planned for the spring of 2010. The first increment of the two-part upgrade called for install-
ing the ks-60 units in each of the three missile wing launch control centers. Although Minot’s 91st Missile Wing had been scheduled to receive the first delivery in the spring of 2008, contractor problems in production delayed deployment until 2009. Even so, by that summer the entire Minuteman III force had received the ks-60 cryptology device.42

The second element involved integrating the ks-60’s capabilities into the Minuteman communications network to enable missile crews to key in codes remotely. Northrop Grumman began work on this element in late 2009 and expected to have the upgrade completed by 2015, as required by the National Security Agency. When finished, the second increment would improve physical security by eliminating an estimated 1,800 hours of “penetration” or open site time per year and improving force security and nuclear safety.43

The Bush Administration Assesses the Minuteman III

With the majority of the flight system and ground system upgrades and replacements to be completed by 2012, Air Force leaders fully expected the Minuteman III to remain operational until at least 2020. This left open the question of what land-based ICBM deterrent the nation required after that date. Should the Air Force continue with incremental upgrades to the Minuteman III, or should it develop an entirely new, improved ICBM to replace the Minuteman? In 2001, the Bush administration initiated a major assessment of the Minuteman III’s future role in the U.S. nuclear arsenal.

In the congressionally mandated 2001 Nuclear Posture Review, the Defense Department addressed the new post-Cold War, post 9/11 security environment and the role of U.S. strategic nuclear forces in it. Threats now came less from Russia than from other state and non-state players with interests in ballistic missile delivery systems and weapons of mass destruction. The difficulty of predicting the new threats compelled the Defense Department to move from a threat-based to a capabilities-based approach to response planning. With Russia no longer a major threat, it argued, the United States needed to “move away from mutual assured destruction” and no longer rely on an extensive array of offensive nuclear forces for strategic deterrence.44

As part of adapting to the altered threat environment described in the Nuclear Posture Review, the Defense Department developed a “New Triad” of strategic forces to replace the Cold War Triad of bombers, SLBMs, and ICBMs. The three legs of the new Triad consisted of 1) defenses, both active and passive, including a ballistic missile defense system; 2) a responsive infrastructure, with a focus on enhancing the country’s nuclear infrastructure and technology base and eliminating non-essential weapons; and 3) nuclear and non-nuclear strike capabilities, which included the three elements of the Cold War Triad together with conventional strike options. The New Triad would integrate the three legs by means of command and control, intelligence, and flexible planning that would enable the United States to provide
“rapid and reliable employment of strike and defense forces, to manage crises, deter attacks, and [execute] military operations.”\textsuperscript{45}

The Nuclear Posture Review validated the continued requirement for an ICBM force as a strategic deterrent and called on the Defense Department to develop a replacement for the Minuteman III. The subsequent Defense Planning Guidance for Fiscal Years 2002–2007 directed the Air Force to “pursue concepts for missile systems to begin replacing the Minuteman III…by 2020.” Air Force Chief of Staff General John P. Jumper responded in early 2002 by issuing a requirement for a land-based long-range missile force capable of providing strategic deterrence through the year 2040, as well as addressing “new and emerging threat environments that are marked with uncertainty.” General Jumper identified two alternatives for the future system. One involved another Minuteman III service life extension program that would begin before 2020, while the other would be to develop a completely new, more sophisticated missile that would use existing components and technology, as much as possible, to keep costs down. At the same time, planners fully expected that a more efficient and reliable follow-on ICBM would significantly lower costs by requiring fewer maintenance and security personnel to support the system. A new ICBM also offered the prospect of improved range, greater accuracy, and rapid response to “strategic ‘relocatable’ and emerging targets,” referred to as Prompt Global Strike capability.\textsuperscript{46}

An Air Force request, in September 2003, for industry to suggest delivery vehicle and security concepts resulted in thirty separate proposals for the delivery vehicles, six for command, control, communications, and computers, and five for security and force protection measures. These became the basis for an analysis of land-based strategic deterrent alternatives led by Hill’s ICBM Systems Program Office. The study also embraced the launch control center, transportation requirements from operating base to launch sites, and the question of fixed-site basing in Minuteman III silos or some type of mobile system.\textsuperscript{47}

The study team spent all of 2004 and most of 2005 critically examining and testing various concepts that, potentially, could meet land-based strategic deterrent mission requirements. By the fall of 2005, it had completed the two-year study and the Air Staff approved it in November. Issued in early 2006, the study recommended a three-stage booster with enhanced propulsion technologies, an upgraded guidance system using GPS [Global Positioning System], and a “trajectory-shaping reentry vehicle.” The alternative command and control system would use high-speed fiber and wireless technologies, while the security alternative consisted of elements the Air Force would implement in its fifteen-year ICBM security modernization program. As for deployment, silo basing represented the only practical and affordable option. The study asserted that the recommended capabilities and alternatives could be realized through an affordable, incremental approach instead of pursuing an entirely new weapon system.\textsuperscript{48}

\textsuperscript{*} See Appendix VI-8.
General Kevin P. Chilton, commander of Air Force Space Command, agreed that the incremental approach was the “preferred course [of action]” given the difficult challenge of acquiring funding for a new ICBM during a “global war on terror” and a country focused on two major conventional wars. Air Force headquarters concurred. The initial plan called for installation of incremental upgrades to begin about 2018, with full operating capability scheduled for the late 2020s. The improved Minuteman III would be capable of operating to the year 2040.49

The Air Force Inactivates the 564th Missile Squadron

Meanwhile, OSD and the Air Force took action by means of the Quadrennial Defense Review (QDR) to help ensure the Minuteman III could remain operationally capable until at least 2020. In the 2005 version of the congressionally-mandated review, the size of the Minuteman fleet became an issue during deliberations on force structure and arms control strategies. By the fall of 2005 it became known that the QDR panel recommendations included reducing the size of the fleet and possibly using some of the Minuteman IIIs in a conventional role. At this point, the Senate ICBM coalition swung into action. Led by Senator Conrad R. Burns of Montana, the coalition of senators from states with ICBM wings sent a joint letter to Secretary of Defense Donald H. Rumsfeld on 21 September urging that he make no reductions, whatsoever. Retaining the full force of 500 Minuteman IIIs with single nuclear reentry vehicles, the senators argued, was vital in the post-9/11 environment because of expanding Russian and Chinese nuclear programs. They also opposed using ICBMs with conventional warheads because this, they said, would “unduly weaken nuclear deterrence.” The senators proved unable, however, to forestall a reduction in force structure.50

While visiting Malmstrom in January 2006, General Chilton announced that the forthcoming QDR would call for a reduction from 500 to 450 Minuteman IIIs, and the 50 missiles to be eliminated would be those of Malmstrom’s 564th Missile Squadron, the former Squadron 20. When issued by the secretary of defense on 6 February 2006, the final 2005 QDR confirmed the reduction, asserting that it reflected the “New Triad priorities developed during the 2001 Nuclear Posture Review.” The deactivated missiles also would help ensure that the Minuteman III force could remain operational until 2020. Indeed, an Air Force Space Command analysis had concluded that Propulsion System Rocket Engines and Propellant Replacement Program boosters would not be depleted until 2024 and 2023, respectively, long after the year 2020 sustainment objective.51*

The congressional delegates from ICBM states refused to give up, however, and in 2006 and 2007 helped pass several measures opposing the reduction. Most significant proved to be the fiscal year 2007 National Defense Appropriations Act, which required the Air Force to provide Congress a detailed report justifying the ICBM deactivation. It also directed the Air Force to “modernize Minuteman III intercontinental

* See Appendix VI-9.
ballistic missiles in the United States inventory as required to maintain a sufficient supply of launch test assets and spares to sustain the deployed force of such missiles through 2030.” Although Air Force leaders had asserted that incremental upgrades, as prescribed in the analysis of land-based strategic deterrent alternatives, could extend the Minuteman’s life span to 2040, the congressionally mandated target year of 2030 became the new standard.52

On 16 March 2007, the Air Force submitted the required report, arguing that inactivating the 564th Missile Squadron would not diminish U.S. deterrent capabilities in light of the changed strategic threat following the end of the Cold War. The report also noted that the deactivated missiles would provide sufficient components and spare parts to enable the Air Force to extend the Minuteman III’s service life to 2030, as directed by Congress, and still leave enough boosters for operational test launches. Lastly, the report described the significant cost savings expected from inactivation of the 564th Missile Squadron.53

Although Congress remained concerned about the capability of the industrial base to support future Minuteman modernization, the Air Force received permission to proceed with deactivation of what had been termed the “odd squad.” Unlike the nine Minuteman III WS 133A-M squadrons, which deployed Boeing-manufactured communications systems, the 564th possessed the General Electric WS-133B system. The Boeing command and control systems relied on a redundant matrix of hardened, underground cables interconnecting the launch sites and launch control centers. The General Electric configuration, on the other hand, used a single-strand network of hardened, buried cables with a medium-frequency radio to provide command and control and system monitoring. The two communications systems also required their own unique training programs for maintenance personnel and launch crews as well as a separate logistics supply chain.54*

In May 2007, Air Force Space Command issued a four-phase plan for deactivating the weapon system and inactivating the squadron. Phase one called for deactivation and decertification of the launch control centers and launch facilities, beginning in June 2007 and ending in July 2008. The five launch control centers would not start drawing down until the last missile had been deactivated and the launch facilities decertified. Inactivation of the 564th Missile Squadron would follow and be completed no later than 30 September 2009. Phase two, also scheduled for completion by the end of September 2009, involved selecting and removing equipment that could be used by other missile units. The third phase focused on deactivating support amenities at the unit facilities, while the last phase dealt with dismantling and disposing of the sites.55

The 341st Missile Wing began deactivation of the first site, launch facility Sierra-38, near Brady, Montana, on 12 July 2007. Over the course of the next year, wing personnel proved able to eliminate a missile a week, with the fiftieth Minuteman removed

* See Appendix VI-10.
On Alert

from launch facility Tango-41 on 28 July 2008, on schedule. The 341st Civil Engineer Squadron then assumed responsibility for the launch sites and control centers, which had been placed in 30 percent caretaker status. In a moving inactivation ceremony at Malmstrom on 15 August 2008, Twentieth Air Force Commander Major General Roger W. Burg presented the Air Force Outstanding Unit Award to the the 564th Missile Squadron. 56

Although Air Force leaders believed the deactivated missiles from the 564th Missile Squadron would extend the Minuteman III’s operational life to 2030, a major concern centered on the ability of the ICBM industrial base to sustain continued Minuteman III modifications, let alone support design, development, and production of an entirely new missile. Led by the Senate missile coalition, the Senate Committee on Appropriations expressed its concerns. Its report on the 2008 Department of Defense Appropriations Bill directed the Air Force to “conduct a study on the capability of the defense industrial base to maintain, modernize, and sustain the Minuteman III system until 2030, and on the industrial base’s capability to replace the Minuteman III with a follow-on land-based strategic deterrent after 2030.” 57

When the Air Force submitted its “Report on ICBM Industrial Base Capabilities” in October 2008, it cited two reports from 2006 that already had prompted congressional and OSD concerns. One, a study by OSD’s ICBM Long-Range Requirements Planning Steering Group, predicted “a decline in development, production, and sustainment skills as current life extension efforts conclude.” In its argument, the study cited an expected loss of significant portions of the skilled workforce and the likely departure of companies from the ICBM industry between the close of the programmed modernization process underway and production of a new system. 58

The “Report of the Defense Science Board Task Force on Future Strategic Strike Skills” was more alarming. Issued in March 2006, it asserted that “the strategic strike area most at risk today is ballistic missiles.” The report also noted that the move of the ICBM System Program Office from Norton to Hill in the early 1990s “resulted in the decimation of what had been a strong and unique acquisition staff,” and that few Air Force personnel in the present ICBM program had experience in system or subsystem design. The Air Force would face a major decline in design capability in the next five years and, with the sustainment program, within the next ten years. Unanticipated failures needing analysis, testing, and redesign might prove too challenging for “current skills” because application programs to maintain skills had been too few in number and significantly underfunded. Equally disturbing, a large section of experienced military, civilian, and contractor personnel were approaching retirement. 59

The Air Force report clearly recognized the problems with the ICBM industrial base described in the two 2006 reports it referenced. It also affirmed that sustainment funding alone would not preserve the industrial base in the absence of Minuteman modernization or follow-on ICBM programs. To bridge the gap between the end of the current Minuteman III modernization programs and the resumption of upgrades or development of a new missile, the Air Force proposed increased funding for its
ICBM Demonstration/Validation Program. Cooperating closely with the Navy, the Air Force would center its effort on guidance, propulsion, and reentry vehicle applications. Specifically, maintaining a low-rate, solid-rocket motor, life-extension production line would establish the basis to sustain essential manufacturing and facility, as well as material and supplier capabilities. At present, however, current and planned funding could neither extend the operational life of the Minuteman III from 2020 to 2030 nor maintain the industrial base needed to design and develop a successor.60

General C. Robert Kehler, commander of Air Force Space Command, succinctly described the challenges surrounding the Minuteman III in a meeting with defense reporters in the spring of 2008. “I believe we can extend…[the Minuteman III]…to 2030…[but unknown is]…how much more investment will be required,” he remarked. Even if the Air Force extended the Minuteman’s life another ten years, he said, it was time to consider a replacement given the lead-time required. Indeed, Air Force Space Command called for defining “requirements for transitioning from the current Minuteman system and begin[ning] development of requirements for the next generation nuclear strike capability” in 2010. Further decisions on the future of the land-based strategic deterrent, however, would have to await the new Obama administration’s attention.61

The Obama Administration Addresses the Minuteman III’s Future

When President Barack Obama’s security team initiated a review of the nuclear force structure in early 2009, the Minuteman III’s fifteen-year modernization program to extend its life to 2020 had largely been completed. The immediate issues involving the ICBM leg of the nuclear Triad centered on action needed to keep the Minuteman operational to the congressionally-mandated year of 2030, address the need for a replacement after that date, and ensure the survival of the ballistic missile industrial base throughout future improvement efforts. The administration’s deliberations on national defense embraced the three key assessment venues of the Quadrennial Defense Review, the Nuclear Posture Review (NPR), and the New START Treaty. Of the three, the NPR and New START Treaty would have the most direct impact on strategic force structure and the ultimate fate of the Minuteman III.62

In the spring of 2009 the Senate ICBM coalition became aware of an analysis being conducted by administration officials in preparation for the next year’s Nuclear Posture Review. The discussions focused on how best to maintain stable deterrence at lower nuclear force levels while meeting proposed arms control objectives. The senators worried that the ICBM force might incur further reductions, and in response that November, the coalition issued a white paper on the “criticality” of the ICBM to the nation’s security. Affirming the continued requirement for the strategic Triad, the report argued, “ICBMs are the most stabilizing part of the triad.” Their wide dispersal, it stated, presented an assured second-strike capability, while ensuring the survivability of the bomber and submarine legs of the Triad and providing extended deterrence to allies. Additionally, ICBMS were the most cost effective deterrent, with the Minuteman III
costing less than a third that of a Trident II or strategic bomber. Moreover, whereas the nuclear capable bombers and submarines required substantial ongoing investments, the ICBMs needed only evolutionary improvements to reach the 2030 service life target. Our ICBM force, the study concluded, would remain the most stabilizing element of the U.S. nuclear posture by retaining the full 450 missiles and converting each missile to a single warhead ICBM. The senators also saw no inconsistency in maintaining a 450-missile force while negotiating a New START Treaty “that codifies the gains we have made and hope to make in reducing our reliance on nuclear weapons.”

In the 2010 Nuclear Posture Review that appeared on 6 April 2010, the Obama administration reasserted the importance of maintaining the Triad of heavy bombers, SLBMs, and ICBMs in order to deter potential enemies, protect allies and partners abroad, and further global stability. The three legs of the Triad, however, would be sustained at reduced nuclear force levels in order to meet requirements of the New START Treaty. Although the NPR did not recommend a specific number of ICBMs for elimination, other administration sources suggested reducing the Minuteman III force from 450 missiles to 420. Because all deployed ICBMs were to be de-mirved, the Minuteman III would have only one warhead, to “enhance the stability of the nuclear balance by reducing the incentives for either side to strike first.” Citing the ICBM advantages of high readiness, secure command and control, and low operational costs, the NPR confirmed that the Defense Department would continue the modernization program to ensure that the strategic missile fleet remained operational to the mandated target date of 2030.

Two days after issuing the 2010 Nuclear Posture Review, the United States and Russia signed the New START Treaty. By January 2011, both sides had ratified the document, and the treaty entered into force on 5 February 2011. The new treaty was to remain in effect for ten years and allow the parties seven years to meet the reduced force numbers that it required. Each side agreed to reduce its inventory of deployed warheads from the Strategic Offensive Reductions Treaty figure of 2,200 to 1,550, and retain no more that seven hundred deployed nuclear weapons-capable heavy bombers, SLBMs, and ICBMs. In terms of force structure, when the administration submitted the treaty to the Senate on 13 May 2010, it included a plan that asserted that the United States would remove at least 30 missile silos and retain a force of up to 420 Minuteman III launchers.

The new treaty also made it easier to retain empty missile silos. Under the original START, silos without missiles that had not been destroyed counted as deployed missiles with the appropriate number of warheads attributed to that missile. Having retained the deactivated Peacekeeper missile silos in caretaker status meant that they counted as operational missile launch sites with each, in effect, deploying eight declared warheads. Under New START, neither side had to destroy its silos. Each party now could develop “other procedures” to eliminate the silo simply by disabling the launch facility to prevent it from launching a missile. Accordingly, the United States could eliminate the fifty deactivated, non-deployed Peacekeeper silos, the fifty deacti-
vated, non-deployed Minuteman III silos of the 564th Missile Squadron, and Vandenberg’s three non-deployed silo launchers without destroying them, and thereby remove them from the total launchers counted under the New START treaty.66

In addition to establishing positions in conjunction with the New START treaty, the Nuclear Posture Review also directed the Defense Department to address the issue of a replacement for the Minuteman III after 2030. Declaring that a decision on a new ICBM need not be made for several years, the NPR nevertheless charged the Defense Department to initiate assessments of alternatives in fiscal years 2011 and 2012. The study was to examine a variety of options for developing a cost-effective “way forward” for a follow-on ICBM that would meet the administration’s objective of stable deterrence at lower force levels.67

Accordingly, in January 2011, Air Force Global Strike Command began studies on a capabilities-based assessment of a future ground-based strategic deterrent. Focusing on developing a requirements baseline for such features as the system’s desired speed, payload, and range, command analysts completed the initial study in July and forwarded it to Air Force headquarters. Between 2012 and 2014, the Air Force planned to conduct an analysis that would recommend the best option for a follow-on ICBM. As with earlier land-based strategic deterrent assessments, however, the choice would be between developing an entirely new ICBM or continuing with another incremental upgrade program. The latter might be the best option, as it had been four years earlier, should fiscal constraints or changes in strategic policy preclude investing in an entirely new weapon system. In either case, the challenge would be to sustain the industrial ICBM workforce and the design, development, and production elements necessary to achieve either alternative as well as to extend the life of the Minuteman III to 2030.68

The Minuteman III Combat Crew Experience in the New Century

The debate on the Minuteman’s future in the first decade of the twenty-first century did not directly affect Minuteman crewmembers. On the surface, their duties had changed little over the previous forty years of Minuteman operations. Crews maintained their busy schedule of standing alert, undergoing emergency war orders training, taking part in missile procedures trainer rides, and participating in local and higher headquarters inspections. By this point women had been fully integrated into the missile force; unlike their pioneer predecessors, they did not encounter problems or receive special consideration or scrutiny related to gender. For all missileers, working with nuclear weapons continued to demand a standard of perfection that could not be compromised.69

On the other hand, the post-9/11 security environment compelled missileers to do more with less in a number of areas. One of these involved the 72-hour “alert transformation” experiment. The advent of Rivet Save in 1977 had enabled SAC to eliminate six hundred missile personnel by replacing a fluctuating 24- to 72-hour alert schedule with a stable 24-hour period for a two-person crew. With a modification in place that prevented an unauthorized launch by a single crew officer, one crewmember could...
sleep while on duty. The 24-hour alert policy remained in effect until 2006, when the new strategic environment convinced Twentieth Air Force to implement a 72-hour schedule for three-person crews.\footnote{See pp. 78–80.}

Faced with the financial constraints produced by the “global war on terror,” the ongoing modernization program to upgrade the aging Minuteman III, and growing personnel costs, Air Force leaders turned to “force shaping,” or manpower reduction, as the major means of offsetting increasing weapon system costs. As a result, in fiscal year 2006 nearly 40,000 personnel Air Force-wide, including 487 “surplus” officers in the space and missile operations (138) career field, lost their positions. Air Force headquarters offered a number of incentives to transfer to “undermanned” service specialties or, more likely, to separate from the Air Force.\footnote{See pp. 78–80.}

The manpower reductions and budget constraints convinced General Deppe, Twentieth Air Force commander, to introduce the 72-hour alert construct. It would, he expected, “improve operations, reduce manpower, save money, and limit the mileage missile crews travelled.” The general’s concept also promoted the objective of a missile alert facility “cohesive unit,” whereby the concept of crew integrity would be expanded to include the enlisted personnel assigned to duty topside. On 1 October 2006, Twentieth Air Force began a three-month test of the program involving one squadron from each of the three missile wings. Malmstrom’s 341st Missile Wing selected the 490th “Far-Siders” as its test squadron, because its crews had to travel farther to their missile alert facilities than any other Twentieth Air Force crewmembers. During the test period, the impact of force-shaping reductions became clear when Malmstrom had to supplement the “Far-Siders” with additional experienced crew commanders from the wing staff to enable the squadron to cover its alert responsibilities. Because wing and squadron leaders also worried about crewmember fatigue, they provided crewmembers a “Counter-Fatigue Guide,” which included an Air Force Research Laboratory recommendation that crewmembers be given two to three days of rest between 72-hour cycles.\footnote{See pp. 78–80.}

Senior leaders at the Twentieth Air Force and wing levels remained optimistic during the test period, and considered the experiment sufficiently successful to extend “alert transformation” to all wing squadrons in February 2007 except Malmstrom’s 564th Missile Squadron. A variety of studies soon revealed serious shortcomings with the 72-hour alert policy. While the two person 24-hour alert schedule called for 90 officers on alert every day, the three person 72-hour alert program required 135 daily with another 135 on “protected time off.” Personal reliability program issues, health problems, and unscheduled leave contributed to an alert scheduler’s nightmare, with back-to-back alerts becoming more prevalent as shortages increasingly compelled wings to violate the time-off promise.\footnote{See pp. 78–80.}

Assigning additional wing personnel did not make up the shortfall, and problems with crew commander Manning proved especially challenging. The new crew
concept established three levels of experience (l1, l2, l3) for each three-person crew. The l3 crew commander usually had two to three years of experience, the l2 deputy crew commander averaged eight to fourteen months on crew, while an officer who had recently completed initial missile training filled the newly created position of l1 junior deputy commander. During alert operations, most crew commanders found it necessary to spend their entire three days in the capsule, while the two less experienced deputies rotated “off duty” upstairs in the alert facility. As one veteran of the “72s” explained, “We were gone two weeks a month and coming in on every day we weren’t on alert for training, testing, etc.” Drained mentally and physically from the 72-hourrotations, crewmembers never had enough “off-duty time” between alerts to recover completely.74

General Deppe also had attempted to reduce the crewmembers’ workload by providing internet (Netlink) capability to the capsules without raising information security concerns. Adopting the plan of Master Sergeant Doug Angel, 91st Maintenance Group technical engineer, the cpu was installed topside in the Missile Alert Facility and linked by cable to a screen and keyboard in the capsule below. Although Netlink enabled crewmembers to access internet college course material and communicate with family members, its main purpose was to enable crewmembers to complete required training during their duty period in the capsule. Most officers, however, did not take advantage of this option, complaining that they were too busy to undertake training while on alert. Even though Netlink did not realize its original objective, it was one element of the “72s” that endured beyond 2011. Crews continued to rely on capsule internet connectivity every day for administrative and training requirements, and wing operations groups made it a priority to keep Netlink fully operational.75

Attempts to address personnel shortages by having missile alert facility off-duty time count as time off proved unsuccessful, and schedulers found that the addition of a third crewmember made it nearly impossible to maintain integral crew rates essential for developing crew cohesiveness. The need for more crew commanders led to upgrading the junior crewmembers to deputy crew commanders in only twelve to eighteen months rather than the long-established eighteen to twenty months. This increased the already high level of fatigue, while crew commanders often became too exhausted to spend sufficient time training and mentoring their deputies. Most alarming, studies showed that nearly three times more critical errors occurred during the “72s” than during 24-hour alerts. Finally, the missile alert facility “cohesive unit” objective never materialized, as crewmembers declared that topside enlisted support personnel would “just as soon not be bothered and [expected] the crewmember to either go work out, go to sleep, or as a minimum to stay out of the way.”76

By the spring of 2008, the only positive results seemed to be the 10 percent reduction in miles traveled and 50 percent savings in fuel consumption. In early April, Major General Burg, who had succeeded Major General Deppe as Twentieth Air Force commander, recognized the failure of alert transformation in a memorandum to the icbm crew force. “After the year-long trial of the 3-person missile combat crew,
72-hour alert construct,” he said, it became clear that the “unintended consequences, such as a measurable decrease in crew proficiency, strong evidence of crewmember fatigue, and increased manpower requirements [that required at least fifty-six more 13s billets per wing] outweighed the cost savings realized.” He directed the wings to return to the two-crewmember, 24-hour alert schedule on 1 May 2008.77

Crewmembers wholeheartedly approved. Veterans of “72s” and officers who experienced the aftermath agreed that the “alert transformation” produced a culture in which missileers lost sight of the “big picture” in their concern to survive the next alert to get some time for their families, or simply to catch up on lost sleep. Proficiency suffered as well, as 12 deputy commanders were “grand-fathered” in as mission combat commanders, which created a “lasting uneasy effect” about their qualifications and experience. Only two years after the experiment could officers assert that the bad habits and poor morale had been largely overcome. As one participant of the “72s” commented, “I don’t think there is a crewmember out there that looks back fondly on seventy-two-hour alerts. It killed morale and motivation and left a gap in proficiency that is [only now, in 2011] matriculating out of the crew force.”78

At the time Major General Burg cancelled the 72-hour alert policy, he found himself embroiled in the aftermath of a far more serious issue that would impact the lives of Minuteman III missileers. In late August 2007 a flight of B-52 bombers carrying twelve air-launched cruise missiles flew from Minot Air Force Base, North Dakota, to Barksdale Air Force Base, Louisiana. Although scheduled for retirement, six of the missiles had live nuclear warheads rather than the normal dummy warheads. A year earlier four forward-section assemblies from the Minuteman III had been sent to Taiwan in error. Alarmed at the Air Force’s improper handling of nuclear weapons and concerned about the security of the U.S. nuclear arsenal, Secretary of Defense Robert M. Gates initiated a number of OSD and Air Force investigations and studies to determine the immediate circumstances, identify long-term problem areas, and recommend steps needed to “reinvigorate the nuclear enterprise.”79

In the first of many dismissals, Secretary Gates, in June 2008, fired the secretary of the Air Force and Air Force chief of staff in view of “an erosion of performance standards within the involved commands and a lack of effective Air Force leadership oversight.” He then appointed a task force chaired by former Secretary of Defense James R. Schlesinger to offer “independent advice on the organizational, procedural and policy improvements necessary to ensure that the highest levels of accountability and control are maintained in the department’s stewardship of nuclear weapons, delivery vehicles, sensitive components and basing procedures.”80

The Schlesinger Report and other studies concluded that Air Force senior leadership had lost focus on the “nuclear enterprise” following the end of the Cold War. The Schlesinger Report, in particular, reaffirmed the importance of the nuclear mission, noting that the Air Force maintained responsibility for 60 percent of U.S. operational nuclear weapons. Yet, the service had decentralized its nuclear enterprise and shifted its focus to the new post-9/11 mission and resource priorities of the Iraq
and Afghanistan conflicts. After identifying long-standing training and manpower deficiencies, the studies recommended reemphasizing the continued importance of nuclear deterrence, measures to improve personnel training and assignment opportunities, a more vigorous inspection regime, and a number of organizational changes. Among the latter, the most important was the establishment of Air Force Global Strike Command at Barksdale Air Force Base on 7 August 2009. Air Force headquarters assigned the new command responsibility for managing both nuclear bombers and the Minuteman III ICBM force. The ICBM mission transferred from Air Force Space Command to Air Force Global Strike Command on 1 December 2009.  

The Air Force also implemented the more rigorous inspection regime called for in the Schlesinger Report. The extraordinary level of oversight and inspection activities embraced ten inspections and staff assistance visits that significantly increased the level of scrutiny and workload for both Minuteman ICBM wing staff and squadron crewmembers. The intensified inspection program became a focus of the April 2011 Defense Science Board’s “Independent Assessment of the Air Force Nuclear Enterprise.” While praising the success of the program, the report also lamented the “unintended consequence” of the excessive workload in both the operating and logistics wings. At Minot, for example, the investigation showed 469 “days of special effort” in 2009, with as many as four activities on the same day, while commanders had only 65 days, including weekends and holidays, to address normal mission requirements. Missileers complained that the frequency of the inspections provided too little time to correct deficiencies, and that their activities seemed more driven by inspections than the requirements of their mission. The inspection regime seemed especially burdensome given its appearance in the wake of the 72-hour alert experience.

The return of 24-hour alerts in 2008 meant that once again line crews usually did from six to eight alerts per month. By 2011, given manning shortfalls, most crewmembers stood eight alerts, the maximum allowable without a waiver. Normally, the unit made up shortfalls with flight commander and instructor and evaluator crews. While alert duty remained rigorous and demanding, crewmembers could point to recently completed or ongoing quality of life improvements designed to make alert duty in the missile alert facility capsule more agreeable. Many capsules received new television sets that benefited from improved satellite television subscriptions, and the addition of long-distance phone service made it easier to communicate with family members during alert. An upgrade to the environmental control system, part of the ongoing fifteen-year Minuteman modernization program, proved to be more significant. Not only did the new system provide a humidifier and improved temperature control in the capsule, its emergency air conditioning unit proved to be much quieter than its predecessor.

Perhaps no capsule “sustainment” effort affected crewmembers more directly than the program to replace piping and insulation in the missile alert facility. While this modification definitely made alerts “more comfortable” by ending the sewage backup
that filled the area under the capsule, crews had to be present eight hours each day
for a week at a time to escort contractors doing the work in order to retain the launch
control center’s nuclear certification. During their shift, they had to don special masks
and heavy-duty hearing protection to filter out the smoke, dust, and noise produced
by the welding equipment. As one crewmember recounted, “It was honestly one of
the most unpleasant things I’ve had to do during my crew tour.” Modifying all fifteen
missile alert facilities in the wing took nearly a year and a half, with all crewmembers
sharing the burden. A related “bathroom modification” for some capsules involved
replacing the “prison” toilet, with its connected sink and a mirror above it, along with
the “Minutemaid” privacy curtain that could be drawn from one side of the capsule
to the other. Although the new hard-sided enclosure, with its separate sink and toilet,
provided more privacy, not all crewmembers considered it a necessary quality-of-life
improvement.84

Despite the programs to improve life in the capsule, an aging launch control center
kept crewmembers busier on alerts working to keep equipment online. As one mis-
sileer noted, “Our capsules are still falling apart, equipment does not want to function
as intended, and crews operate the weapon system regardless of how difficult it is
to keep everything operational.” Crewmembers still had to shout to hear each other
because of the degraded communications equipment. Since sustainment of the launch
facility and missile had the top priority for maintenance personnel, capsule “write-
ups” received little attention. The requirements for standard maintenance and modi-
fications to the launch facilities, in fact, left few resources available for launch control
facility needs. To their credit, crews continued to keep the weapon system sufficiently
operational to meet all command and control requirements and to maintain positive
control and nuclear surety. Yet, as a crewmember concluded, “For a renewed focus on
the nuclear enterprise, we are hurting for people, material, and facilities.”85

Not surprisingly, many crewmembers interviewed by investigators of the Air Force
nuclear enterprise expressed concern about their career field and their career pros-
tspects. The larger Air Force, missileers frequently complained, neither understood
nor respected their mission in spite of the importance of the nuclear enterprise. They
pointed, for example, to the dearth of information about the ICBM mission at every
level of the Air Force professional military education curriculum, while all aspects of
Air Force public relations consistently seemed to omit the ICBM mission. Given this
perception, investigators determined that leadership at the operational level had dif-
culty convincing crewmembers “that their service is valued commensurate with the
declared priority of their mission.”86

The investigators also examined the condition of the missile career field and found
it wanting. They noted that although the demand for entry-level crew officers at the
three missile wings remained high, follow-on assignments in the staff supervisory
structure above the squadron level were limited. Since missile and space operations
officers belonged to the same 13S career field, many missile officers transferred to a
space specialty after their initial four-year tour and remained on the space side to take
advantage of expanding mission opportunities. The resulting leaner pool of dedicated missileers, primarily in the field grade ranks, had fewer prospects for promotion and command assignments compared to officers with both space and missile experience. In one report, examiners asserted, “The ICBM force [had] lost 10 years of nuclear expertise through follow-on assignments to the space field.”

In an effort to better manage its relatively limited number of personnel with nuclear backgrounds, the Air Force restructured the 13s career field in the fall of 2010 by establishing a nuclear-experience tracking system. The field still included both space and missile officers, but now officers at the three ICBM wings became “nuke-tracked” or “space-tracked.” Space-tracked officers were able to leave for a space assignment after their initial four-year missile crew commitment, while nuke-tracked personnel got extended at the wings to fill available staff positions. Initially, the wings had more capable nuke-tracked volunteers than positions available and had to send them to fill space billets. Yet, because officers who declined a nuke-tracked position could separate, and the wing could not fill the slot with a space-tracked officer, the wing would have to waive the four-year alert requirement for a crewmember and assign him or her to the vacant staff position. This meant one less officer available to stand alert, which contributed to manning shortfalls. Although the system’s inflexibility resulted in substantial officer shortages in ICBM operations and large surpluses in space operations, the new formalized nuclear career path provided early identification and development of officers to fill important positions in the future.

At the same time, the Air Force sought to expand the professional horizons of its nuclear-track officers through a two-week advanced ICBM operations course held four times per year at Twentieth Air Force headquarters. The in-depth course, with classes limited to sixteen officers each, focused on the nuclear enterprise and the historical and current development of nuclear systems and acquisition and sustainment processes. Students also received instruction in nuclear proliferation, nuclear policy and legal conventions, and visited Los Alamos National Laboratory and other facilities associated with the nuclear mission. The operations groups at the respective ICBM wings selected nuclear-coded officers based on wing scheduling priorities and the number of student billets available. Instruction began in March 2010, and by the end of 2011 eighty-seven nuclear officers had graduated from the course. Air Force leaders considered the advanced ICBM operations course an important career broadening initiative for nuclear-coded officers and an incentive to encourage retention in the nuclear career field.

Whether the new 13s policy would lead to better assignment and promotion opportunities for missileers remained uncertain, despite the renewed attention accorded the ICBM force under the “reinvigoration of the nuclear enterprise” program. Moreover, the Air Force has offered no special incentives for young lieutenants to become missileers. Gone was the Minuteman Education Program, for example, so the prospective crewmember might only be attracted to missiles to move up to a staff position in operations or leave missiles for a more appealing space assignment after completing the
initial commitment. In a sense, Minuteman missile crew duty had not changed in forty years. It remained intensely rigorous both physically and mentally for missileers, who faced long hours on alert and in training, away from their families. Inconsistent sleep patterns often produced extreme fatigue, intensified by the nuclear mission. As one officer remarked, “One of the toughest things about this job is the standard of perfection that dealing with nuclear weapons demands. This expectation of perfection is part of everything we do, even the little things, and that constant pressure can be exhausting at times.” Not surprisingly, the missile career field continued to attract few volunteers. As missileers are fond of saying, “I didn’t choose missiles, missiles chose me.”

Even so, whether volunteer or non-volunteer, missile officers continued to take considerable pride in supporting a mission that demanded perfection. The professionalism and esprit de corps that long characterized the missile force continued to emerge particularly in times of travail. A good example was the response to the disastrous Minot flood in June 2011 that deluged 4,100 homes and forced the evacuation of 10,000 residents from the city. The heavy North Dakota rains and flooding kept missileers busy keeping missile sites free from water, while maintenance and security personnel had to perform countless inspections of those sites particularly susceptible to water damage. Unit manning also suffered when the housing shortage compelled the wing to halt the arrival of newly assigned officers. Yet, the disaster brought the entire community, military and civilian, together in a united effort to assist one another, recover, and move forward. In the words of one officer, “The truly remarkable part of the flood was how quickly people opened their homes and hearts to help those affected!” Countless volunteers from the base worked in the city to fill sandbags, pump out basements, and help with the long rebuilding process. As another crewmember recounted several months after the flood, Air Force personnel “especially have [banded] together to help each other and ensure no one is without a support system. It has been truly remarkable to see the good spirits that continue to persist through this event!”

The impressive morale reflected in Minot’s response to the flood no doubt benefited from the wing’s “recovery” from the difficult period that dated primarily from the 2007 nuclear incident. During the so-called “dark days” of 2007-2009, one operations group commander and one wing commander were fired and overall morale plummeted. Crewmembers who experienced this period much preferred to emphasize the recovery that they attributed to a recent outstanding operations group commander and their own hard work, which brought the Minot missileers awards of “best ICBM Wing,” “best Ops Group,” “best OSS [Operations Support Squadron],” and “best training program.” As one Minot veteran commented, “Currently morale is good…and leadership has such an important impact.”

An Uncertain Future
At the outset of the new century’s second decade, the ICBM community faced significant challenges and great uncertainty. Air Force leaders expected the “reinvigoration
of the Air Force nuclear enterprise” to bring renewed appreciation for the nuclear deterrent mission of the ICBM force. Clearly, the establishment of Air Force Global Strike Command provided more focus on the ICBM mission and more direction to the Minuteman force. Yet, would the new command be able to realize its objective—to attain the level of stewardship demanded and received by the Strategic Air Command during the Cold War? Would the Air Force also be able to provide greater career opportunities for prospective missileers? A realistic assessment would require more time, perspective, and depend on decisions regarding the future of the ICBM leg of the Triad.93

Every post-Cold War U.S. administration reaffirmed the important role played by nuclear weapons and the continuing requirement for an ICBM force. With the nation's focus in the new century on conventional warfare and non-state enemies, however, the proper function of nuclear weapons in the nation’s defense remained an open question. Supporters of the Minuteman III offered the traditional arguments for retaining the venerable land-based strategic deterrent. Widely dispersed in large numbers, Minuteman missiles provided credible response, protected the other legs of the Triad, offered allies a nuclear umbrella, and represented the most cost-effective element of the strategic nuclear deterrent. Some Minuteman proponents also favored using part of the force in a conventional capacity. Opponents, on the other hand, questioned the need for a nuclear Triad, suggesting that the Trident II SLBM force should replace both Minuteman ICBMS and nuclear bombers.94

While national defense policy called for retaining an ICBM element, the size of the force would depend in large part on arms control decisions and the state of the nation’s economy. Already expected to be reduced from 450 to 420 missiles, Minuteman force levels would likely fall further under provisions of future strategic force reduction treaties. Budget constraints would also determine the affordability of retaining a large ICBM contingent and the most effective way to modernize the force. For defense planners, the question surrounding the Minuteman III continued to center on whether to sustain or to replace the aging deterrent and how best to ensure the capabilities of a declining industrial base.

Looking back from the perspective of the twenty-first century’s second decade, the ICBM landscape appeared very different than it did during the Cold War. From a high point of 1,054 ICBMS first reached in 1968, the current Minuteman III force had shrunk to less than half that number. The striking power of the fleet also had diminished substantially. Gone were the fifty-four Titan IIs with their nine-megaton warheads and the fifty Peacekeepers that deployed ten MIRVed warheads each. Yet, the 450 single-warhead Minuteman IIIs, deployed in five states in missile fields spread over 34,600 square miles, remained a potent force. Despite an altered strategic landscape as well, Minuteman operators continued to provide an important element of the nation's strategic deterrent. In that sense, the nuclear mission had not changed. It still required highly motivated men and women prepared to pursue the standard of perfection demanded by the stewardship of nuclear weapons.95
Every twenty-first century Minuteman III missileer also could take pride in being part of an honored tradition of service, whose heritage continued to be promoted by a very active Association of Air Force Missileers (AAFM). With more than 3,500 members having joined since its inception in 1993, the AAFM’s mission is to keep missileers informed, recognize outstanding missileers, and preserve “our missile history.” As the past serves to inform the present, the contributions of previous missile veterans have established an important legacy for present and future missileers to preserve and enhance.96
Appendices

APPENDIX I-1

Ballistic Missile and Space Systems Organizational Structure*

APPENDIX II-1

**Atlas and Titan Contractors***

<table>
<thead>
<tr>
<th></th>
<th><strong>Atlas</strong></th>
<th><strong>Titan</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Airframe</td>
<td>Convair</td>
<td>Martin</td>
</tr>
<tr>
<td>Guidance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio-inertial</td>
<td>General Electric</td>
<td>Bell Telephone</td>
</tr>
<tr>
<td>All-inertial</td>
<td>A.C. Spark Plug</td>
<td>American Bosch and MIT</td>
</tr>
<tr>
<td>Propulsion</td>
<td>North American</td>
<td>Aerojet-General</td>
</tr>
<tr>
<td>Nose Cone</td>
<td>General Electric</td>
<td>AVCO</td>
</tr>
<tr>
<td>Computer</td>
<td>Burroughs</td>
<td>Remington Rand</td>
</tr>
</tbody>
</table>

---

APPENDIX II-2
F. E. Warren Air Force Base Atlas Sites*

* Source: 90th Missile Wing, History Office, Archive.
APPENDIX II-3

Artist Conception of an Atlas F Launch Site*

# APPENDIX II-4

## Atlas Squadron Milestones*

<table>
<thead>
<tr>
<th>Squadron</th>
<th>Support Base</th>
<th>Number and Type</th>
<th>Organized*</th>
<th>Turnover to SAC</th>
<th>Operational</th>
<th>1st ICBM Off Alert</th>
<th>Last ICBM Off Alert</th>
<th>Last ICBM Shipped</th>
<th>Squadron Inactivated</th>
</tr>
</thead>
</table>

* Before 1960 the term was synonymous with "activated."

* On Jul 1, 1961, the Atlas D squadron at Offutt and the Atlas E squadron at Warren exchanged designators.


---

APPENDIX II-5

Titan I Site Layout*

* Source: http://www.siloworld.net/ICBM/TITAN/T1/sideview1.htm
APPENDIX II-6

**Titan Squadron Milestones***

<table>
<thead>
<tr>
<th>Squadron</th>
<th>Support Base</th>
<th>Number and Type</th>
<th>Activated</th>
<th>Turnover to SAC</th>
<th>Operational</th>
<th>1st ICBM Off Alert</th>
<th>Last ICBM Off Alert</th>
<th>Last Shipped</th>
<th>Inactivated</th>
</tr>
</thead>
</table>

*On July 1, 1961, the 568th SMS and the 569th SMS were discontinued. They were replaced by the 724th SMS and the 725th SMS respectively.*

APPENDIX III-1

Comparison of Titan I and Titan II*

<table>
<thead>
<tr>
<th></th>
<th>Titan I</th>
<th>Titan II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (feet)</td>
<td>98</td>
<td>104</td>
</tr>
<tr>
<td>Diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stage 1</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>stage 2</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Weight fueled (pounds)</td>
<td>220,000</td>
<td>330,000</td>
</tr>
<tr>
<td>Range (nautical miles)</td>
<td>5,500</td>
<td>5,500</td>
</tr>
<tr>
<td>Thrust (pounds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stage 1 (sea level)</td>
<td>300,000</td>
<td>430,000</td>
</tr>
<tr>
<td>stage 2 (altitude)</td>
<td>80,000</td>
<td>100,850</td>
</tr>
<tr>
<td>Speed (mach number)</td>
<td>21.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Guidance</td>
<td>radio-inertial</td>
<td>inertial</td>
</tr>
<tr>
<td>Reentry vehicle (ablative)</td>
<td>AVCO Mark 4</td>
<td>GE Mark 6</td>
</tr>
<tr>
<td>Number produced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>research &amp; development</td>
<td>47</td>
<td>33</td>
</tr>
<tr>
<td>production</td>
<td>108</td>
<td>108</td>
</tr>
<tr>
<td>Average cost</td>
<td>$21,484,000</td>
<td>$17,087,000</td>
</tr>
</tbody>
</table>

APPENDIX III-2

Titan II Silo Diagram*

APPENDIX III-3
Davis-Monthan AFB Missile Construction Sites*

APPENDIX IV-1
Minuteman Weapon System Deployment*

APPENDIX IV-2

Minuteman Weapon System Deployment*

* Source: Ogden Air Logistics Center, Minuteman WS Annex, August 1990, p. 11.
APPENDIX IV-3

Minuteman Weapon System Description*

APPENDIX IV-4
Minuteman Weapon System Description*

* Source: Ogden ALC, Minuteman WS Annex, August 1990, p. 89.
APPENDIX IV-5

Minuteman Launch Facilities*

* Source: Ogden ALC, Minuteman WS Annex, August 1990, p. 87.
APPENDIX IV-6
Minuteman Launch Control Facilities*

APPENDIX IV-7

Minuteman Technical Specifications*

Technical Specifications

Length:  
53.8 feet (MM I/A)  
55.11 feet (MM I/B)  
57.7 feet (MM II)  
59.9 feet (MM III)

Weight:  
65,000 pounds (MM I)  
73,000 pounds (MM II)  
78,000 pounds (MM III)

Range:  
6,3000 miles (MM I)  
7,021 miles (MM II)  
8,083 miles (MM III)

Propulsion: Minuteman was a three-stage, solid-fuel missile. The specifications for each stage are given below.

Stage I  MM I, MM II, and MM III used the same 210,000-pound thrust motor

Stage II  MM I and MM II used a 60,000-pound thrust motor  
          MM III used a 60,300-pound thrust motor

Stage III  MM I and MM II used a 35,000-pound thrust motor  
          MM III used a 34,000-pound thrust motor

Guidance: All-inertial

Accuracy:  
MM I = 1.5 miles  
MM II = 1.0 miles  
MM III = 800 feet

Reentry vehicle:  
MM I/A–Mark 5  
MM I/B–Mark 11  
MM II–Mark 12  
MM III–Mark 12A

Warhead:  
MM I/A: one W-59 warhead, 1 megaton yield  
MM I/B: one W-56 warhead, 1.2 megaton yield  
MM II: one W-56 warhead, 1 to 2 megaton yield  
MM III: two or three W-62 or W-78 warheads  
        W-62 = 170 kiloton yield  
        W-78 = 375 kiloton yield

Contractors

Airframe: Boeing Airplane Company, Seattle, Washington
Propulsion:  
Stage I: Thiokol Chemical Corporation, Brigham City, Utah  
          Stage II: Aerojet Solid Propulsion Company, Sacramento, California  
          Stage III: Hercules Powder Company, Magna, Utah
Guidance: Autonetics Division of Rockwell Corporation, Anaheim, California
Reentry Vehicles:  
Mark 5–AVCO, Wilmington, Massachusetts  
Mark 12–Generasl Electric, Philadelphia, Pennsylvania  
Mark 12A–Generasl Electric, Philadelphia, Pennsylvania

* Source: Lonnquest and Winkler, To Defend and Deter, pp. 241-242.
APPENDIX IV-8

Minuteman Missile Dimensions*

APPENDIX IV-9

Minuteman III Major Features*

* Source: Ogden ALC, Minuteman WS Annex, August 1990, p. 41.
APPENDIX IV-10
Minuteman III Missile Operation*

* Source: Ogden ALC, Minuteman WS Annex, August 1990, p. 43.
APPENDIX IV-11

Minuteman Flight Sequence of Events*

* Source: Ogden ALC, Minuteman WS Annex, August 1990, p. 89.
APPENDIX V-1
Closely Spaced Basing*

APPENDIX V-2
Peacekeeper, LGM/MGM-118A*

APPENDIX V-3

Peacekeeper Missile, Cross-Sectional Drawing*

APPENDIX V-4
Peacekeeper in Minuteman Silo Sites*

APPENDIX V-5

Peacekeeper Canister Subsystem *


224
APPENDIX V-6

Peacekeeper Launch Facility*

APPENDIX V-7
Peacekeeper Rail Garrison Launch Car*

* Source: BMO, History of Ballistic Missile Organization, 1 October 1989-30 September 1990, p. 73.
Appendices

APPENDIX V-8
Small ICBM Weapon System*

APPENDIX VI-1

Minuteman III Reentry System Configurations*

APPENDIX VI-2

Minuteman III REACT Weapon System Console*

APPENDIX VI-3
Minuteman III NS-20 and NS-50 Missile Guidance Sets*

APPENDIX VI-4

Minuteman III Propulsion System Rocket Engine (PSRE)*

* Source: Ogden ALC, Minuteman WS, Spring 2005, p. 28.
APPENDIX VI-5

Minuteman III Safety Enhanced Reentry Vehicle (SERV) Program*

APPENDIX VI-6

Minuteman III Communications Network*

APPENDIX VI-7

Minuteman III Launcher Security System (Typical)*

APPENDIX VI-8
The New Strategic Triad*

APPENDIX VI-9

Minuteman III—341st Space Wing Missile Field*

APPENDIX VI-10

Minuteman III Squadron Command and Control Network*

Chapter I. The Air Force Enters the Missile Age, 1945–1955

1. It also should be noted that the Key West Agreement worked out by the Joint Chiefs of Staff at Key West, Florida, in March of 1948 accorded the Air Force operations in air space, but did not address activities in outer space. Logically, the Air Force thus devoted its attention and budget priorities to air-breathing cruise missiles. Robert Frank Futrell, Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907–1960, Vol. 1 (Maxwell Air Force Base, Alabama: Air University Press, 1989), p. 198.


3. DeVorkin, Science with a Vengeance, pp. 168–182; Constance McLaughlin Green and Milton Lomask, Vanguard: A History (Washington, d.c.: Smithsonian Institution Press, 1971), pp. 10–11. A modified Viking would provide the booster for the four-stage Project Vanguard, the nation’s first “civilian” space program. Despite development by the Office of Naval Research, the Vanguard generally is regarded as a largely civilian program in contrast with its competitors for America’s scientific satellite entry in the International Geophysical Year program.


6. See note 5.
10. Ibid., pp. 52–55.
11. Beard, Developing the ICBM, p. 61.
12. J. D. Hunley, Preludes to U.S. Space-Launch Vehicle Technology: Goddard Rockets to Minuteman III (Gainesville: University Press of Florida, 2008), p. 204. After the Korean War the Eisenhower administration would also rely on the Nike Ajax antiaircraft missile and Matador, a land-attack cruise missile, operational in December 1953 and March 1954, respectively.
14. Neufeld, Development of Ballistic Missiles, p. 45; John L. Chapman, Atlas: The Story of a Missile (New York: Harper & Brothers, 1960), pp. 27–28. Chapman argues that the AAF was interested in a preliminary assessment, with perhaps development occurring five to ten years hence. This helps to explain why Convair’s missile was to have only a 5,000-pound delivery capability when the two types of existing atomic bombs weighed approximately 9,000 and 10,000 pounds, respectively.

22. See note 21.


28. Beard, Developing the ICBM, pp. 130–145. Ongoing doubts about the project’s technical feasibility rather than roles and missions concerns apparently prompted the Air Staff to refer ARDC’s request to the Guided Missiles Committee. Since spring 1950, the Air Force had been authorized exclusive development of long-range strategic missiles, although the Army and Navy continued to contest both development and operational responsibility for missiles. Neufeld, Development of Ballistic Missiles, p. 56.


30. Neufeld, *Development of Ballistic Missiles*, pp. 74–79. The program’s priority designation of 1-b reflected the deliberate, systematic approach favored by the Air Staff.


38. Divine, *Sputnik Challenge*, p. 18;


The von Neumann Committee is often referred to as the Teapot Committee. According to Dr. Simon Ramo, however, this designation applies only to a second committee, which Gardner formed at the same time, to examine non-strategic missile programs. The latter received the name Teapot Committee when Gardner objected to Ramo’s first suggestion, Tea Garden, because he believed the association with his own name was too close. By contrast, the von Neumann Committee should receive no other designation than Strategic Missile Evaluation Committee. Dr. Simon Ramo, interview by Mr. George W. Bradley, Director of History, Air Force Space Command, 7 March 1997.


44. On Schriever’s background and experience in the Air Force research arena, especially with long-range planning, see Lonnquest, “Face of Atlas,” pp. 50–55, 114–116.


57. Converse, *Rearming for the Cold War*, chapters 5 and 9; Johnson, *The United States Air Force and the Culture of Innovation*, pp. 50–52, 77–86. Johnson describes Schriever’s early role in promoting the weapon system concept, particularly as key author of the April 1951 “Combat Ready Aircraft” study. This important staff paper proposed methods to accelerate the development cycle yet also deploy a fully operational weapon system to the field units. These methods
included concurrency and by the end of the Korean War had been adopted by the Air Research and Development Command. Lonnquest notes that the term “concurrency” was not part of the Air Force acquisition community’s vocabulary in the 1940s and 1950s. Even Schriever’s Western Development Division did not use the term. See John Lonnquest, “Building Missiles: Concurrency and the Legacy of the Early Air Force ICBM Program,” in Providing the Means of War: Perspectives on Defense Acquisition, 1945-2000, ed. Shannon A. Brown (Washington, D.C.: United States Army Center of Military History and Industrial College of the Armed Forces, 2005), pp. 97–110.

58. RP-1 stands for Rocket Propellant-1.


6. Eisenhower officials responded to the critics by arguing that, while the Soviets might have a modest superiority in number of ICBMs, this did not constitute a “deterrent gap” in view of the U.S. retaliatory strategic arsenal. Robert J. Watson, Into the Missile Age, 1956–1960, Vol. IV,
History of the Office of the Secretary of

7. The Gaither report on the state of the nation’s strategic deterrent forces also proved influential in the administration’s deliberations to expand the missile force. This report of the Security Resources Panel of the Office of Defense Management Science Advisory Committee, named for its chairman, called for a massive expansion of strategic forces, including an increase in ICBM squadrons from eight to sixty. Not accelerating the missile force, it warned, would allow the Soviet Union to critically threaten the United States by 1959 or 1960. See Watson, Into the Missile Age, 1956–1960, pp. 183–187.

mined force levels, interservice differences found Air Force leaders normally working through its Ballistic Missile Committee with its counterpart OSD Ballistic Missiles Committee (BMC) and its chairman, William M. Holaday, initially the assistant to the secretary of defense for guided missiles and later director of guided missiles. In April 1959, he once again became the special assistant for guided missiles, with responsibility for advising the Secretary of Defense on the progress of missiles in development to operational status. He remained chairman of the OSD BMC. See Watson, Into the Missile Age, 1956–1960, p. 362.


15. Lonnquest and Winkler, To Defend and Deter, p. 33. Engineers determined that an ablative, blunt-body nose cone that dissipated heat by shedding its outer layers during reentry proved superior to the heat sink nose cone, whose large copper alloy core absorbed heat. The president’s message declared, “This is the President of the United States speaking. Through the marvels of scientific advance, my voice is coming to you via a satellite circling in outer space. My message is a simple one: Through this unique means I convey to you and all mankind, America’s wish for peace on Earth and goodwill toward men everywhere.” See Federation of American Scientists, “SCORE,” FAS Space Policy Project, http://www.fas.org/spp/military/program/com/score.htm (accessed 31 October 2011); Hunley, Preludes to U.S. Space-Launch Vehicle Technology, p. 229; Lonnquest, “Face of Atlas,” pp. 263–264.


20. See note 15.

22. Stumpf, *Titan II*, p. 21; Hunley, *Preludes to U.S. Space-Launch Vehicle Technology*, pp. 260–262. Stumpf argues that, with the contract stipulating a 77 percent in-flight reliability figure, the Titan I met its requirement with a 78 percent reliability record. He cites Greene, who does not explain precisely how in-flight reliability was measured. See, Greene, *Development of the SM-68 Titan*, p. 97. Hunley states that the Titan I’s R&D flights totaled fifty-seven, with thirty-eight successful, nineteen failures or partially successful, for a 67 percent success rate.


24. Lonnquest and Winkler, *To Defend and Deter*, pp. 313–314. The Navy received the southern portion of Cooke when the Army transferred the northern section to the Air Force. The Navy maintained a missile base at Point Arguello until 1964, when the Air Force acquired this property and named the range the Western Test Range.


32. Lonnquest and Winkler, To Defend and Deter, pp. 440–441.

33. Ibid.


37. Lonnquest and Winkler, To Defend and Deter, pp. 309–441.


50. See note 45.
52. See note 48.
53. LeMay is quoted in Goldsworthy, “ICBM Site Activation,” p. 156.
55. Hearings, Air Force Intercontinental Ballistic Missile Base Construction Program, passim.
56. Ibid., p. 62.
57. Ibid., pp. 222–225.
58. Air Force Ballistic Systems Division, Lessons learned in ICBM Site Activation, p. 29; Air Force Systems Command, The Site Program 1961, p. 18. BSD’s Configuration Control Board in Los Angeles handled change requests considered outside the purview of the local Sataf control board.
Space Command, 2004), pp. 254–266.


65. Neufeld, Development of Ballistic Missiles, pp. 179, 204.


70. Lonnquest and Winkler, To Defend and Deter, p. 101.


73. Ibid., pp. 49–52; Neufeld, Development of Ballistic Missiles, pp. 217–218;
Johnson, *The United States Air Force and the Culture of Innovation*, pp. 90–94. The criteria for determining missile reliability tended to be imprecise and often varied with the particular subsystem component test being conducted. Reliability is often equated with successful flight operations, and Johnson states that the initial Air Force target of 50 percent success under wartime conditions meant, for engineers from Ramo-Wooldridge, that the success rate for missiles under ideal test conditions missiles should be 90 percent. This remained unachievable for the early, liquid propellant Atlas and Titan ICBMs.


For discussion of configuration control, see Johnson, *The United States Air Force and the Culture of Innovation*, pp. 94–102. Johnson notes that configuration control began with Minuteman in the fall of 1959, with the process for Atlas D beginning with flight 33D on 29 September 1960, prior to Golden Ram.


86. Lonnquest and Winkler, *To Defend and Deter*, p. 407.


88. Ibid., p. 367.


90. The deactivation plan was termed


93. Kaplan and his co-authors argued that the Kennedy administration continued its rapid missile build-up after realizing the missile gap was a myth in order to confront expected Soviet production increases and offset potential political and military challenges to the West that the Soviets’ ICBM force emboldened them to mount. See Kaplan, Landa, and Drea, *The McNamara Ascendency*, pp. 298–302.

94. John Lonnquest argues that concurrency was not revolutionary and must be viewed as a subset of the weapon system management concept. See Lonnquest, “Face of Atlas,” pp. 231–243.


Chapter III. The “Mighty” Titan II, 1963–1987


3. Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1980, pp. 625, 634. J. D. Hunley argues that Congress proved willing to fund both the Titan II and the Minuteman I because of their different but complementary roles. With its larger warhead, the Titan II functioned as a genuine counterforce weapon, able to destroy Soviet missiles in their silos; Minuteman I served more in support of deterrence, as a countervalue, or countercity, missile. See J. D. Hunley, Preludes to U.S. Space-Launch Vehicle Technology: Goddard Rockets to Minuteman III (Gainesville: University Press of Florida, 2008), p. 264.


12. See note 11.


19. Hunley describes the inconsistenc-

29. Ibid. The always uneasy relationship between Air Force offices and the Army Corps of Engineers continued. Army engineers viewed with displeasure what they considered Air Force encroachment on their construction contractor prerogatives, as late as 1963. See, for example, Cyrus R. Vance, Secretary of the Army, “Army-Air Force Relationship on Matters of Design and Construction,” Memorandum for the Secretary of the Air Force, 7 January 1963, and other correspondence in the Corps of Engineers Research Collection.


37. CEBMCO Davis-Monthan History, pp. ii.1–ii.3.

38. U.S. Army Corps of Engineers, Ballistic Missile Construction Office, (CEBMCO), History of the Real Estate

40. *CEBMCO Davis-Monthan History*, pp. iv.4–iv.7, ix.3.


43. *CEBMCO Davis-Monthan History*, pp. iv.2, v.4; Stumpf, *Titan II*, p. 127. Critical path scheduling focused on the series of key tasks that determined the completion date of the project. Carefully tracking the critical path and the resources required improved the ability to finish the project on time.

44. *CEBMCO Davis-Monthan History*, pp. iv.9–iv.11; Lonnquest and Winkler, *To Defend and Deter*, p. 301.


46. Stumpf, *Titan II*, pp. 130–143. The 308th Strategic Missile Wing’s emergency combat capability meant that not all facilities were on alert, but could be rapidly put on alert if necessary. This status reflected the problem with oxidizer leaks at the Little Rock sites.


For a comprehensive description of the accident and subsequent investigation, see Stumpf, *Titan II*, pp. 215–221.


56. *Ibid*.


60. The Air Force wanted a missile capable of launching 7,000 pounds 6,500 nautical miles to attain a CEP of 0.2 nautical miles and be housed in a hard-rock silo able to withstand shocks up to 3,000 pounds per square inch. Nalty, *USAF Ballistic Missile Programs, 1967–1968*, pp. 56–61.


74. It should be noted that the 1967 competition was termed “Curtain Raiser.” The 1968 competition was not held due to Vietnam commitments, and from 1982 to 1985 SAC changed the name from Olympic Arena to “SAC Missile Combat Competition.” The nickname “Olympic Arena” returned in 1986, only to be replaced by “Olympic Shield” the next year. Presented to the Air Force by Boeing Corporation in 1967, the Blanchard Trophy honored General William H. Blanchard, the recently deceased Air Force Vice Chief of Staff. Strategic Air Command, *Olympic Arena: The Saga of SAC’s Missile Combat Competition* (Offutt Air Force Base, Nebraska: Office of the Historian, 19 January 1977, Revised 20 February 1987), pp. 1–4, 23, 26.

75. Strategic Air Command, *History of the Strategic Air Command, 1 January–31 December 1978*, pp. 469–471; Strategic Air Command, *History of the Strategic Air Command, 1 January–31 December 1982*, Historical Study No. 195, Vol. 1, pp. 559–560. For Blanchard Trophy winners see Strategic Air Command, *Olympic Arena: The Saga of SAC’s Missile Combat Competition*, p. 27. This publication also describes the yearly unit and individual winners. One frequent competitor from the 308th Strategic Missile Wing, then-Sergeant Rodney L. Holder, described how the process began the December prior to the spring competition, with extensive written tests and numerous simulator rides with various individuals to select the two best crews. They would then continue with extensive classroom instruction and ten to twelve missile procedures trainer sessions per month, whereas normally crews received only one four-hour simulator ride a month. Col Rodney L. Holder, USAF (Ret.), email to the author, 26 July 2010.


77. *Ibid*.

79. Ibid; Russo, Guide for Titan II Crew Officer, p. 2; Holder, email to the author, 26 July 2010. Serving as a new deputy combat crew commander at the 308th Strategic Missile Wing in 1982, Linda Aldrich confirmed Holder’s comments, but stressed that she needed to spend much of her available time studying the technical orders because of the “hands on” approach needed to operate and maintain the Titan II weapons system. Minuteman did not require the same technical focus from its crewmembers. Titan II crewmembers who pursued a masters degree did so with tuition assistance, but without the advantages accorded Minuteman personnel in the Minuteman Education Program. Col Linda S. Aldrich, USAF, email to the author, 25 July 2010.


86. Col Ronald V. Bouchert, USAF (Ret.), email to the author, 12 July 2010. He explained that they solved the bathroom situation by making signs with “occupied” on one side and “unoccupied” on the other. The uniform issue, however, required more attention. At that time, missileers wore dark blue fatigues with shirttail tucked in. Providing the women small men’s sizes made the chest pockets located in the pants area, with the prestigious missile badge worn on the left pocket not visible. The interim solution proved to be rearranging the pockets, while the eventual fix was to resize women’s shirts appropriately.

87. Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1978, pp. 607–611. The two women also received considerable attention from national media and the British Broadcasting Corporation. See Fornes’ account in, Patricia Fornes, Col, USAF (Ret.) “Thirty Years Since…,” Association of Air
Notes


89. Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1978, pp. 607–608; Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1980, pp. 728–729; Bouchert, email to the author, 12 July 2010. Surveys determined that those enlisted women already serving in missile maintenance had the same job designations as the missile crews, and a lateral move that required the rigors of night duty had little appeal.

90. Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1980, p. 634.

91. Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1978, pp. 446–447; Stumpf, Titan II, p. 145. Holder cites the air conditioning as “the biggest issue on the Titan system.” Overheating became a growing problem with an aging piping system beset by mineral deposits and cooling towers that would shut down from overheating. Holder, email to the author, 26 July 2010.


93. See note 91.


97. Ibid., pp. 613–616.


99. Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1980, pp. 621–627; Stumpf, Titan II, pp. 242–245. Rodney Holder, the ballistic systems analyst technician on the combat crew on duty at the site, observed that the propellant transfer team had been waiting all day to do the repressurization procedure while a pneudraulics team repaired a hydrau-
lic system to permit lowering of level 2 platforms in the silo. He argued that they would have normally been home by the time they started work and were anxious to get their work done. Holder, email to the author, 26 July 2010.


114. In July 1984, SAC authorized the donation of the 390th Strategic Missile Wing’s deactivated launch complex 571–7 to the Tucson/Pima Air Museum, “in recognition of the close and friendly ties existing between Davis-Monthan

Chapter IV. The “Ace in the Hole” Minuteman, 1945–1991

1. Rick W. Sturdevant, Air Force Space Command/ho, “Ace in the Hole,” 24 March 2009. According to a Malmstrom Air Force Base history, the first Minuteman launch facility, Alpha-06, went on alert on 26 October, followed by four more missiles over the next four days, with the last missile in the flight placed on alert on 10 November. The SAC chronology notes that SAC accepted the first of ten Minuteman ICBMs on the 26th, and the “first model A Minuteman I ICBMs were placed on alert” on 27 October.


6. Piper, The Development of The sm-80 Minuteman, pp. 5–7; Neil Sheehan,


9. Piper, The Development of The sm-80 Minuteman, pp. 9–10; Western Development Division, WDTB, “Solid Propellant Rockets for TB M,” Memorandum to Col Charles H. Terhune, Jr., 16 June 1955. A number of Air Force programs proved helpful to the Navy’s solid-propellant Polaris IRBM program (initiated in February 1956), and the subsequent interchange of development information proved important for both the Polaris and Minuteman development. For example, Polaris used the 2.5 inch diameter gyros and accelerometers that MIT developed under Air Force contract, and, in the engine design area, polyurethane with aluminum additives, strip-wound cases, a four nozzle configuration for each engine, and forward facing thrust termination devices. See, Western Development Division, WDTWQA, “History of Air Force Solid Propellant Ballistic Missile Development,” May 1958; Western Development Division, WDTSL, “Relationship between Navy and Air Force Solid Propellant Development,” May 28, 1958; Hunley, Preludes to U.S. Space-Launch Vehicle Technology, pp. 291–311.


11. Ibid., pp. 13–14. The Air Staff’s proposal called for a solid-propellant IRBM with a range of 500 to 2,000 miles able to deliver a warhead weighing between 300 and 1,000 pounds; Col B. P. Blasingame, WDTB, Air Force Ballistic Missile Division, “ICBM Solid Propellant Program,” Memorandum for Colonel Terhune, 17 July 1957.

12. On 18 September, Colonel Blasingame urged the Ballistic Missile Division to avoid the mistakes of the Titan program by conducting a through systems design study, including the necessary ground support system, before establishing a comprehensive contractor program for the proposed solid-propellant ICBM. To head the program, he also called for the appointment of the “most able leader” in the division. Not surprisingly, Schriever turned to Hall to direct the effort. Col B. P. Blasingame, WDTB, Air Force Ballistic Missile Division, “New Ballistic Missile System Office,” Memorandum for Col Terhune, 18 September 1957; Piper, The Development of The sm-80 Minuteman, p. 18; Hall, The Art of Destructive Management, pp. 51–53.

13. Col Edward N. Hall, WDTQ, Air


19. John Lonnquest attributes the deployment schedule being moved forward by a year to Secretary of the Air Force James Douglas mistakenly telling Congress the missile would be operational in 1962 rather than 1963, as projected by the Air Force. Preferring not to change his testimony, Douglas directed the Ballistic Missile Division to have the missile operational a year earlier. This led the Air Force to implement risky “all up” rather than traditional component testing. See John C. Lonnquest and David F. Winkler, To Defend and Deter: The Legacy of the United States Cold War Missile Program, USACERL Special Report 97/01 (Rock Island, Illinois: Defense Publishing Service, 1996), p. 246.

which accorded it the highest industrial priority. See Piper, *The Development of The sm-80 Minuteman*, p. 57.


35. Although the first all-up missile launch from the silo in August 1961 failed when the missile blew up after engine ignition, the second attempt at Cape Canaveral on 17 November 1961 proved fully successful. Hunley, Preludes to U.S. Space-Launch Vehicle Technology, pp. 317–318; Piper, The Development of The sm-80 Minuteman, pp. 197–201.


38. Ibid.; Lonnquest and Winkler, To Defend and Deter, pp. 249–250. Lonnquest asserts that initially planners wanted to site the missiles as far south as Georgia, Oklahoma, and Texas.


47. The lower 62 feet of the liner consisted of ¼ inch steel plate with the lower
52 feet of the tube encased in 14 inches of reinforced concrete. _CEBMC0 Technical Facilities Malmstrom_, pp. 3-1, 3-2, 4-2-4-7; Hayes, “ICBM Site Construction,” p. 403; Hayes, in _CEBMC0 History of the Operations Division_; Engel et al, _The Missile Plains_, p.65; U.S. Army Corps of Engineers, Ballistic Missile Construction Office (CEBMC0), _Warren Area Minuteman History_, Corps of Engineers Research Collection (Alexandria, Virginia: Office of History, Headquarters Army Corps of Engineers, n.d), pp. 7–8 (hereafter cited as _CEBMC0 Warren Area Minuteman History_); Lonnquest and Winkler, _To Defend and Deter_, p. 84.

48. For the first two wings, the equipment room’s roof was about a foot above ground level, but hardened at ground level for the next three wings. _CEBMC0 Technical Facilities Malmstrom_, pp. 3-2; Engel et al, _The Missile Plains_, pp. 81, 88–90; _CEBMC0 Warren Area Minuteman History_, p. 7; Lonnquest and Winkler, _To Defend and Deter_, p. 255.

49. _CEBMC0 Technical Facilities Malmstrom_, pp. 3-2, 4-1; Engel et al, _The Missile Plains_, pp. 84–86; _CEBMC0 Warren Area Minuteman History_, pp. 3-5, 8-9; Hayes, “ICBM Site Construction,” p. 403; Lonnquest and Winkler, _To Defend and Deter_, pp. 250–254.

50. For the launch control facilities at Wings III through VI, planners decided to have the equipment moved from the support building to a well-protected buried launch control equipment building located next to the control center. _CEBMC0 Technical Facilities Malmstrom_, p. 3-2, 4-1; Engel et al, _The Missile Plains_, pp. 82–84; _CEBMC0 Warren Area Minuteman History_, p. 4; Lonnquest and Winkler, _To Defend and Deter_, pp. 250–252.

51. _CEBMC0 Technical Facilities Malmstrom_, pp. 11-1–11-22; Goldsworthy, letter to the author, 29 July 2009; _CEBMC0 Warren Area Minuteman History_, p. 4; Lonnquest and Winkler, _To Defend and Deter_, p. 367. Six workers were killed during construction at the Malmstrom sites.

52. Goldsworthy, letter to the author, 29 July 2009. Goldsworthy praised the support he received from patriotic Montana citizens in general and from the Great Falls mayor and Chamber of Commerce, in particular.


57. Despite the “identicality” promoted by the Corps of Engineers and the Ballistic Missile Division, the construction experience at each base reflected issues unique to that location, such as the need to avoid Indian land for missile sites in South Dakota and Minot’s near elimination as a base because of its housing deficiencies. For the unique characteristics of the different bases, see Lonnquest and Winkler, To Defend and Deter, Part iii: Site Overviews. The Minuteman I wings at Minot Air Force Base, North Dakota, and Whiteman Air Force Base, Missouri, became operational on 19 March 1964 and 30 June 1964, respectively. Early Minuteman missiles relied on optical alignment procedures that used a bench along the silo wall to achieve accuracy requirements. James C. Mesco, “Manuscript Review Comments,” 7 October 2011.


65. From a cep of 1.1 to 1.5 nautical miles for Minuteman I, the Minuteman
II’s CEP improved to between 0.26 and 0.34 nautical miles. The superior accuracy made the Minuteman II a genuine counterforce weapon. For discussion of the dramatic changes in guidance that occurred in the second generation Minuteman that centered on integrated circuits, a more automatic alignment method, a beryllium stable platform, and the Draper PIGA-G accelerometer with gas instead of ball bearing, see MacKenzie, *Inventing Accuracy*, pp. 203–214; Nalty, *USAF Ballistic Missile Programs, 1964–1966*, p. 6; Hunley, *Preludes to U.S. Space-Launch Vehicle Technology*, pp. 325–326.


ogy of the Ballistic Missile Organization, 1945–1990, pp. 115, 119, 128, 129. Minuteman IIIs at Minot and Grand Forks deployed the Mark 12 reentry system, while Warren and Malmstrom’s 564th Strategic Missile Squadron (the redesignated 20th Strategic Missile Squadron) used the Mark 12A.

74. Chanute ran training courses, three a day for six hours each. Engel et al, The Missile Plains, pp. 113–114; Capt Clark L. Wingate, Man and the Missile: Factors Affecting Human Efficiency and Morale, Air Command and Staff College Thesis No. 1542-64 (Maxwell Air Force Base, Alabama, 20 April 1964), pp. 8–10, 16–17; Capt Pierce L. Smith, Motivation of Minuteman Missile Crews, Air Command and Staff College Thesis No. 1322-65 (Maxwell Air Force Base, Alabama, March 1965), pp. 13–16. In the early Minuteman years, officers entering the field needed just two years of college, but this requirement changed in the 1970s given the pool of potential missileers and the SAC-sponsored masters degree program. In the 1970s the Personnel Reliability Program was termed the Human Reliability Program.

75. Strategic Air Command, Guide for Minuteman Crewmembers, June 1977, pp. 3–4; Smith, Motivation of Minuteman Missile Crews, p. 16; Wingate, Man and the Missile: Factors Affecting Human Efficiency and Morale, pp. 17–19; Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1977, Historical Study No. 166, Vol. 1, p. 528; David A. Anderton, Strategic Air Command (New York: Charles Scribner’s Sons, 1976), pp. 142–143. When female officers underwent initial qualification training at Vandenberg, the course had been extended to fourteen weeks.

76. Strategic Air Command, “Combat Readiness Training for Ballistic Missile Units and Crews,” Manual 50-16 (Omaha, Nebraska: Headquarters Strategic Air Command, 1 July 1963), pp. 1–3. With pre-missile procedures tainer (mpt) preparation and post-trainer ride assessments, the mpt sessions could last up to five hours. Mesco, “Manuscript Review Comments,” 7 October 2011.


78. Ibid., p. 144; Engel et al, The Missile Plains, pp. 109–111, 115; Wingate, Man and the Missile: Factors Affecting Human Efficiency and Morale, pp. 26–27. In later years the requirement for the sidearm was eliminated.


80. Engel et al, The Missile Plains, p. 115; Anderton, Strategic Air Command, pp. 144–145. As one former missileer recounted, “Crew Members received both actual and exercise/test Emergency Action Messages (eams) throughout their alert. The messages came at random
and required decoding actions by both crew members to authenticate real or exercise. The messages began with a voice transmission via the Primary Alerting System whereby the SAC Command Post or other National Military Command Authority used verbal alpha/numeric characters to provide the message. The crew members independently copied and decoded the messages at their consoles and agreed on the actions for the EAM and acknowledged it to their squadron command post in the missile field.” Both the Strategic Automated Command and Control System machine and the survivable Low Frequency Communication System then provided paper copies, but the message also was heard on particular UHF frequencies. The message communication sequence could take up to fifteen minutes to complete one EAM, and often crews averaged recording four messages per hour, excluding random test messages. Beginning in 1982, when the Air Force began installing the Air Force Satellite Communications System in the launch control facilities, crews received communication tests from the airborne command posts. Mesco, “Manuscript Review Comments,” 7 October 2011.

81. See note 80. In later years the deputy commander’s console received a launch enable control group signal panel requiring that an unlock code be inserted to ready the missile for launch.

82. Lonnquest and Winkler, To Defend and Deter, p. 244; Anderton, Strategic Air Command, pp. 145.

83. In the early 1960s, the Minuteman 1 alert tour had been 24 hours, with three crewmembers alternating an 8-hour tour topside. Strategic Air Command,


85. Strategic Air Command, History of the Strategic Air Command, 30 July 1975–30 June 1976, Historical Study No. 161, Vol. 1, pp. 470–474. Noise came from the air sent through the equipment racks to cool the dated technology as well as EAMS transmitted over the various communications systems. A cooling failure in the control center activated the Emergency Air Conditioning Unit, which required crewmembers to use head sets, with a voice enunciator and ear phones. Mesco, “Manuscript Review Comments,” 7 October 2011.

86. See note 85. Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1977, pp. 526–527. Only a small portion of the launch enabling information remained stored in the red metal box. Under Rivet Save, the ratio of six launch crews per flight remained. To maintain the 6:1 ratio, SAC decided to delete 550 rather
than 600 crewmember authorizations, but then determined that 81 more should be retained to account for excess travel time between sites and bases that had not been considered earlier.

87. By the 1980s, first lieutenants often served in the position of Minuteman Missile Crew Commander. In the 1980s, SAC’s implementation of operation Global Shield, which tested every aspect of its role in the 5109, meant longer alert tours involving two crews at each launch control facility on heightened vigilance for the three day exercise. Mesco, “Manuscript Review Comments,” 7 October 2011; Strategic Air Command, History of the Strategic Air Command, 30 July 1971–30 June 1972, pp. 630–632; see Chapter 111, note 81, this study; Wingate, *Man and the Missile: Factors Affecting Human Efficiency and Morale*, pp. 6–7; Maj Thomas J. Gosling, Maj James W. Knapp, and Maj Kenneth R. Morrison, *Future Management Applications in the Minuteman Operations Career Area: A Call to Action*, Air Command and Staff College, A Research Study Submitted to the Faculty (Maxwell Air Force Base, Alabama, May 1975), pp. 17–18.


89. For single African-American airmen at Minot in the 1970s, the isolation and prejudice they experienced led them to occupy a dining hall on the base in January 1975. A SAC investigation report agreed with many of the airmen’s complaints and implemented a program to deal with grievance and morale problems. Led by the 91st Strategic Missile Wing’s Social Actions Office, the effort focused on improving recreation facilities on base and developing a better relationship between Minot residents and the airmen. Strategic Air Command, *History of the Strategic Air Command, 30 July 1975–30 June 1976*, pp. 592–599; Gosling, Knapp, and Morrison, “Future Management Applications in the Minuteman Operations Career Area,” pp. 22–25; Col Norman B. “Blaine” McAlpin, USAF (Ret.), who served as a maintenance officer at Malmstrom in the late 1970s, emphasized the isolation situation at both Malmstrom and Minot, but noted its positive impact in creating stronger military and civilian relationships. Col Norman B. “Blaine” McAlpin, USAF (Ret.), email to the author, 8 March 2011.

90. Along with these three programs, SAC maintained its rigorous inspection and evaluation requirements to measure force performance. Most important were the Operational Readiness Inspections every eighteen months, the Nuclear Surety tests, and visits from the 3901st Strategic Missile Evaluation Squadron to review training programs, compliance with technical orders, and the quality of unit maintenance. By the 1980s, crewmembers averaged six to eight alerts per month. Mesco, “Manuscript Review Comments,” 7 October 2011.

92. Strategic Air Command, *Guide for Minuteman Crewmembers*, June 1977, pp. 44–45. Glory Trips drew support from a good portion of the base personnel. According to one missileer, “Raising money was a necessity,” and the base held fundraisers to purchase clothing for the team, including patches and pins. Additionally, the wing paid to fly civilians to Vandenberg on military aircraft as a part of its community relations program. Lt Col Michael J. Precella, USAF (Ret.), email to the author, 15 March 2011 and 17 March 2011.

93. See Chapter III, p. 81, this study. For the history of the competition and listing of participants and trophy winners, see Strategic Air Command, *Olympic Arena: The Saga of SAC’s Missile Combat Competition* (Offutt Air Force Base, Nebraska: Office of the Historian, 19 January 1977; Revised 20 February 1987). For a description of the 1973 competition, see Anderton, *Strategic Air Command*, pp. 150–156. Expressing the general sentiment of Olympic Arena participants, frequent competitor Rodney Holder considered the experience the “most rewarding and most fun” of his missile career. Col Rodney L. Holder, USAF (Ret.), email to the author, 26 July 2010.


man Education Program,” 6 November 1986, p. 4.


98. Strategic Air Command, *Missile Operations Duty Handbook*, SAC Pamphlet 55-13, 30 December 1988, pp. 3–4. Missile officers who were not crewmembers could enroll in the Minuteman program courses, but on a tuition assistance basis only.


103. Strategic Air Command, SAC Military *Chronology, 1939–1988*, p. 82; Aldrich, “Opening the Blast Doors to Women,” p. 7; Aldrich, interview by the author, 15 June 2010; Donovan, “The Integration of Women Onto Minuteman Missile Crews,” pp. 104–108. Both women worried that they were selected because of their gender. The senior officers making
the decisions assured them that their performance warranted their selection. In January 1988, Aldrich was reassigned to the 4315th Crew Training Squadron at Vandenberg as an instructor.


106. See note 105.


109. Strategic Air Command, *History of the Strategic Air Command, 1989*, pp. 198–199. When mixed-gender crews appeared, SAC installed a privacy curtain that crewmembers could pull across the capsule to divide the front of the alert area from the toilet area. Disliked by both male and female crewmembers, the so-called “Minute Maid” curtain was replaced when SAC installed a hard-sided toilet enclosure as part of Project Glowing Patriot. Not every crewmember approved of the new latrine modifications. Many, it seems, would have preferred that the money be used for a type of incentive pay for alert duty. Once again, SAC refused to address this twenty-year old issue. McAlpin, email to the author, 21 March 2011; Precella, email to the author, 17 March 2011.


112. Strategic Air Command, *History of
the Strategic Air Command, 1 January–30 December 1985, pp. 544–546; Strategic Air Command, History of the Strategic Air Command, 1988, pp. vii-23 to vii-24; Strategic Air Command, History of the Strategic Air Command, 1989, p. 195; Strategic Air Command, History of the Strategic Air Command, 1990, pp. 426–428. One maintenance officer who helped develop the original Rivet MILE concept argued that the key challenge was “convincing SAC and the larger Air Force of the need,” given that not all senior officers appreciated the fact that missiles cannot simply be sent periodically for depot repair or that infrastructure and ground support remain part of the weapon system. Two launch facilities at Warren stayed off alert during Rivet MILE because of concurrent Peacekeeper deployment. McAlpin, email to the author, 21 March 2011.


117. Minuteman III testing totaled sixty-eight of the seventy needed between 1980 and 1989. At the end of the decade only twenty-two Minuteman II missiles remained available for flight-testing. Strategic Air Command, History of the Strategic Air Command, 1990, pp. 401; GAO, Minuteman Weapon System, pp. 1–2, 3–4, 18, 19.

118. Degraded liners became a problem as the stage 2 motor approached its 17th year. As the older missile, Minuteman II’s stage 2 motor replacement preceded the Minuteman III change out. Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1984, p. 532; Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1986, p. 615; GAO, Minuteman Weapon System, pp. 15–17.


120. GAO, Minuteman Weapon System, pp. 6; Lonnquest and Winkler, To Defend and Deter, pp. 131–132.
Chapter V. The “Ultimate Deterrent” Peacekeeper, 1971–2005


16. Ibid., pp. 33–34. Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1982, Historical Study No. 195, Vol. 1, pp. 561–562, 567–568. Deploying at one Minuteman wing minimized command, control, and communications, while the closer spacing of Minuteman silos would become important were the administration to use the Army Ballistic Missile Defense assets for added survivability. Basing the MX in more northerly Minuteman silos would also prove important when technical and political decisions led to a reduction in the MX’s range. The late 1986 IOC date had in fact been established in 1979.

17. Ibid., pp. 34–35. Apparently the first choice for naming the MX was “Peace-maker.”


19. Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1982, pp. 563–570; Gibson, The History of the US Nuclear Arsenal, p. 28; Ballistic Missile Organization, Chronol-
ogy of the Ballistic Missile Organization, 1945–1990, p. 166; Stoss, “MX, Part II,” p. 9. Stoss notes that many congressmen were uncomfortable dealing with a scheme that clustered missiles close together rather than the traditional basing criteria of separation.


22. See note 20; Scowcroft, Report of the President’s Commission on Strategic Forces, 6 April 1983, pp. 15–21.

23. Scowcroft, “Report of the President’s Commission on Strategic Forces,” 6 April 1983, pp. 15–22; Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1983, pp. 604–609; Ballistic Missile Office, History of the Ballistic Missile Office, 1 October 1981–30 September 1983, pp. 35–37; Stoss, “MX, Part II,” p. 10. Stoss argues that deploying Peacekeepers in Minuteman silos would be $10 billion cheaper than closely spaced basing and $30 billion cheaper than multiple protective shelters. The Scowcroft Commission, however, projected five-year deployment costs of $14.6 billion, $22.9 billion, and $22.9 billion for the silo, closely space basing, and multiple protective shelter options, respectively (p. 22). At this point, in its assessment the commission viewed the Peacekeeper as the potential replacement for the Minuteman. In another section of the report, the committee members argue that the “mutual survivability shared by the ICBM force and the bomber force” precludes the need for additional protective measures for the Peacekeeper (p. 17). The SAC historian notes that Congress could, for the first time, approve Peacekeeper silo basing because 1) the program otherwise would be ended, 2) other basing schemes continued to prove too controversial, and 3) the commission’s proposals represented a bipartisan consensus.

24. Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1982, p. 561; Strategic Air Command, History of the Strategic Air Command, 1 January–30 December 1983, pp. 603–604. In addition to the propulsion contractors, Morton Thiokol, Aerojet, and Hercules, the MX associate contractors included Martin Marietta (airframe), Westinghouse (canister), Rockwell Autonetics (guidance and control), Northrop (inertial measurement unit and third generation gyro), Boeing (basing), AVCO (reentry vehicle), Honeywell (specific force integrating receiv-


27. Space and Missile Test Organization and Western Space and Missile Center, *History of Space and Missile Test Organization and Western Space and Missile Center, 1 October 1984 to 30 September 1985*, Vol. 1, pp. 53–54; United States Air Force, *Final Supplemental Environmental Impact Statement. Peacekeeper in Minuteman Silos Program*, December 1991, p. 10; Ballistic Missile Organization, *Chronology of the Ballistic Missile Organization, 1945–1990*, p. 373; Gibson, *The History of the US Nuclear Arsenal*, p. 27. Whereas two or three personnel with a missile loader could rearm the MX silo in several days, it required two ten-person Minuteman teams working 12-hour shifts seventeen days to rearm just one missile.


36. Martin Marietta, m-x Missile Development Flight Test Status Summary, 1982, pp. 6–7; Space and Missile Test Organization and Western Space and Missile Center, History of Space and Missile Test Organization and Western Space and Missile Center, 1 October 1979 to 30 September 1980, pp. 75–84. The Vandenberg historian provides comprehensive descriptions of the test facilities constructed and the archeological constraints.

37. Space and Missile Test Organization and Western Space and Missile Center, History of Space and Missile Test Organization and Western Space and Missile Center, 1 October 1986 to 30 September 1987, pp. 36–38; Ballistic Missile Organization, Chronology of the Ballistic Missile Organization, 1945–1990, pp. 167, 168, 172, 373–375.

38. Space and Missile Test Organization and Western Space and Missile Center, History of Space and Missile Test Organization and Western Space and Missile Center, 1 October 1979 to 30 September 1980, p. 70; Space and Missile Test Organization and Western Space and Missile Center, History of Space and Missile Test Organization and Western Space and Missile Center, 1 October 1986 to 30 September 1987, pp. 36–38; Ballistic Missile Organization, Chronology of the
Ballistic Missile Organization, 1945–1990, pp. 167, 168, 172, 374–376. The eighteenth test flight, on 19 March 1989, was the first launched by the Airborne Launch Control Center. The remaining two scheduled flights were cancelled due to the success of the program.


40. Strategic Air Command, History of the Strategic Air Command, 1 January–31 December 1983, p. 611; Strategic Air Command, SAC Missile Chronology, 1939–1988, p. 72; Gibson, The History of the US Nuclear Arsenal, p. 29. Although not as northerly as Malmstrom and Grand Forks, it was north of potential sites in Utah, Nevada, and New Mexico. The more northerly location proved fortuitous when the Peacekeeper received the Mark 21 reentry system and the heavier W-87 reentry vehicle, which resulted in an overall range reduction. The new payload arrangement also put the Peacekeeper beyond SALT II limits, which required removal of fuel from the fourth stage, further reducing the missile’s range.


42. See note 40.


Strategic Missile Wing, “Demonstration and Acts of Civil Disobedience, April 1984–September 1986,” 8 October 1986, pp. 1–5. One crewmember remembered on one occasion being followed back to base on the interstate highway by two unidentified men awaiting his departure at the end of the launch site’s access road. After base security forces he contacted arrived, the demonstrators exited the highway, but were seen later observing other sites. Col Rodney L. Holder, USAF (Ret.), email to the author, 28 June 2011.


49. See note 47.


54. Holder, email to the author, 28 June
Notes to pages 152-157

2011; Col Norman B. “Blaine” McAlpin, USAF (Ret.), email to the author, 18 November 2011. Titan II and Minuteman veteran Holder was one of the first cadre of Peacekeeper combat crew members selected for Peacekeeper duty.

55. See note 54. As McAlpin noted, “In practice, it was usually easier and quicker to return the second LCC to operational status (thus removing the entering argument for single flight ops) than it was to manually safe all the LFS in the ‘mini-squadron.’”

56. Holder, email to the author, 28 June 2011; McAlpin, email to the author, 18 November 2011. Without correct isolation, Peacekeeper signals would get on the Minuteman network, and vice versa, producing “noise on the line” faults. More often, the timing requirements would become the issue because the LF depended on only one or two network cables.

57. Holder, email to the author, 28 June 2011.


62. Department of State, Continuing the Acquisition of the Peacekeeper Missile,


66. See note 62. The Air Force announced the selected bases in November 1989. Those bases not selected were Blytheville, Malmstrom, Minot, and White-man. Criteria included the accessibility of existing rail lines, extent of railroad improvements needed, availability of appropriate land, and local public support.


72. Space and Missile Test Organization and Western Space and Missile Center, *History of Space and Missile Test Organization and Western Space and Missile Center, 1 October 1986 to 30 September 1987*, pp. 70–73; Ballistic Missile Orga-
nization, *History of the Ballistic Missile Organization*, 1 October 1990–30 September 1992, Chapter iv. To Congress and the general public, the Small ICBM was the “Midgetman,” a name never condoned by the Air Force.


80. 90th Space Wing, “Peacekeeper Sustainment/Deactivation.”

81. *Ibid.* Often crews referred to themselves as CDB and REACT crews, referring
to Peacekeeper and Minuteman, respectively.

82. Other modifications and upgrades available to Minuteman but not Peacekeeper included the Extreme High Frequency Communications System (MEECN) to ensure secure, reliable, and survivable communications between the LCCs and the National Command Authority, as well as the flight guidance system replacement initiative and the engine upgrade program to replace the solid rocket motors of all three stages. The Minuteman III also received a new Missile Guidance Set and Internal Measurement Unit. Air Force Space Command, *History of Air Force Space Command, 1 January 1994–31 December 1998 and 1 January 1999–31 December 2003, Combined*, pp. 143–156; 90th Space Wing, *“Peacekeeper Sustainment/Deactivation.”*


84. Holder, email to the author, 28 June 2011. Holder was one of the first three deputy commanders selected for Peacekeeper training. Like his fellow selectees, he considered it an honor to be chosen; Strategic Air Command, “SAC Missile Chronology, 1939–1988,” p. 81; 90th Strategic Missile Wing, *History of the 90th Strategic Missile Wing, 1 January–30 June 1988*, p. 21. In November 1988, the 400th Strategic Missile Squadron received its first three female officers. Rod and Melissa Reiday, who served at Warren and Vandenberg in the late 1990s, recall that officers entering the missile career field often chose Peacekeeper over Minuteman. Maj Gerard “Rod” Reiday, USAF (Ret.), and Capt Melissa Reiday, USAF (Ret.), email to Col Rodney L. Holder, USAF (Ret.), 28 June 2011.


87. See note 83. Following alert site evaluations, stan/eval teams also carried out evaluations in the missile procedures trainer.

88. 90th Space Wing, *History of the 90th Space Wing, 1 July–31 December 1998*, pp. 23–24, 27. On 1 July 1998, the term Force Development Evaluation replaced that of Follow-On Operational Test and Evaluation Program for ICBM operational testing. The three operational testing programs described in the paragraph are Olympic Play, Giant Pace Simulated Electronic Launch–Peacekeeper (SELP),
and Glory Trips.

89. Holder, email to the author, 28 June 2011.

90. Ibid.

91. Ibid.; Reidy and Reidy, email to Col Rodney L. Holder, USAF (Ret.), 28 June 2011; Lowe, email to the author, 29 June 2011. Peacekeeper veteran Jonathan Lowe especially appreciated his system when a shortage of instructors at Vandenberg led to him becoming REACT qualified. One 400th Missile Squadron commander admitted that, given the Peacekeeper’s uncertain future, several new crewmembers expressed concerns for their career progression. These concerns soon abated; and the commander noted the pride felt by all squadron personnel when he arranged for a ten-year anniversary celebration in 1996 and invited the 1986 contingent. Col Barry D. Kistler, USAF (Ret.), interview by the author, 2 June 2011.

92. For Peacekeeper performance figures, see the 90th wing histories for the 1991–1998 period; 90th Space Wing, “Peacekeeper Sustainment/Deactivation.”


94. 90th Space Wing, History of the 90th Space Wing, 1 January–31 December 1998, pp. 41–44; 90th Space Wing, History of the 90th Space Wing, 1 January 2000–31 December 2001, pp. 18–19; Air Force Space Command, History of Air Force Space Command, 1 January 1994–31 December 1998 and 1 January 1999–31 December 2003, Combined, pp. 170–179. The initial baseline inspection took place at Malmstrom on 5 March 1995. When Air Force Space Command assumed responsibility for the ICBM force on 1 July 1993, the 90th Missile Wing was redesignated the 90th Space Wing. The other missile wings had been redesignated space wings on 1 October 1992. The ICBM wings had been designated strategic missile wings from 21 February 1963 until 1 September 1991, at which time Air Combat Command assumed responsibility for the ICBM force from SAC and the wings were redesignated missile wings and the strategic missile squadrons redesignated missile squadrons. The missile squadrons retained their designation under Air Force Space Command, and when the space wings were redesignated missile wings on 1 July 2008.


97. See note 93.
103. 90th Space Wing, History of the 90th Space Wing, 1 January 2005–31 December 2007, pp. 28–34. Throughout the process security personnel faced the challenge of protecting personnel and material whose movement schedules were public knowledge. No incidents occurred, and no injuries marred the process.
facilities. The 30 percent caretaker option meant that the facilities received only an annual topside inspection. Although the least costly alternative for the Air Force, it resulted in 70 percent of the facility unusable in three years.


Chapter VI. The Once and Future Minuteman III, 1991–2011


Notes


8. Ibid., pp. 149–154. The Guidance Replacement Program is discussed below. Actual deployment of the Mark 21/W87 weapon set would have to await deactivation of the Peacekeeper.


15. The GRP would replace the D37D computer, missile guidance set controller, P92 amplifier, and wet slug tantaum capacitors and formvar transformers. A six-month work stoppage occurred while Martin-Marietta unsuccessfully protested the contract award. The Air Force also had to contend with a General Account-


21. See note 20. A second phase of the program would have included an accuracy upgrade, but SAC and then AFSPC declined to support the upgrade. In their view, the Minuteman III did not require Peacekeeper accuracy. Col Norman B. “Blaine” McAlpin, USAF (Ret.), interview by the author, 15 November 2011.


28. Beginning with the modification of the payload bulkhead assembly, the serv program included six major hardware elements, five software modifications, four support software modifications, a variety of additional support equipment, as well as command and control software for react compatibility. Northrop Grumman, Minuteman III, 3 March 2004, p. 97; Air Force Space Command, History of the Air Force Space Command, 1 January 2004–31 December 2005, pp. 64–66; Ogden Air Logistics Center, Minuteman Weapon, July 2001, p. 74.


31. The original 1960s-era equipment had a ten-year projected life span. Only the brine chillers had been replaced, and


33. EHF techniques provided faster recovery from scintillation caused by high-altitude nuclear detonations and better protection from jamming. The MEECN modernization program also included transitioning from UHF and SHF satellite communications systems to the more secure and effective Military Strategic and Tactical Relay (MILSTAR) “switchboard in space” and Ultra High Frequency Follow-On satellites, both with EHF transponders. Additionally, E-4B and E-6B aircraft would receive VLF/LF High Data Rate receivers and the launch control centers would acquire terminals removed from B-1 and B-52 aircraft that now included a High Data Rate capability. Air Force Space Command, History of the Air Force Space Command, 1 January 2004–31 December 2005, pp. 69–73; Air Force Space Command, History of the Air Force Space Command, 1 January 2004–31 December 2005, pp. 140–141; Northrop Grumman, Minuteman III, February 2010, p. 151; Federation of American Scientists, “ICBM Launch Control Centers (LCC) Communications,” http://www.fas.org/nuke/guide/usa/c3i/icbm-lcc.htm (accessed 15 September 2011).

34. See note 33.

35. See note 33.


8; McAlpin, interview by the author, 15 November 2011.


43. While the upgrade reduced site penetration time for security teams, it did not reduce the manpower requirements for maintenance crews who had used the security “penetrations” for periodic maintenance and inspections. Col Jeffrey E. Frankhouser, USAF, 20AF/A4, Lt Col Paul L. Johnson, USAF, 20AF/A3, and Mr. Arthur T. Beisner, 20AF/A9, interview by the author, 15 November 2011.


engineer personnel conducted quarterly drive-by inspections and a yearly topside inspection. McAlpin, interview by the author, 15 November 2011.


60. United States Air Force, Report on ICBM Industrial Base Capabilities, pp. 10–13. Intended to sustain industrial and laboratory work, the Demonstration/Validation Program had been in place for a number of years, funded at low levels. McAlpin, interview by the author, 15 November 2011.


62. The important Quadrennial Defense Review report issued in February 2010 addressed major themes such as defense strategy, “rebalancing” the force establishment, personnel support, and reform measures but neither discussed the ICBM element specifically nor included it in its listing of main elements of Air Force force structure. Department of Defense, Quadrennial Defense Review Report, February 2010, p. xvii.


64. The NPR also asserted that the U.S. would develop non-nuclear prompt global strike capabilities. Department of Defense, Nuclear Posture Review Re-


66. The party eliminating the launchers by “other procedures” might be required by the other party to provide a demonstration. Without eliminating the deactivated, non-deployed silo launchers at F.E. Warren, Malmstrom, and Vandenberg, the U.S. would be severely challenged to achieve the required limit of 800 deployed and non-deployed ICBM launchers, SLBM launchers, and heavy bombers configured to carry nuclear weapons. On 13 August 2008, the U.S. attempted to lower its treaty warhead total by having the Joint Staff declare that the fifty Peacekeeper silos had been converted to Minuteman III silos. For the START database, they now counted as 50 warheads rather than 500 warheads. Russia, however, subsequently protested the conversion, and the United States reversed its decision. On 23 November 2006, the U.S. declared the Peacekeeper attributed with eight warheads. The treaty also permitted the U.S. to deploy conventional warheads on its ICBMs but required that they be counted as nuclear warheads under the treaty. Although the inspection regime proved similar to START’s, the new treaty required fewer inspections. “Protocol to the Treaty between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms,” 8 April 2010, Part Three, Section III, para 2, http://www.state.gov/documents/organization/140047.pdf; USAF Central Node, CMTS System Change Request, SCR/SPR Number AF08-024, “All Deployed Peacekeeper launchers at FEWarren are now MM-III launchers,” 13 August 2008; Headquarters, United States Air Force, A5XP, “[On Alert] Manuscript Comments,” 12 July 2012; Woolf, “The New START Treaty: Central Limits and Key Provisions,” November 24, 2010, pp. 6–7, 14–15.


68. Woolf, U.S. Nuclear Weapons: Changes in Policy and Force Structure, 4 May 2011, p. 14; Maj Gen William A. Chambers, Assistant Chief of Staff, Strategic Deterrence and Nuclear Integration, “Presentation to the Senate Armed Services Committee Subcommittee on Strategic Forces, United States

69. Lt Col Anita Feugate-Opperman, USAF, email to the author, 8 September 2011; Capt Diane E. Percy, USAF, email to the author 25 August 2011; Capt Jannel A. Emery, USAF, email to the author, 19 September 2011; Capt Alina V. Matson, USAF, email to the author, 6 September 2011; Capt Nicole S. Holmstrom, USAF, email to the author, 4 September 2011.


75. General Deppe never felt that crewmembers took advantage of Netlink’s opportunities and argued that having to do their training after leaving the capsule meant that the “72s” actually reduced their time available for training. Maj Gen Thomas Deppe, USAF (Ret.), interview by George W. Bradley, Air Force Space Command/ho, 11 Decem-
ber 2011; Mr. George W. Bradley, Air Force Space Command/110, email to the author, 15 February 2012; Col Norman B. “Blaine” McAlpin, USAF (Ret.), email to the author, 16 February 2012.

76. See note 72. Matson, email to the author, 6 September 2011.

77. See note 72.

78. 90th Missile Wing, History of the 90th Missile Wing, 1 January 2008–31 December 2009, n.p.; Holmstrom, email to the author, 4 September 2011; Percy, email to the author 25 August 2011; Matson, email to the author, 6 September 2011.


83. As traditionally the case, a crewmember unable to perform alert for whatever reason felt worse for his/her replacement than the person filling in. McAlpin, email to the author, 6 September 2011; Feugate-Opperman, email to the author, 8 September 2011; Lt Col Larry D. Opperman, USAF, email to the author, 9 September 2011; Percy, email to the author 25 August 2011; Emery, email to the author, 19 September 2011.

84. The sewage “fix” did not completely solve the issue for at least one squadron, which reported that the bathroom fans in about half of the capsules were not operational. As for the “bathroom modification,” one missileer explained that none of the crewmembers using the “prison” toilet system thought the upgrade necessary but were not allowed to vote on the matter. As a result, “[w]e now
own toilets and all their associated smells are trapped in a four-sided box.” Feugate-Opperman, email to the author, 8 September 2011; Opperman, email to the author, 9 September 2011; Percy, email to the author 25 August 2011; Emery, email to the author, 19 September 2011; Col Norman B. “Blaine” McAlpin, usaf (Ret.), email to the author, 21 March 2011; Col Norman B. “Blaine” McAlpin, usaf (Ret.), interview with the author, 15 November 2011; Matson, email to the author, 6 September 2011; Holmstrom, email to the author, 4 September 2011.

85. One missileer recounted the story of a visit from a retired general. When asked about launch control center sustainment plans, he avoided the question and spoke instead about new warhead modifications that would extend the life of the missile. Holmstrom, email to the author, 4 September 2011.

86. The more senior missileers remained unhappy that their Strategic Missile Wing had been redesignated Space Wing, and a space badge replaced their missile badge. With the ICBM mission now belonging to Global Strike Command, missileers interviewed expressed their hope that regulation and direction would replace instruction and guidance in a nuclear operations and maintenance arena that had little flexibility for ad hoc innovation. *DSB Report 2011*, pp. 27–28, 36.


88. *Ibid.*, p. 44; Col Robert M. Walker, usaf, email to Col Norman B. “Blaine” McAlpin, usaf (Ret.), 22 September 2011. Colonel Walker cited the Headquarters Air Force memo, “Nuclear Career Path Designation Process for 13S Officers,” 10 Sep 2010, which states, “To the greatest extent possible, only ‘nk’ officers should be assigned to fill...staff positions designated for nuclear experienced officers. This allows non-‘nk’-coded officers to immediately start gaining depth in space operations.” McAlpin explained that when crewmembers approached the end of their initial crew tour, the career field manager at Air Force headquarters worked with the functional managers at AFSPC and AFGSC to create a quota for the year groups being considered. With that number established, the wing operations groups filled their fair share through volunteers and “recruits.” After that list was consolidated, the functional managers did any required vetting, or “horse-trading,” and the list was finalized. Col Norman B. “Blaline” McAlpin, usaf (Ret.), email to the author, 7 February 2012; Burg, “The Future of the Land-Based Deterrent Under Air Force Global Strike Command,” p. 7; Col Arthur T. Beisner, ii, usaf (Ret.), email to Col Norman B. “Blaine” McAlpin, usaf (Ret.), 21 September 2011; Capt Nicole S. Holmstrom, usaf, email to the author, 14 September 2011. The restructuring of the nuclear career field and the higher attrition rate at Minot made officer shortages greater at that base.

89. Normally, Vandenberg and each ICBM wing had four slots available per class. Maintenance and security forces officers could attend on a stand-by basis when a class was not filled by 13S officers. As of January 2012, each class had a slot reserved for a maintenance officer. See, Twentieth Air Force, “Advanced ICBM Operations Course Master List of Objectives,” AOIC 12-002 (F. E. Warren...

90. The Minuteman Education Program was discontinued in the mid-1990s. Feugate-Opperman, email to the author, 8 September 2011 and 9 September 2011; Opperman, email to the author, 9 September 2011; Percy, email to the author 25 August 2011; Matson, email to the author, 6 September 2011; Emery, email to the author, 19 September 2011.


95. Senate ICBM Coalition, The Long Pole of the Nuclear Umbrella, p. 11.

96. As of the summer of 2011, the Association of Air Force Missileers’ Missile Heritage Fund had donated $160,000 to museums and continued to sponsor awards for and assist with recognition programs for Global Strike Command. Col Charles G. Simpson, USAF (Ret.) email to the author, 23 August 2011; see, also http://www.afmissileers.org/.
## Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAF</td>
<td>Army Air Forces</td>
</tr>
<tr>
<td>ABM</td>
<td>Anti-ballistic Missile</td>
</tr>
<tr>
<td>AFBMD</td>
<td>Air Force Ballistic Missile Division</td>
</tr>
<tr>
<td>AFLC</td>
<td>Air Force Logistics Command</td>
</tr>
<tr>
<td>AFSC</td>
<td>Air Force Systems Command</td>
</tr>
<tr>
<td>AFSPC</td>
<td>Air Force Space Command</td>
</tr>
<tr>
<td>AMC</td>
<td>Air Materiel Command</td>
</tr>
<tr>
<td>ARDC</td>
<td>Air Research and Development Command</td>
</tr>
<tr>
<td>BMD</td>
<td>Ballistic Missile Defense</td>
</tr>
<tr>
<td></td>
<td>Ballistic Missile Division</td>
</tr>
<tr>
<td>BRAC</td>
<td>Base Realignment and Closure</td>
</tr>
<tr>
<td>CEBMCO</td>
<td>Corps of Engineers Ballistic Missile Construction Office</td>
</tr>
<tr>
<td>CEP</td>
<td>Circular Error Probable</td>
</tr>
<tr>
<td>CIA</td>
<td>Central Intelligence Agency</td>
</tr>
<tr>
<td>DEW</td>
<td>Distant Early Warning</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>EWO</td>
<td>Emergency War Order</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GRP</td>
<td>Guidance Replacement Program</td>
</tr>
<tr>
<td>HQ</td>
<td>Headquarters</td>
</tr>
<tr>
<td>ICBM</td>
<td>Intercontinental Ballistic Missile</td>
</tr>
<tr>
<td>IMU</td>
<td>Inertial Measurement Unit</td>
</tr>
<tr>
<td>IOC</td>
<td>Initial Operational Capability</td>
</tr>
<tr>
<td>IRBM</td>
<td>Intermediate Range Ballistic Missile</td>
</tr>
<tr>
<td>JCS</td>
<td>Joint Chiefs of Staff</td>
</tr>
<tr>
<td>LCF</td>
<td>Launch Control Facility</td>
</tr>
<tr>
<td>LEP</td>
<td>Life Extension Program</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>LF</td>
<td>Launch Facility</td>
</tr>
<tr>
<td>MEECN</td>
<td>Minimum Essential Emergency Communications Network</td>
</tr>
<tr>
<td>MGCS</td>
<td>Missile Guidance and Control System</td>
</tr>
<tr>
<td>MILE</td>
<td>Minuteman Life Extension</td>
</tr>
<tr>
<td>MIRV</td>
<td>Multiple Independently Targetable Reentry Vehicles</td>
</tr>
<tr>
<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
</tr>
<tr>
<td>MMP</td>
<td>Minutemen MEECN Program</td>
</tr>
<tr>
<td>MX</td>
<td>Missile Experimental</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
</tr>
<tr>
<td>NPR</td>
<td>Nuclear Posture Review</td>
</tr>
<tr>
<td>NSC</td>
<td>National Security Council</td>
</tr>
<tr>
<td>ODM</td>
<td>Office of Defense Mobilization</td>
</tr>
<tr>
<td>OSD</td>
<td>Office of the Secretary of Defense</td>
</tr>
<tr>
<td>PRP</td>
<td>Propulsion Replacement Program</td>
</tr>
<tr>
<td>PSI</td>
<td>Pounds per Square Inch</td>
</tr>
<tr>
<td>PSRE</td>
<td>Propulsion System Rocket Engine</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>REACT</td>
<td>Rapid Execution and Combat Targeting</td>
</tr>
<tr>
<td>SAB</td>
<td>Scientific Advisory Board</td>
</tr>
<tr>
<td>SAC</td>
<td>Strategic Air Command</td>
</tr>
<tr>
<td>SALT</td>
<td>Strategic Arms Limitation Treaty</td>
</tr>
<tr>
<td>SATAF</td>
<td>Site Activation Task Force</td>
</tr>
<tr>
<td>SELM</td>
<td>Simulated Electronic Launch-Minuteman</td>
</tr>
<tr>
<td>SERV</td>
<td>Safety-enhanced Re-entry Vehicle</td>
</tr>
<tr>
<td>SIOP</td>
<td>Single Integrated Operations Plan</td>
</tr>
<tr>
<td>SLBM</td>
<td>Sea-launched Ballistic Missile</td>
</tr>
<tr>
<td>SLEP</td>
<td>Service Life Extension Program</td>
</tr>
<tr>
<td>SORT</td>
<td>Strategic Offensive Reductions Treaty</td>
</tr>
<tr>
<td>SPO</td>
<td>System Program Office</td>
</tr>
<tr>
<td>SRV</td>
<td>Single Re-entry Vehicle</td>
</tr>
<tr>
<td>START</td>
<td>Strategic Arms Reduction Treaty</td>
</tr>
<tr>
<td>TCP</td>
<td>Technological Capabilities Panel</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>TRW</td>
<td>Thompson Ramo Wooldridge, Inc.</td>
</tr>
<tr>
<td>USAF</td>
<td>United States Air Force</td>
</tr>
<tr>
<td>WAC</td>
<td>Women's Army Corps</td>
</tr>
<tr>
<td>WDD</td>
<td>Western Development Division</td>
</tr>
<tr>
<td>WS</td>
<td>Weapon System</td>
</tr>
</tbody>
</table>
Bibliography

Books


**Articles**


Hebert, Adam J. “Making it Without a Minuteman IV.” *Air Force Magazine* 90, no. 6 (June 2007): 54–56.


Klass, Herschel V. “1st incentive contract...Minuteman Site Construction.” *Air Force Civil Engineer* 2, no. 2 (May 1961): 20–21.


Pomeroy, Steven A. “Highball! Missiles and Trains.” *Air Power History* 57, no. 3 (Fall 2010): 22–33.


Studies


Bowe, Donovan K., Colonel, USAF. Retention of Junior Officers in the Minuteman Mis-


Bibliography

1987. 90th Missile Wing Archive.


**Theses and Dissertations**


Stoss, Fred B., III, “MX Intercontinental Ballistic Missile: A Historical Study of the

**Congressional Documents**


**Published Government Reports**

*General Accounting Office*


*Department of Defense*


**Congressional Research Service**


**Executive Branch**

United States Department of State. *Continuing the Acquisition of the Peacekeeper Missile*. Special Report No. 123. 4 March 1985.

Scowcroft, Brent, Chairman. *The President’s Commission on Strategic Forces. Report of the President’s Commission on Strategic Forces*. 6 April 1983.
**Newsletters, Fact Sheets, Program Descriptions**


**Internal Reports, Policy Documents, and Speeches**


Air Force Audit Agency. “Report of Audit: Minuteman Education Program.” 6 No-


Chambers, William A., Major General, Assistant Chief of Staff, Strategic Deterrence and Nuclear Integration. “Presentation to the Senate Armed Services Committee Subcommittee on Strategic Forces, United States Senate.” 6 April 2011. Reprint. Air Force Space Command Archive.


Strategic Air Command. “Minuteman II Deactivation/Minuteman III Conversion, 341


Western Development Division, WDTP. “Solid Propellant Rockets for TBM.” Memorandum to Colonel Charles H. Terhune, Jr. 16 June 1955. Space and Missile Systems Center Archive.


**Interviews**


**Correspondence with Active Duty and Retired Missile Officers**


Bouchert, Ronald V., Colonel, USAF (Ret.). Email to the author, 12 July 2010.

Emery, Jannel A., Captain, USAF. Email to the author, 19 September 2011.

Feugate Opperman, Anita, Lieutenant Colonel, USAF. Emails to the author, 8 September 2011, and 9 September 2011.


Holmstrom, Nicole S., Captain, USAF. Emails to the author, 4 September 2011, and 14 September 2011.

Lowe, Jonathan E., Lieutenant Colonel, USAF. Email to the author, 29 June 2011.


Matson, Alina V., Captain, USAF. Email to the author, 6 September 2011.

Opperman, Larry D., Lieutenant Colonel, USAF. Email to the author, 9 September 2011.

Percy, Diane E., Captain, USAF. Email to the author 25 August 2011.


Simpson, Charles G., Colonel, USAF (Ret.). Email to the author, 23 August 2011.
Smith, Jason D., Major, USAF. Emails to the author, 8 September 2011, 31 January 2012, 2 February 2012, and 3 February 2012.

Walker, Robert M., Colonel, USAF. Email to Norman B. “Blaine” McAlpin, Colonel, USAF (Ret.), 22 September 2011.

Correspondence with Military Officials

Bradley, George W., Air Force Space Command/ho. Email to the author, 15 February 2012.


Stewart, Bruce S., Air Force Global Strike Command/HO. Email to the author, 31 August 2011.

Sturdevant, Rick W., Air Force Space Command/HO. Email to the author, 18 October 2011.

Chronologies


Handbooks/Guidebooks


**Official Histories**

**U.S. Army Corps of Engineers**


On Alert


*Strategic Air Command*


Strategic Air Command. *History of the Strategic Air Command, 1 January–30 June 1965*. Historical Study No. 98.


Strategic Air Command. *History of the Strategic Air Command, 1 January – 31 December 1987*.

Strategic Air Command. *History of the Strategic Air Command, 1988*.

Strategic Air Command. *History of the Strategic Air Command, 1989*.

Strategic Air Command. *History of the Strategic Air Command, 1990*.

**Air Force Space Command**


**Space and Missile Systems Organization**


**Ballistic Missile Office/Organization**


**Space and Missile Test Organization/Western Space and Missile Center**

Space and Missile Test Organization and Western Space and Missile Center. *History of
Space and Missile Test Organization and Western Space and Missile Center, 1 October 1979 to 30 September 1980.

Space and Missile Test Organization and Western Space and Missile Center. History of Space and Missile Test Organization and Western Space and Missile Center, 1 October 1984 to 30 September 1985.

Space and Missile Test Organization and Western Space and Missile Center. History of Space and Missile Test Organization and Western Space and Missile Center (SAMTOWSMC), 1 October 1986 to 30 September 1987.

90th Strategic Missile/Space Wing


Other


Strategic Air Command. History of the 706th Strategic Missile Wing (ICBM-Atlas) and 389th Air Base Group, 1st Missile Division, Strategic Air Command: Francis E. Warren


Index

138 career field, 190, 192, 194, 195
526th ICBM Systems Wing, 174, 177, 179, 180
9/11 (September 11, 2001), 169, 182, 184, 189, 192

AC Spark Plug Division, 33, 62, 65
Accident Investigation Board (SAC), 89
Adelman, Barnet R., 98
Advanced ICBM, 136–138
Advanced Inertial Reference Sphere, 146
Aerobee, 2
Aerojet-General Corporation, 56, 61, 92, 98, 117, 118, 119
Aerospace Corporation, 55, 139
Aerozine 50, 61, 92
Afghanistan, 193
Air Force Academy, 62, 83
Air Force Ballistic Missile Division/Ballistic Missile Division (AFBMD), 23, 32, 33, 36, 37, 38, 40, 41, 43, 44, 45, 46, 47, 60, 61, 68, 70, 99, 101, 102, 103, 104, 105, 106, 107, 110, 111, 112, 117
Air Force Center for Environmental Excellence, 164
Air Force Global Strike Command (AFGSC), 189, 193, 197
Air Force Logistics Command (AFLC), 31, 36, 47, 55, 86, 124, 131
Air Force Military Personnel Center, 82
Air Force Nuclear Enterprise, 193, 194, 197
Air Force Research Laboratory (AFRL), 190
Air Force Space Command (AFSPC), 92, 164, 165, 167, 170, 172, 173, 179, 180, 184, 185, 187, 193
Air Force Space Surveillance Network, 166
Air Force Systems Command (AFSC), 20, 21, 31, 39, 47, 67, 102, 105, 109, 124, 137
Air Materiel Command (AMC), 5, 10, 21, 22, 43, 45, 47, 96
Air Research and Development Command (ARDC), 9, 13, 15, 20, 28, 35, 43, 47, 48, 98, 102
Air Staff, 3, 5, 6, 8, 9, 10, 12, 13, 14, 15, 19, 21, 22, 28, 35, 51, 55, 62, 64, 77, 98, 99, 103, 104, 183
Air Training Command, 49, 90, 93
Airborne Launch Control System, 151
Aircraft
B-1, 109, 114, 137, 138, 139
B-2, 170
B-47, 25, 96
B-52, 25, 109, 138, 170, 192
B-58, 22, 25, 39
C-5A, 62, 137
EC-135, 151
F-102, 25
Albright, Madeleine, 163
Aldrich, Linda S., Colonel, 129
Aldridge, Edward C. “Pete,” Jr., 156
Allen, H. Julian, 11
Allen, Lew Jr., General, 49, 88
Alliant Techsystems, Inc. (ATS), 175
Altus Air Force Base, Oklahoma, 54
Ames Research Laboratory, 11
Anderson, Clinton, Senator, 21, 54
Anderson, Orvil A., Major General (also Anderson Report), 9
Angel, Doug, Master Sergeant, 191
Anti-ballistic missile (ABM) facilities, 4, 142, 170
Antiballistic Missile Treaty (1972), 165
Applied Physics Laboratory (Johns Hopkins University), 2
Area Engineer (Army Corps of Engineers), 46, 47, 48, 71, 111, 114
Chain, John T., General, 130, 133
Change Control Branch (SATAF), 47
Chanute Air Force Base, Illinois, 36, 49, 120
Charyk, Joseph V., 46
Cheney, Richard B., 134, 157, 169, 172
Cheyenne, Wyoming, 38, 147, 148, 149, 150, 164
Chico, California (Titan I), 54
Chidlaw, Benjamin, General, 5
Chilton, Kevin P., General, 184
Chrysler Corporation, 10
Church of Jesus Christ of Latter-day Saints, 141
Circular error probability (also CEP), 11, 66, 76, 105, 136
Clean Sweep, 51, 52
Closely Spaced Basing (also dense pack), 141, 142, 147
Coded Switch System, 87
Cohen, William S., 164
Command Data Buffer (also CDB), 132, 159, 173
Configuration Control Board (Ballistic Systems Division), 51
Configuration Control Board (Minuteman), 111
Console Operations Program software, 178
Consolidated Vultee Aircraft Corporation (also Convair), 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 22, 24, 25, 30, 37, 49
Cornwall, France E., 46
Corps of Engineers Ballistic Missile Construction Office (also CEBMCO), 45, 46, 47, 68, 69, 71, 72, 111, 112
Counter-Fatigue Guide (Minuteman III alert), 190
Cristadoro, Maurice A., Jr., Brigadier General, 39
Cuban Missile Crisis, 53, 57, 95, 115
Damascus, Arkansas, 89
Davis-Monthan Air Force Base, Arizona, 57, 68, 70, 71–74, 87, 91, 94, 141
Davis, Bennie L., General, 90, 128
Dean, Nancy K., Captain, 129
Dederick, Missouri, 170
Defend the United States of America Act of 1997, 163
Defense Planning Guidance (FY 2002–2007), 183
Defense Science Board, 186, 193
Del E. Webb Corporation, 113
Department of Defense (DoD), 4, 20, 23, 97, 100, 139, 140, 141, 148, 154, 165, 182, 183, 186, 188, 189
Department of Defense Appropriations Bill (2008), 186
Deppe, Thomas F., Major General, 177, 190, 191
Diamant, 97, 103
Director of Guided Missiles, 101, 102
Distant Early Warning (DEW) line, 22
Dole, Robert J. “Bob,” Senator, 90
Doolittle, James H. “Jimmy,” Lieutenant General, 10
Draper, Charles S. “Stark,” 11, 62, 65
Drell, Sydney (also see Drell Report), 176, 177
DuBridge, Lee A., 21
Duma (Russia), 164, 165
Duty Not Involving Alert (DNIA), 130
Dyess Air Force Base, Texas, 54, 155
Eastern Missile Test Center (Cape Canaveral, Florida), 30
Edwards Air Force Base, California, 110, 136
Eighth Air Force, 89, 109
Eisenhower Administration, 14, 16, 27, 28, 29, 99, 104, 106, 107, 116
Eisenhower, Dwight D., President, 14, 15, 16, 19, 20, 21, 22, 28, 29, 32, 39, 56, 117
Ellis, Richard H., General, 88
Ellsworth Air Force Base, South Dakota, 42, 115, 116, 118, 123, 134, 169
Embedded Memory Array Dynamic unit, 178
Emergency war order (ewo), 50, 78, 79, 86, 120, 121, 160, 171, 189
Enhanced Nuclear Detonation Safety system, 176
Eniwetok Atoll, 12
Environmental Control System (ECS), 178–179, 193
Environmental Protection Agency, 164, 173
Extended Life Program (Titan II), 86, 87
Fairchild Air Force Base, Washington, 41, 155
Faith and Resistance Retreat, 149
Fast-rising B-plug, 180
FBI, 153
Federal Mediation Service, 47
Fifteenth Air Force, 82, 123, 160
Finletter, Thomas K., 10
Fletcher, James C., 117
Fluor Corporation, 72, 73
Forbes Air Force Base, Kansas, 41
Fornes, Patricia M., Colonel, 85
Fort Bliss, Texas, 2

Gardner, Trevor, 15–17, 18, 19, 20, 21–22, 23, 24, 100
Gates, Robert M., 192
Gates, Thomas S., 27, 30, 44
Gemini program, 64, 66, 67
General Motors Corporation, 33, 62
General Samuel C. Phillips Award, 162
General Services Administration, 55, 56
George A. Fuller Company, 38
Gerrity, Thomas P., Major General, 45, 46, 47
Getting, Ivan A., 139
Giant Pace, 125
Gillette, Hyde, 22
Gilpatrick, Roswell L., 47
Glasser, Otto J., Lieutenant General, 31, 39
Glenn L. Martin Company, 33
Global Positioning System (GPS), 62, 139, 183
Global War on Terror, 169, 184, 190
Glory Trip, 125
Glowing Patriot, 131
Golden Ram, 51, 55
Goldsworthy, Harry E., Lieutenant General, 47, 48, 112, 114, 115
Gorbachev, Mikhail, President (Soviet Union), 134, 169
Gould, Gordon T., Jr., Major General, 115
Grand Central Rocket Company, 98
Grand Forks Air Force Base, North Dakota, 116, 118, 148, 155, 156, 170, 173
Great Falls, Montana, 104, 112
Ground launched cruise missile (GLCM), 64, 83
GTE Corporation, 133
Guggenheim Aeronautical Laboratory at the California Institute of Technology (also Caltech), 13
Guidance Replacement Program (GRP), 173, 174–175
Guided Missiles Committee (DoD), 12

Hardwick, Strother B., Colonel, 71
Hastings, Vernon L., Colonel, 35, 36, 37, 45
Hawk Springs, Wyoming, 135
Hayes, Thomas J., Brigadier General (USA), 43, 69
Head Disk Assembly, 178
Hercules Powder Company (also Hercules Corporation), 107
Hickman, Warren W., Colonel, 150, 152
Hill Air Force Base, Utah, 104, 106, 115, 170, 175, 178, 180
Hoapili, Evan, Colonel, 166
Holloway, Bruce K., General, 82
Holmes, Brainard, 67
House Armed Services Committee, 153, 164, 176
House Subcommittee on Military Construction, 46
Human Resources Laboratory, Lackland Air Force Base, Texas, 85
ICBM Cryptology Upgrade, 181–182
ICBM Demonstration/Validation Program, 187
ICBM Security Modernization Program, 180–181, 183
ICBM System Program Office (SPO), 174, 186
Improved Launch Control System (ILCS), 132
Improved Minuteman II, 118
Independent Assessment of the Air Force Nuclear Enterprise (DSB), 193
Indian Springs, Nevada, 146
Inertial Measurement Unit (IMU), 87, 145, 153, 157, 173
Inglewood, California, 19, 20, 44, 117
Initial qualification training, 78, 120, 129, 160
Iraq, 192
IRBM (Intermediate range ballistic missile), 16, 18, 20, 22, 26, 29, 61, 62, 96, 97, 98, 99, 100, 103, 109, 144
Jackson, Henry M. “Scoop,” Senator, 21
Jet Propulsion Laboratory, 2, 96
Joint Chiefs of Staff (JCS), 15, 50, 86, 101, 103
Joint Committee on Atomic Energy, 21
Joint Staff (JCS), 172
Jones, David C., General, 84
Jones, Teer, and Winkelman, 71
Jumper, John P., General, 165, 183
Junó, 2
Jupiter, 2, 16
Kazakhstan, 158
Keesler Air Force Base, Mississippi, 49
Kehler, C. Robert, General, 187
Keller, T.K., 10, 64
Kelley, Jay W., Lieutenant General, 83, 93
Kennedy, John F., President, 36, 47, 56, 95, 115, 116
Khrushchev, Nikita, Premier, 29, 95
KI-22 cryptographic device, 181
Killian, James R., Jr., 14, 16, 19, 21, 22
Kistiakowsky, George B., 47
Korean War, 10, 14, 25
KS-60 cryptographic device, 181, 182
Kwajalein Missile Range (Marshall Islands), 125, 147
Lackland Air Force Base, Texas, 85
Lahlum, Arthur H., Colonel (USA), 112, 113, 114, 115
Laird, Melvin R., 78
Lamm v. Weinberger, 149
Lamm, Richard D., 149
Large [Solid] Rocket Feasibility Program, 98
Larson Air Force Base, Washington, 42, 52, 54
Launch control facility, 37, 66, 114, 121, 122, 123, 149, 152, 161, 194
Launch control officer, 49, 119, 126, 127
Launch Enable Control Group panel, 124
Lawrence Livermore National Laboratory, 176
LeMay, Curtis E., General, 3, 4, 34, 36, 37, 45, 50, 51, 53, 97, 101
Lincoln, Nebraska, 36, 149
Little Rock Air Force Base, Arkansas, 68, 71, 73, 74, 88, 89, 91, 93, 94, 155
Lockheed (also Lockheed-Martin), 22, 166, 177
Lockheed Martin Space Systems, 166
Long Reach, 53
Long-Term Readiness Evaluation (Titan II), 75
Loral Command and Control Systems, 133
Lord, Lance W., General, 166, 167
Lowry Air Force Base, Colorado, 42, 44, 48, 49
Lutman, Charles C., Colonel, 112
Magna, Utah, 175
Malina, Frank, 2
March Air Force Base, California, 123
Mark, Hans M., 90
Marshall Islands, 120, 125, 147
Martin Marietta, 89, 171
Massachusetts Institute of Technology (MIT), 7, 11, 19, 62, 65, 100, 118, 139
Masters in Business Administration (MBA), 127
Matador, 6, 64
McConne, John A., 10
McConnell Air Force Base, Kansas, 68, 71, 73, 74, 81, 85, 87, 88, 89, 91, 93, 94, 136
McConnell, John P., General, 136
McElroy, Neil H., 4, 101, 102, 103
McNamara, Robert S., 31, 53, 54, 55, 56, 57, 59, 60, 76, 77, 95, 116, 117, 118
McNarney, Joseph T., Lieutenant General, 3
McPeak, Merril A., General, 177
Memory Controller Group drawer, 132
Military Aircraft Storage and Disposition Center (Norton Air Force Base, California), 92
Miller, George D., Lieutenant General, 148
Millikan, Clark, Dr., 13
Milner, Robert S., Colonel, 52
Milstar satellite communications system, 159
Minneapolis, Minnesota, 156
Minot Air Force Base, North Dakota, 116, 118, 120, 160, 170, 171, 172, 175, 176, 177, 179, 180, 181, 182, 192, 193, 196
Minot, North Dakota, 125, 196
Minotaur IV space launch vehicle, 166
Minuteman Education Program, 126–128, 195
Minuteman Force Modernization Program, 118
Minuteman I, 78, 95–116, 118, 119, 123, 137, 144
Minuteman IA, 110, 112, 115, 116, 118, 119
Minuteman IB (LGM-30B), 115, 116, 117, 119, 120
Minuteman II, 95, 116, 118, 119, 120, 123, 125, 131, 132, 133, 134, 157, 158, 169, 170, 171, 173
Minuteman IIF (SM80/LGM-30F), 118
Minuteman Long Range Plan, 131
Minuteman Minimum Essential Emergency Communications Network (MEECN) Program (MMP), 179–180
Mira Loma Air Force Station, California, 55
Missile Career Symposia, 83
Missile Electronics and Computer Assembly, 145
Missile Guidance and Control system (MGCS), 145, 151, 162
Missile Guidance Computer (D-37), 132, 134
Missile Management Working Group, 82, 123
Missile Potential Hazard Network, 89
Missile procedures trainer, 78, 80, 81, 90, 121, 132, 159, 161, 162, 189
Missile Sites Labor Commission, 36, 47
Modernized Minuteman II, 118
Morton Thiokol, 144, 146, 153
Moser, John T., Colonel, 89
Mountain Home Air Force Base, Idaho, 42
Multiple independently targetable reentry vehicle (also MIRV), 119, 137, 140, 143, 158, 159, 163, 171, 172, 177, 178, 188, 197
Multiple Protective Shelters (MPS), 140, 141
Mutual Assured Destruction, 182
MX missile (also see Peacekeeper), 91, 136–154
National Aeronautics and Space Administration (NASA), 20, 62, 64, 66, 67, 100, 109
National Defense Appropriation Act (1998), 163
National Defense Appropriations Act (2007), 184
National Military Establishment, 4
National Security Act (1947), 4
National Security Agency, 109, 181, 182
National Security Council, 10, 16, 21
National Security Council paper 68 (also NSC 68), 10
National Strategic Target List, 50
Navaho, 5, 6, 8, 11, 13, 16, 18, 25, 97
Naval Research Laboratory, 2
Netlink, 191
New Look, 14, 15
New START Treaty (2011), 177, 187, 188, 189
New Triad, 182, 184
Nike Ajax, 61
Nike Zeus, 4, 55
Nixon, Richard M., President, 77, 123, 136
North American Aviation, 11, 30, 32
Northrop Aerospace, 153
Northrop Electronics Division, 146
Northrop Grumman, 168, 174, 176, 177, 178, 180, 181, 182
Norton Air Force Base, California, 55, 92, 109
NS-17 Guidance System, 132
NS-20 Guidance System, 132, 173
NS-50 Guidance System, 173, 174, 175
Nuclear Posture Review (1994), 170, 171, 172
Nuclear Posture Review (2001), 164, 165, 182, 183, 184
Nuclear Posture Review (2010), 177, 187, 188, 189
Nuclear Surety Inspection, 161, 162
Nuclear Weapons System Safety Group, 124
Nuke Watch, 149
Nunn, Samuel A. “Sam,” Senator, 154
Oaks, Robert C., Major General, 128
Obama, Barak H., President, 187, 188
Occupational and Environmental Health Laboratory, Brooks Air Force Base, Texas, 93
Office of Defense Mobilization, 21
On Alert

Office of the Secretary of Defense (also OSD), 12, 18, 21, 22, 29, 30, 34, 35, 38, 51, 53, 55, 60, 63, 68, 74, 76, 77, 86, 89, 101, 102, 103, 106, 117, 136, 137, 140, 143, 146, 158, 164, 165, 170, 184, 186, 192
Office of the Secretary of the Air Force, 22, 100
Officer effectiveness reports, 128
Officer Training School, 124
Offutt Air Force Base, Nebraska, 36, 40, 42, 45, 48, 50
Ogden Air Logistics Center (ALC), Hill Air Force Base, Utah, 86, 87, 88, 89, 90, 124, 125, 131, 132, 133, 150, 170, 172, 174, 176, 177, 178, 181
Oklahoma City Air Material Area, 45
Olympic Arena (also see Olympic Arena Missile Combat Competition), 81, 94, 125, 126
On-Site Inspection Agency, 162
Operation Big Star (also Big Star), 104, 106, 117, 155
Operation Castle, 17
Operation Paperclip, 2
Operational Readiness Inspection, 53, 80, 122, 161
Operational System Test Facility, 37
Operational Test and Evaluation program, 125
Orbital Suborbital Corporation, 166
Orr, Verne, 128

Pacer Down, 88
Patrick Air Force Base, Florida, 34
Peacekeeper ICBM, 59, 86, 93, 94, 109, 117, 128, 130, 134, 135–167, 168, 170, 171, 172, 173, 175, 176, 177, 188, 189, 197
Peacekeeper Rail Garrison, 117, 154–157, 158
Perry, William J., 163
Personal Reliability Program, 190
Phillips Petroleum Company, 98
Phillips, Samuel C., General, 107, 109, 110, 162
Plant 77, 106
Plattsburgh Air Force Base, New York, 41, 56, 57
Pogo effect, 67
Point Loma, California, 8
Polaris IRBM, 22, 56, 98, 101, 103, 104, 108, 11, 144
Ponzer, Tina M., Airman First Class, 85
Poseidon Sea Launched Ballistic Missile, 76
Power, Thomas S., General, 34, 35, 37, 50, 51, 57, 104, 126
Pratt and Whitney, 175
Primakov, Yevgeny, 163
Princeton Institute for Advanced Study, 17
Project Green Jug, 74
Project Hermes, 2
Project MX-774 (also MX-774), 3, 6, 7
Project Rivet Save, 123
Project Thumper, 4
Project Top Banana, 74
Project Wizard, 4
Project Wrap Up, 74
Project Yard Fence, 74, 75
Prompt Global Strike, 183
Propulsion Replacement Program (PRP), 173, 174, 175–176
Propulsion System Rocket Engine (PSRE) program, 174, 176, 184
Putin, Vladimir, President (Russia), 165
Putt, Donald L., General, 9, 12, 15, 102
Q ICBM, 99, 101
Quadrennial Defense Review (QDR) (2005), 184
Quadrennial Defense Review (QDR) (2010), 187
Quarles, Donald A., 28, 31, 35, 38, 100
<table>
<thead>
<tr>
<th>Rail Garrison, 155, 156, 157</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ralph M. Parsons Company, 70, 111</td>
</tr>
<tr>
<td>Ramo-Wooldridge Corporation, 17, 18, 19, 23, 24, 30, 33, 61, 98, 99, 100</td>
</tr>
<tr>
<td>Ramo, Simon, 23</td>
</tr>
<tr>
<td>RAND Corporation, 10, 15, 17, 19, 21</td>
</tr>
<tr>
<td>Rapid Execution and Combat Targeting (also react), 131, 132, 133, 134, 159, 162, 166, 172, 173, 178</td>
</tr>
<tr>
<td>REACT Service Life Extension Program (SLEP), 178</td>
</tr>
<tr>
<td>Reaction Motors, Incorporated, 8</td>
</tr>
<tr>
<td>Reagan administration, 60, 91, 137, 141</td>
</tr>
<tr>
<td>Reagan, Ronald W., President, 23, 141, 142, 143, 149, 154, 155, 157</td>
</tr>
<tr>
<td>Redstone, 2, 5, 6, 10</td>
</tr>
<tr>
<td>Redstone Arsenal (Huntsville, Alabama), 2</td>
</tr>
<tr>
<td>Reentry systems</td>
</tr>
<tr>
<td>Mark 2, 32</td>
</tr>
<tr>
<td>Mark 3, 40</td>
</tr>
<tr>
<td>Mark 4, 33, 65</td>
</tr>
<tr>
<td>Mark 5, 108</td>
</tr>
<tr>
<td>Mark 6, 65, 90</td>
</tr>
<tr>
<td>Mark 11C, 116, 118</td>
</tr>
<tr>
<td>Mark 12, 119, 120, 148, 165, 166, 171, 176, 177</td>
</tr>
<tr>
<td>Mark 12A, 119, 120, 146, 148, 171, 176, 177, 178</td>
</tr>
<tr>
<td>Mark 21, 146, 147, 151, 153, 164, 165, 166, 171, 176, 177, 178</td>
</tr>
<tr>
<td>Reliability and Aging Surveillance Program (RASP), 78, 87, 92</td>
</tr>
<tr>
<td>Remote visual assessment system, 180, 181</td>
</tr>
<tr>
<td>Report on ICBM Industrial Base Capabilities (2008), 186</td>
</tr>
<tr>
<td>Reserve Officer Training Corps, 62, 124</td>
</tr>
<tr>
<td>Ridenour, Louis N. (Ridenour Report), 9</td>
</tr>
<tr>
<td>Ritland, Osmond J., Major General, 42, 104, 105, 106</td>
</tr>
<tr>
<td>Rivet Cap, 91, 92, 93, 94</td>
</tr>
<tr>
<td>Rivet Hawk, 78</td>
</tr>
<tr>
<td>Rivet Minuteman Integrated Life Extension program (also Rivet MILE), 131, 132, 158, 172, 173</td>
</tr>
<tr>
<td>Rivet Save, 123, 124, 189</td>
</tr>
<tr>
<td>Roche, James G., Dr., 135</td>
</tr>
<tr>
<td>Rock, Kansas, 88</td>
</tr>
<tr>
<td>Rocket Fuel Handlers Clothing Outfit, 89, 90</td>
</tr>
<tr>
<td>Rocketdyne engine, 6, 145</td>
</tr>
<tr>
<td>Rockwell Autonetics Division, 145, 153</td>
</tr>
<tr>
<td>Rocky Mountain Arsenal, Denver, Colorado, 92</td>
</tr>
<tr>
<td>RP-1, 25, 33, 54</td>
</tr>
<tr>
<td>Rumsfeld, Donald H., 164, 184</td>
</tr>
<tr>
<td>Rust, Clayton A., Colonel, 71</td>
</tr>
<tr>
<td>Sacramento, California, 87, 92</td>
</tr>
<tr>
<td>Safeguard, 78, 142</td>
</tr>
<tr>
<td>Safety Enhanced Reentry Vehicle (SERV) program, 166, 174, 176–178</td>
</tr>
<tr>
<td>Safety Enhancement Committee (SAC), 88</td>
</tr>
<tr>
<td>San Antonio Air Logistics Center, Texas, 92</td>
</tr>
<tr>
<td>San Bernardino Air Material Area, California, 55</td>
</tr>
<tr>
<td>San Jose, California, 175</td>
</tr>
<tr>
<td>Schlesinger, James R. (also see Schlesinger Report), 192, 193</td>
</tr>
<tr>
<td>Scientific Advisory Board, 9, 13, 20, 31, 105, 139</td>
</tr>
<tr>
<td>SCORE (Signal Communications Orbiting Relay Equipment), 32, 39</td>
</tr>
<tr>
<td>Scowcroft, Brent, Lieutenant General (also Scowcroft Report), 142, 143, 146, 150, 157</td>
</tr>
</tbody>
</table>
Sea launched ballistic missile, 76, 91, 138, 149, 158, 182, 188, 197
Searcy, Arkansas, 75
Sega, Ronald M., Dr., 167
Senate Committee on Appropriations, 186
Senate Preparedness Subcommittee, 73
Senate Subcommittee on Government Operations, 47
September 11, 2011, 169
Service Life Analysis Program (Titan II), 87, 92
Service Life Extension Program (SLEP), 178–179, 183
Sharp, Dudley C., 69
Sheppard Air Force Base, Texas, 49, 78, 85
Sheppard, Harry R., Representative, 46, 47
Simpson, Charles G., Colonel, 54
Simulated Electronic Launch-Minute-man (SELM), 125
Single Integrated Operational Plan (SIOP), 50, 59, 60, 87, 91, 125, 131, 132, 164
Single Reentry Vehicle, 171, 172
Site Activation Task Force (also SATAF), 36, 45, 46, 47, 48, 71, 72, 111, 112, 115, 116, 150, 151, 152
Small ICBM, 143, 157, 158
Snark, 5, 6, 8, 16, 18, 25, 97
Southeast Asia, 55, 124
Soviet Union, 7, 10, 14, 16, 27, 28, 29, 56, 59, 77, 92, 134, 139, 140, 141, 143, 156, 158
Spaatz, Carl A., General, 3
Space and Missile Systems Office, 124, 143
Space Systems Division, 31, 47, 105
Space Technologies Laboratories, 61
Special Aircraft Project Office, 21
Sputnik, 27, 29, 32, 37, 48, 56, 99, 101, 105
SS-16 ICBM, 137
SS-18 ICBM, 137, 138, 140, 142, 155, 158, 163
SS-19 ICBM, 137, 140, 155
SS-24 ICBM, 163
SS-9 Scarp, 77
Standard Oil Company of Indiana, 98
Star-48V motor, 166
START I, 134, 158, 162, 163, 164, 169, 172
START II, 158, 159, 162, 163, 164, 165, 171, 172, 177
State of the Union address (1992), 157, 158
Stephens, Allen W., Colonel, 49
Story, Worth, 38
Strategic Air Command (SAC), 14, 15, 28, 30, 34, 35, 36, 37, 38, 42, 45, 47, 48, 49, 50, 51, 52, 53, 55, 56, 57, 59, 62, 64, 68, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 91, 92, 93, 95, 101, 104, 106, 109, 115, 116, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 136, 137, 139, 148, 150, 151, 152, 153, 154, 155, 156, 158, 159, 160, 161, 162, 189, 197
Strategic Arms Limitation Treaty (SALT), 91
Strategic Arms Reduction Talks, 134, 157
Strategic Missiles Evaluation Committee, 17, 18, 62, 97
Strategic Offensive Reductions Treaty (SORT), 165, 188
SuperTel Network, 181
Surprise Attack Panel, 19
Swanke, Edwin A., Colonel, 45
Sycamore Canyon, San Diego, California, 30, 49
Symington, W. Stuart, 4
Talbott, Harold E., 19, 32
Technological Capabilities Panel (TCP), 19, 21, 22
Terhune, Charles H., Jr., Lieutenant General, 97, 101, 102
Thiokol Chemical Corporation, 96, 107
Thompson Ramo Wooldridge, Inc. (TRW), 144
Index

Thor, 16, 18, 20, 26, 35, 37, 62, 65, 96, 97, 98, 99, 100, 102, 109
Titan, 18, 20, 24, 26, 27—94, 96, 97, 99, 100, 101, 102, 103, 111, 113, 116, 122, 125, 126, 128, 130, 143
Titan I, 28, 33, 34, 37, 42–48, 49, 51, 52, 53, 54, 55, 56, 57, 59, 60, 61, 63, 64, 65, 66, 68, 69, 70, 72, 73, 82, 95, 102, 111, 116
Titan II, 20, 28, 33, 53, 55, 56, 57, 58, 59–94, 95, 111, 120, 123, 124, 125, 126, 128, 129, 138, 141, 143, 144, 197
Titan II Weapon Condition Safety Report, 89, 90
Townes, Charles H., 141
Triad, 59, 60, 74, 86, 134, 141, 143, 154, 168, 170, 172, 182, 184, 187, 188, 197
Trail's End club (Warren), 167
Trident II SLBM (also Trident SLBM), 91, 149, 170, 188, 197
Truman, Harry S., President, 2, 5, 8, 10, 12, 14, 64
Tucson, Arizona Titan II Residencies
  Ajo Residency, 71
  Benson Residency, 71
  Nogales Residency, 71
  Oracle Residency, 71
  Rillito Residency, 71
Turkey, 21
Twentieth Air Force, 175, 177, 186, 190, 191, 195
Twenty Year Technical Plan, 131
Twining, Nathan F., General, 19, 101
U-2, 15, 22, 56, 105
U.S. Army Corps of Engineers (also Corps of Engineers), 27, 38, 41, 43, 44, 45, 46, 47, 48, 67, 68, 69, 70, 71, 72, 73, 111, 112, 116, 150
Ukraine, 158
United Aircraft Corporation, 97, 110
Universal Space Guidance system, 87
V-2, 2, 6, 7, 8, 31, 97
Vandenberg Air Force Base, California, 30, 34, 35, 36, 37, 40, 41, 44, 45, 48, 49, 50, 51, 52, 53, 55, 56, 63, 66, 67, 68, 69, 74, 75, 76, 77, 78, 80, 81, 83, 85, 92, 93, 120, 121, 125, 126, 129, 146, 147, 160, 161, 166, 177
Vandenberg, Hoyt S., General, 5, 9, 10
Vanguard, 32
Vicksburg, Mississippi, 92
Vietnam, 124
Viking II, 13
Von Karman, Theodore, 1, 2, 5, 6, 9
Von Neumann Committee (also Teapot Committee), 17, 18, 19, 22
Von Neumann, John, 16, 17, 18, 22, 62
Warheads
  w-38, 40
  w-49, 40
  w-56, 116, 118
  w-59, 108
  w-62, 119, 120, 165
  w-78, 119, 120, 146
  w-87, 146, 153, 161, 165, 166, 171, 176
Wac Corporal, 2
Wade, James P., 140
Wake Island, 37
Walker Air Force Base, New Mexico, 46
War Department, 3, 4, 5
Warheads, 8, 11, 12, 17, 20, 29, 39, 54, 75, 115, 119, 120, 135, 137, 138, 140, 142, 143, 146, 158, 161, 163, 164, 165, 169, 171, 172, 177, 184, 188, 192, 197
Waterton Canyon, Littleton, Colorado, 33
Weapon System (WS)-107A (Atlas), 13
Weapon System 107A-2 (Titan), 33, 62, 64
Weapon System 133A (Minuteman), 97, 103, 118
Weapon System Q (see Q ICBM)
Weapons System Controller, 132
Weinberger, Caspar W., 141, 149

347
Welch, Larry D., General, 130, 133
Welling, Alvin C., Brigadier General (USA), 44, 45, 46, 47, 68, 69
Western Development Division (also see WDD), 18, 19, 20, 21, 22, 23, 24, 25, 27, 28, 30, 31, 32, 35, 36, 39, 40, 42, 62, 96, 97, 98, 99, 102, 105, 174
Western Missile Test Range (Vandenberg Air Force Base, California), 30
Western Solidarity, 149
Western Solidarity v. Reagan, 149
Westinghouse Electric Corporation, 138
Wetzel, Albert J. “Red,” Colonel, 63, 64
White Sands Proving Ground, New Mexico, 2, 8
White, Thomas D., General, 28, 31, 50, 101, 109
Whiteman Air Force Base, Missouri, 118, 128, 129, 130, 134, 169, 170
Wiesner, Jerome B. (also Wiesner Report), 47
Wilson, Charles E., 15
Wing Codes Processing System, 181
Wing II (Minuteman), 115
Wing V1 (Minuteman), 116, 118
Wright Air Development Center, 36, 96, 97, 98
Wright-Patterson Air Force Base, Ohio, 36, 39, 96, 97
WS-133A-M, 185
WS-120A (Peacekeeper), 136
Wurtsmith Air Force Base, Michigan, 155

XL43-NA-3 engine, 11
XLR43-NA-1 engine, 11
XLR87-AJ-5 engine, 63
XLR91-AJ-5 engine, 63

Zuckert, Eugene M., 117