ADAPTING TO FLEXIBLE RESPONSE 1960-1968

HISTORY OF ACQUISITION IN THE DEPARTMENT OF DEFENSE
Glen R. Asner, Series Editor

Volume I: Elliott V. Converse III, *Rearming for the Cold War, 1945–1960* (2012)

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Volume II

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Foreword

Adapting to Flexible Response, 1960–1968, presents a broad overview of weapons acquisition during the John F. Kennedy and Lyndon B. Johnson presidential administrations. It is the second of five planned volumes in the series *History of Acquisition in the Department of Defense*. This volume includes focused case histories of major weapons programs and useful explanations of program management, budgeting, and contracting practices during the 1960s. It captures the influence of politics and national security strategy on acquisition, as well as the unique challenges of fielding weapons for the Vietnam War.

With the advent of the Kennedy administration, political leaders began to exercise greater influence over defense acquisition. Robert S. McNamara, among the most forceful and influential secretaries of defense since the creation of the position in 1947, instituted changes in budgeting, management, and program evaluation during these years that shifted authority from the military services to the Office of the Secretary of Defense. Increased centralization was evidenced most strongly in decisions regarding requirements and funding for the acquisition of major weapon systems. Through a series of case studies across a wide spectrum of acquisition programs, ranging from strategic weapons for the military services to experimental space systems, *Adapting to Flexible Response* provides critical insights on how the political environment of the 1960s influenced individual weapons acquisition programs. Although the extent of Secretary McNamara's involvement in decisions regarding weapon systems generated intense opposition among the services, and some of his reforms were dismantled by his successors, the organizations and processes established during these years had a lasting impact on the Department of Defense, as later volumes in this series will show.

The Defense Acquisition History Project began in January 2001 when Dr. Jacques S. Gansler, at the time the Under Secretary of Defense for Acquisition and Technology, approved funding for the project and secured matching support from the acquisition assistant secretaries for the Army, Navy, and Air Force. Dr. Gansler's successor, Edward C. Aldridge, expressed his support for the project in June 2001, shortly after taking office.

Dr. Gansler and Mr. Aldridge both emphasized the importance of improving the acquisition community's understanding of its own history. As Under Secretary Aldridge put it in his letter endorsing the project:

> For the foreseeable future . . . we will develop and field armed forces in the face of rapidly changing technology and an uncertain and dangerous international environment. I believe that an in-depth, official history of acquisitions in DoD—an analysis of both successes and failures—can help guide us as we seek to acquire the weapon systems we need to meet the national security challenges that lie ahead.

The primary objective of this series is to provide contemporary acquisition professionals with a detailed account of defense acquisition that documents the fate of individual weapons programs, trends in contracting and program management, and key changes in acquisition organizations, processes, and policies in the Department of Defense. It is intended to capture in one place the triumphs, failures, and lessons learned of major weapons programs since World War II. Volume I in this series, *Rearming for the Cold War, 1945–1960*, by Elliott V. Converse III, was published in 2012. The remaining three volumes in the series are planned for publication over the next several years. Additional publications of the acquisition history project, all published by the U.S. Army Center of Military History, include a study of acquisition reform, *Defense Acquisition Reform,1960–2009: An Elusive Goal*, by Dr. J. Ronald Fox; a monograph on R&D in the military services, *Sources of Weapon Systems Innovation in the Department of Defense: The Role of In-House Research and Development, 1945–2000*, by Dr. Thomas C. Lassman; and the proceedings of a symposium on acquisition history, *Providing the Means of War: Historical Perspectives on Defense Acquisition, 1945–2000*, edited by Dr. Shannon A. Brown. These publications and other products of the acquisition history project, as well as an electronic copy of this book, can be found on the OSD Historical Office Web site.

Walter S. Poole received a baccalaureate from Princeton University in 1964 and a doctorate from the University of Pennsylvania in 1968. After a stint with the Joint Chiefs of Staff (JCS) Historical Division, he served in the Army from 1968 through 1970. Dr. Poole returned to the JCS Historical Division in 1970. He retired from that organization, renamed the Joint History Office, as chief of the Histories Branch in December 2000. During his time in that office, Dr. Poole wrote four volumes in *The Joint Chiefs of Staff and National Policy*, coauthored two additional volumes, and coauthored several other books, including *The JCS and the War in Vietnam, 1971–1973*, *The Effort to Save Somalia, 1992–1994*, and *The Chairmanship of the JCS*. He is currently writing a history of the Office of the Secretary of Defense during the presidencies of Richard M. Nixon and Gerald R. Ford.

Dr. Poole completed his work on this volume under the auspices of the Army Center of Military History, when the center was the executive agent for the acquisition history project. A panel of historians and experts convened by the center in 2006 recommended the volume for publication. The OSD Historical Office prepared the volume for publication after the transfer of the acquisition history project to the office in 2011. The views expressed in the volume, nonetheless, are those of the author and do not necessarily represent those of the Office of the Secretary of Defense.

This volume was reviewed for declassification by the appropriate U.S. Government departments and agencies and cleared for release. The volume is an official publication of the Office of the Secretary of Defense, but inasmuch as the text has not been considered by the Office of the Secretary of Defense, it must be construed as descriptive only and does not constitute the official position of the Office of the Secretary of Defense on any subject.

Glen R. Asner
Series Editor

Preface

After the end of World War II, the United States came to rely on superior weapons, primarily the nuclear bomb and its delivery systems, to offset numerical advantages in personnel and materiel held by the Soviet Union and Communist China. During the Dwight D. Eisenhower administration (1953–1961), this meant almost total reliance on such systems in a strategy known as massive retaliation. By the start of the 1960s, however, the Soviet Union was rapidly shrinking the U.S. lead in advanced weaponry. Moreover, some critics had begun to suggest that relying primarily on nuclear weapons to respond to conflicts across the military spectrum actually weakened national security. Although continuing to believe that maintaining the advantage in weapons technology, including strategic systems, was essential for security, the incoming John F. Kennedy administration implemented flexible response, a new strategy that called for increasing conventional military capabilities.

This volume covers the history of acquisition from 1960 to 1968, encompassing the final year of Eisenhower's second term and the presidencies of John F. Kennedy and Lyndon B. Johnson. Under the decisive leadership of Secretary of Defense Robert S. McNamara, the decade witnessed a transformation in defense acquisition. A vigorous and demanding executive who came from a vibrant American auto industry then in its postwar heyday, McNamara brought advanced business practices into the Office of the Secretary of Defense (OSD). He subjected acquisition, which to that point was largely the realm of the uniformed military, to intense civilian scrutiny based primarily on rigorous quantitative analysis of costs and benefits. Combined with centralized control of defense budgets, these practices ensured that the influence of Secretary McNamara and his closest associates was felt across the defense establishment.

The major themes of this volume include the interplay of military strategy and acquisition; growing centralization of defense budgeting; dramatic changes in the acquisition process; and the intense friction that developed between OSD and service leaders over these changes. Other key elements of this story are the responses of both the service acquisition organizations and industry to these developments, as well as the influence of Congress and the scientific community on acquisition policy. Consideration is also given to the growing cost and complexity of military technology; the dramatic effect that outside developments, such as the Vietnam War, had on weapons acquisition programs; significant changes in contracting methods; and the slow development of what would later be called the defense acquisition workforce.

Not all of Secretary McNamara's acquisition reforms can be judged successful. However, such judgments have been conflated with his management of the Vietnam War; in the end, his most significant managerial initiatives would remain permanent fixtures of the evolving U.S. defense establishment. Primary among these has been the five-year defense budget process and the use of quantitative analysis in military decisionmaking. In fact, nowhere have such practices been felt more sharply than in defense acquisition. This volume is in no way a complete history of weapons acquisition; it focuses on the major, more expensive programs that illustrate the trends and themes noted above, with a view to providing a basis for greater understanding of defense acquisition as it exists today.

Acknowledgments

This volume draws primarily on published studies of major weapons programs, the remembrances of key acquisition officials, and, to a lesser extent, on documents housed in U.S. government archives. It could not have been written without the research and analysis of earlier authors of books and articles on the weapon systems covered in this volume or on the recollections of those officials involved in acquisition during the 1960s who graciously shared their knowledge of critical events in oral history interviews, emails, and phone conversations. The author is deeply indebted to all of them.

The author also owes much to a handful of individuals who had the foresight to understand the value to the Department of Defense of a comprehensive history of acquisition. The late Dr. James H. Edgar, Director of Acquisition and Procurement Policy Reform in the Office of the Assistant Secretary of the Army (Acquisition, Technology, and Logistics), deserves credit for his perseverance in promoting the project among senior DoD acquisition officials and helping to launch it. Dr. Alfred Goldberg, former Chief Historian of the Office of the Secretary of Defense, and Dr. Jeffrey J. Clarke, formerly the U.S. Army's Chief of Military History, embraced the project and dedicated great time and effort to obtaining support for it within the Defense Department, thereby helping to ensure its success. Dr. Clarke deserves special recognition for directly overseeing the project from 2001 through 2006. Under Secretary of Defense for Acquisition and Technology, Dr. Jacques S. Gansler, and his successor, Edward C. Aldridge, provided the project financial support and the authority of their position. Other leaders of the DoD history and acquisition communities provided assistance at key points; they included Dr. Linda S. Brandt, Professor and Chair of the Department of Acquisition at the Industrial College of the Armed Forces; Brigadier General John S. Brown, formerly the U.S. Army's Chief of Military History; Dr. Diane T. Putney, former Deputy Chief Historian of the Office of the Secretary of Defense; and the late Dr. Stuart I. Rochester, former Chief Historian of the Office of the Secretary of Defense.

During the seven years of the project's formal existence, acquisition history authors and support staff worked together as a team, sharing what they had learned from their reading and research. Members of this group included Dr. David G. Allen, Dr. Glen R. Asner, Dr. Nancy K. Berlage, Dr. Shannon A. Brown, Dr. Andrew J. Butrica, Dr. Elliott V. Converse III, Dr. Joel R. Davidson, Dr. J. Ronald Fox, Dr. Carolyn C. Halladay, Dr. Thomas C. Lassman, Dr. Walton S. Moody, and Dr. Philip L. Shiman. Dr. Converse, the author of the first volume in the acquisition history series and the project's lead historian, provided direction to the group and set high standards for all authors to follow. Dr. Fox, a highly regarded expert on acquisition, professor at the Harvard Business School, and former senior acquisition official for the Army and the Air Force, served as the project's senior consultant. This volume relies heavily on his insights into contracting and firsthand knowledge of acquisition in the 1960s.

This book might never have been published if not for Dr. Erin R. Mahan, Chief Historian of the Office of the Secretary of Defense. She possesses an exceptional understanding of how knowledge of past acquisition might help the Department of Defense meet the continuing challenge of acquiring the weapon systems necessary for future security. Constrained by limited funding, she nevertheless worked tirelessly to ensure the publication of the first two volumes in the acquisition history series, thereby providing a solid foundation for the publication of subsequent volumes.

Members of a panel organized by the U.S. Army Center of Military History reviewed the manuscript and recommended it for publication. The comments and corrections of reviewers have made this a far better book than it otherwise would have been. Panel members included Dr. Paul Alfieri, Director of Research, Defense Acquisition University; Dr. Jeffrey G. Barlow, Historian, Naval History and Heritage Command; Dr. Nancy Berlage, Historian, Historical Office, Office of the Secretary of Defense; Dr. Linda Brandt, Professor and Chair of the Department of Acquisition, Industrial College of the Armed Forces; Dr. J. Ronald Fox, Jaime and Josefina Chua Tiampo Professor of Business Administration, Harvard University Graduate School of Business Administration; William Heimdahl, Deputy Director, Air Force History and Museums Program; Dr. Blair Haworth, Historian, U.S. Army Center of Military History; Dr. Alex Roland, Professor of History, Duke University; Dr. F.M. Scherer, Professor of Public Policy and Corporate Management in the Aetna Chair, Emeritus, Harvard University, John F. Kennedy School of Government; and Dr. Richard W. Stewart, Chief Historian, U.S. Army Center of Military History.

The OSD Historical Office extensively reviewed and edited the manuscript, significantly improving both its content and style. The author is grateful to Glen Asner, Elliott Converse, Alfred Goldberg, Erin Mahan, Jon Hoffman, the OSD Deputy Chief Historian, and Lisa Yambrick, the OSD Historical Office Senior Editor, for their countless hours of dedicated and skilled work. Outside the office, the author benefited from the review of two chapters by Dr. David N.

Spires of the Department of History, University of Colorado. Special thanks also to Nicholas E. Doyle of OSD Graphics, who designed the layout for the book, and to Kate Mertes, who created the index.

The author appreciably enhanced his understanding of important acquisition issues and programs through telephone conversations, the exchange of emails, and oral history interviews with key participants in acquisition during the 1960s. Among them were Charles A. Bowsher; Harold Brown; James N. Davis; Alain C. Enthoven; Brig. Gen. Alfred L. Esposito, USAF (Ret.); Robert A. Frosch; General Paul F. Gorman, USA (Ret.); Paul R. Ignatius; Robert S. McNamara; Tom Pelick; Dennis H. Trosch; and Rear Adm. Robert H. Wertheim, USN (Ret.).

Several scholars generously shared documents and information, including Dr. Robert S. Cameron, Armor Branch Historian, U.S. Army Training and Doctrine Command; Dr. Edward J. Drea, author of volume VI in the Secretaries of Defense Historical Series; Dr. W. Blair Haworth, Jr., U.S. Army Center of Military History; and Dr. Richard A. Hunt, author of volume VII in the Secretaries of Defense Historical Series.

During the course of his research, the author was ably assisted by the staffs of the Air Force Historical Studies Office; the Manuscripts Division of the Library of Congress; the National Archives and Records Administration, College Park, Maryland; the National Defense University Library; the Naval History and Heritage Command; the OSD Historical Office (OSD/HO); the U.S. Army Center of Military History; and the Washington National Records Center of the National Archives and Records Administration in Suitland, Maryland.

Most of the photographs illustrating this volume came from the online archive of the National Museum of the U.S. Air Force, the Naval History and Heritage Command and its online archive, OSD/HO, and the U.S. Army Center of Military History. Many individuals assisted the author in obtaining the foregoing and other photographs. They included Bill Bahnmaier, Defense Acquisition University; Michael Baker, Air Mobility Command; Richard L. Baker, U.S. Army Military History Institute; Dr. Jeffrey Barlow, Naval History and Heritage Command; Theodore (Ted) Beaupre, U.S. Army Garrison–Detroit Arsenal; Beth L. Crumley, U.S. Marine Corps History Division; Lisa Crunk, Naval History and Heritage Command; Rodney Foytik, U.S. Army Military History Institute; Colin A. Fries, National Aeronautics and Space Administration (NASA) History Office; Joe Gordon, Naval History and Heritage Command; John H. Hargenrader, NASA History Office; Dr. Kaylene Hughes, History Office, U.S. Army Aviation and Missile Command; Joseph Johnson, Defense Acquisition University; Janis Jorgensen, Heritage Collection, U.S. Naval Institute; Howard Kass, the American Helicopter Museum; Sharon W. Lang, U.S. Army Space and Missile Defense Command; Charles D. Melson, U.S. Marine Corps History Division; Dr. Charles P. Neimeyer, U.S. Marine Corps History Division; Jane H. Odom, NASA History Office; Julia O'Leary, the American Helicopter

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Although many people assisted the author in researching and writing this volume, only he is responsible for any errors it may contain.

CHAPTER I

Strategic Setting: Striving for Flexibility

Between 1945 and 1949, U.S. leaders considered the nation's stockpile of atomic bombs to be an effective deterrent against Communist aggression. The American sense of security did not last long, however. The Soviet detonation of an atomic device in August 1949 and the start of the Korean War in June 1950 provided chilling hints of the types of military threats that might emerge in the post–World War II era. Early setbacks suffered by U.S. troops in the Korean War, due in part to poor training and outdated equipment, reinforced the determination of civilian and military leaders to gain qualitative superiority over potential adversaries. Major rearmament across a spectrum of capabilities began in this context. By July 1953, when an armistice halted fighting in Korea, a sizeable military establishment supported by a large defense industry had become a central feature of the U.S. political economy.

EMPHASIZING NUCLEAR RETALIATION

President Dwight Eisenhower decided in 1953 that for the long term, the best deterrent against communism lay in the threat of massive nuclear retaliation. The credibility of that threat came principally from a fleet of long-range bombers, superior in number and quality to those of the Soviet Union. While Eisenhower's strategy emphasized the primacy of the Air Force, the Army and Navy developed their own nuclear delivery systems. Rather than imposing its will on the services, the Office of the Secretary of Defense (OSD) often acted as a referee, weighing in primarily to adjudicate disputes and allowing the services' overlapping programs to go forward. By so limiting its decisionmaking role, OSD drew criticism from Congress and the media for tolerating expensive duplication.

Eisenhower emphasized nuclear striking power, in part because the forces necessary for that purpose would impose less of a burden on the economy than would large conventional forces. Yet the threat of massive retaliation could remain credible only if U.S. nuclear forces enjoyed clear superiority. On 4 October 1957, the Union of Soviet Socialist Republics (USSR) launched Sputnik, the first Earth satellite, into orbit, raising the frightening prospect that nuclear missiles might be launched against American cities from afar. In the missile field, the Soviet Union appeared to be winning the race to deploy intercontinental ballistic missiles (ICBMs), the nuclear delivery system of the future.

Support for improving conventional warfare capabilities began to be heard within the Eisenhower administration even before Sputnik, in the summer of 1957. The development of the Basic National Security Policy (BNSP), the policy document that captured the president's strategic priorities, followed a lengthy process of debate in the National Security Council (NSC) each year. In May 1958, when a new BNSP debate began, some argued that limited war capabilities deserved much more emphasis. President Eisenhower, however, remained convinced that each small war would only make global war more likely. He feared that the burden of creating enough mobile conventional forces would turn America into a garrison state. Accordingly, he approved a policy that placed "main, but not sole, reliance" on nuclear weapons, considering them "as conventional weapons from a military point of view." Nonnuclear forces, combined with those of U.S. allies, would need to do no more than defeat or inhibit local aggression.[1]

The next version of the BNSP, which Eisenhower approved in August 1959, added a requirement to "contemplate situations . . . where the use of nuclear weapons would manifestly not be militarily necessary nor appropriate." The previous characterization of nuclear weapons as "conventional" had disappeared, but Eisenhower called the new requirement a clarification rather than a change in policy. As he put it, trying to prescribe how "limited" U.S. forces would meet local aggression would be "like asking how long is a piece of string."[2] Ballistic missile programs—Atlas, Titan, and Minuteman ICBMs along with Polaris submarine-launched ballistic missiles (SLBMs)—received added funding. By January 1960, a combination of U.S. progress and Soviet problems led to a National Intelligence Estimate that downplayed fears of a missile gap.[3]

How were investments in conventional weapons justified in this context? Late in 1960, the Army argued that it was trying to overcome a four-year procurement drought. Yet the Army's justification for the new M113 armored personnel carrier did not rest on its usefulness as an instrument of national strategy. Rather, the secretary of the Army claimed that the M113 would be more effective at half the price than the M59 it would replace.[4] Similarly, the new M60 tank cost less than its M48 predecessor despite having a better gun, a greater operating radius, and more maneuverability. The Navy could not justify spending for antisubmarine warfare (ASW) forces strictly in terms of convoy protection as was the case during World War II. But it did argue successfully that ASW forces would fill a role in general war, protecting American missile submarines and hunting Soviet boats.[5]

STRATEGY CHANGES QUICKLY, CAPABILITY SLOWLY

President John Kennedy entered office on 20 January 1961 convinced that the threat of nuclear retaliation could not deter a growing range of challenges. He wondered, for example, how strategic nuclear weapons could be used against Pathet Lao and Viet Cong guerrillas in Laos and South Vietnam. To provide the flexibility to fight Communist-inspired "liberation" forces in the Third World as well as Warsaw Pact armies in Europe, Kennedy and his secretary of defense, Robert McNamara, sought to build up nonnuclear forces and capabilities in a strategy known as flexible response. (Table 1–1 outlines the growth of conventional forces during the 1960s.)

Table 1–1: FORCES IN BEING

(Calendar Years 1960–1968)

	1960	1964	1968
B–47 Bombers	1,178	391	--
B–52 Bombers	538	626	579
B–58 Bombers	19	94	76
Atlas ICBMs	12	118	--
Titan ICBMs	--	115	59
Minuteman ICBMs	--	698	967
Polaris SLBMs	32	240	656
Army Divisions	14	16	19
Marine Divisions/Wings	3/3	3/3	4/3
Warships	376	388	423
Attack Carriers	14	15	15
Nuclear Attack Submarines	7	19	33
Air Force Tactical Fighter Wings	16	21	29
Active-duty Personnel	2,476,435	2,687,409	3,547,902

Sources: *DoD Annual Reports*; Raymond V.B. Blackman, ed., *Jane's Fighting Ships 1965–1966* (New York: McGraw-Hill, 1965); J.C. Hopkins and Sheldon A. Goldberg. *The Development of Strategic Air Command: 1946–1986* (Offutt AFB, NE: Office of the Historian, Headquarters Strategic Air Command, September 1986).

Seeing his predecessor's style of management as cumbersome and relatively inflexible, Kennedy abolished Eisenhower's NSC planning and operations coordinating boards. In their place appeared what one staff member called "a 'nervous system' through which the impact of the president's personality and influence can be registered at the operating level in the various agencies," as well as a route by which operators' views could be "flushed up" to the top level.[6] But such an informal approach left open questions regarding how and by whom defense policy and strategy would be defined.

Secretary McNamara, backed by a strong civilian staff, took the lead in the Pentagon. Draft Presidential Memorandums (DPMs) written by McNamara's staff were much crisper and more persuasive to civilian leaders than statements of strategy submitted by the Joint Chiefs of Staff (JCS), which were often compromised by attempts to reach consensus through accommodation of each service's viewpoint. DPMs became the vehicles by which McNamara defined strategy and force structure. Unlike Eisenhower's BNSPs, which were narrative expositions of policies and concepts, many of McNamara's DPMs contained tabulations of alternative force structures and mathematically based justifications of the ones chosen.[7]

Secretary Robert S. McNamara, Gen. Maxwell D. Taylor, and President John F. Kennedy at the White House, January 1963 (*Robert Knudsen/John F. Kennedy Library*)

McNamara, a Ford Motor Company executive lacking experience in national security affairs, drew ideas from think tanks, particularly the RAND Corporation, at the start of his tenure. He found RAND's analyses of controlled escalation especially appealing. In a nuclear war, according to escalation theorists, as long as aircraft and unprotected missiles were the only means of striking targets, any weapons that were not launched promptly would be lost. But the advent of hardened silos for land-based missiles and submerged missile-launching submarines created the possibility of holding weapons back and, by threatening targets with destruction, stopping a nuclear exchange short of all-out devastation.

Whereas Eisenhower believed that force was a blunt instrument to be used sparingly but massively, Kennedy and McNamara thought that a precisely controlled application of pressure by conventional forces (known as "graduated pressure") could achieve a limited objective without risking escalation into nuclear war. A stumbling block lay in many of the weapon systems they inherited, which were tailored for nuclear battlefields and poorly suited for all but relatively small, brief nonnuclear operations. A new strategy required new weapon systems with different kinds of capabilities, but the services proved to be unable and sometimes unwilling to adapt quickly. The Air Force was geared toward massive retaliation, and many of its senior officers, having served in the Strategic Air Command (SAC), were loath to change. When the United States began applying graduated pressure by bombing North Vietnam in 1965, weapon systems designed in the 1950s still filled the inventory. Although the Army stood to gain the most from a new strategy, it thought mainly in terms of refighting campaigns like those of World War II or Korea and shied away from counterinsurgency operations. The Navy had preserved a gamut of capabilities, due partly to its doctrines and a tradition of autonomy in developing its own weapon systems.[8]

In fiscal terms, shifting to a strategy of flexible response did surprisingly little to change funding priorities among the services. During the late 1950s, the Air Force received the most money and the Army the least. By fiscal year (FY) 1964, with the deployment of Minuteman ICBMs in full stride, the Air Force still placed first, at $19.4 billion. The Navy was second at $14.8 billion, due in part to accelerated deployments of Polaris SLBMs. The Army again finished last at $12.5 billion. Air Force and Navy budgets were supposed to start shrinking in 1965 as missile programs neared their objectives. Instead, savings were more than offset by spending for the Vietnam War, which, in employing large numbers of ground forces, brought the services toward rough equality. During FY 1968, totals stood at $25.4 billion for the Air Force, $25.4 billion for the Army, and $21.1 billion for the Navy.[9]

REWORKING NUCLEAR REQUIREMENTS

The first Single Integrated Operational Plan (SIOP) for waging nuclear war, SIOP–62, was completed a few weeks before McNamara took office.[10] When he was briefed about the plan, the secretary labeled its lack of flexibility as "perhaps our most fundamental weakness." The newly appointed civilians in OSD and the NSC staff set out to replace what they called a "spasm" approach to waging nuclear war with a range of options. Holding weapons in a protected reserve after the first exchange might coerce an enemy into ending the conflict. Consequently, the next plan, SIOP–63, was built around three tasks, each with five options.

SIOP–63 also provided for selectively withholding the kinds of attacks specified under each option.[11]

By autumn 1961, new intelligence showed that the United States enjoyed a large and growing lead over the Soviet Union in missile deployments. During the early years of the missile race, the approach to acquiring ICBMs and SLBMs was relatively unconstrained: produce and deploy them in numbers sufficient to outstrip an adversary. Secretary McNamara, through his DPM of December 1963, set a very different standard for sizing strategic retaliatory forces. The new standard was "assured destruction," which McNamara defined as the ability to retaliate, after the USSR had delivered a well-planned and executed surprise attack, by destroying 30 percent of its population, 50 percent of its industrial capacity, and 150 of its largest cities.

Between 1963 and 1965, U.S. strategic retaliatory forces enjoyed a lead that seemed unlikely to be overtaken. In 1964, McNamara leveled off the programmed Minuteman force of ICBMs at 1,000 launchers. Completing the strategic triad would be 54 Titan II ICBMs, 630 B–52 bombers, and 41 Polaris submarines carrying 656 SLBMs. But in 1965, the Soviets started work on an antiballistic missile system with a warhead powerful enough to destroy all three reentry vehicles of a Polaris A–3 SLBM. Moreover, intelligence estimated that by mid-1968, the Soviets would have about 500 ICBMs in hardened and dispersed silos. Thus, looking ahead, U.S. capability to penetrate defenses and destroy or neutralize targets appeared uncertain.[12]

A solution was in sight: multiple independently targetable reentry vehicles (MIRVs). In 1966, Secretary McNamara assigned the highest importance to modifying 31 Polaris submarines so that each could hold 16 Poseidon C–3 missiles. A C–3 would carry 10 or more separately targetable reentry vehicles with very small warheads. Moreover, C–3s would be accurate enough to take out some of the less protected counterforce targets (that is, military targets such as air bases and submarine homeports). Thus, Poseidon would provide not only penetrability but also better accuracy and survivability, allowing a much more controlled response. McNamara further planned to reequip about half the single-warhead Minuteman force with Minuteman IIIs, with each launcher carrying three MIRVs.[13]

Between 1961 and 1968, the focus of acquisition for strategic nuclear weapon systems shifted to improving guidance mechanisms. For example, the "Oscar" series of Transit navigation satellites enabled the locations of targets to be known with greater precision. As the accuracy of delivery improved, the yield and weight of individual warheads were reduced in order to increase the number of separately targetable warheads that ICBMs and SLBMs could carry. For example, the Poseidon C–3 missile was planned to carry either 10 to 14 Mark 3 reentry vehicles (RVs) for penetrating defenses or 2 to 3 Mark 17 RVs with much higher yields for hitting hard counterforce targets. However, a way was found to improve Poseidon's inertial guidance system as much for the Mark 3 as for the bigger Mark 17 without increasing costs. Accordingly, in 1967, McNamara cancelled the Mark 17.[14]

The importance that the administration attached to reaching a strategic arms limitation agreement with Moscow to curb the arms race increasingly affected nuclear strategy and force planning. Secretary McNamara pointed to a lack of clear intelligence on both sides of the Iron Curtain as driving force levels to untenable heights. Because the Soviets "could not read our intentions with any greater accuracy than we could read theirs," he reasoned, "we have both built up our forces to a point that far exceeds a credible second-strike capability against the forces we each started with." As a corrective, McNamara reshaped the force structure to conform with hoped-for arms limitations.[15]

Late in 1967, a National Intelligence Estimate put the Soviet ICBM force at 800 launchers, with 1,000 projected by the end of 1968. While the Joint Chiefs were deeply concerned over an imminent loss of U.S. superiority in launchers, McNamara was not. As he put it in a DPM dated January 1968:

> Numbers of launchers and bombers are a poor measure of the relative capabilities of the U.S. and Soviet strategic forces; total megatons are worse. . . . Factors such as accuracy, reliability, survivability and control are the most decisive in calculating the effectiveness of our forces. Our missiles appear to be more reliable than Soviet missiles; they are more than twice as accurate.
>
> Therefore, the best way to increase the effectiveness of our forces is by further reducing our large warhead forces . . . while putting MIRVs on Minuteman and Poseidon.

McNamara remained certain that the key capability was how many targets could be destroyed rather than how many megatons could be delivered. Ten Mark 3 reentry vehicles carried by a Poseidon C–3 could destroy up to 10 times as many targets as one 10-megaton weapon even though the total combined yield of all 10 vehicles was only 400 kilotons, one-tenth that of the larger weapon.[16]

Late in 1968, a National Intelligence Estimate predicted that the Soviets would take the lead in ICBM launchers by 1970 and, by the mid-1970s, send to sea a submarine force comparable to the Polaris fleet. Defense leaders did not see this forecast as changing the strategic nuclear equation. OSD analysts concluded that in a retaliatory strike during 1968, U.S. forces still could destroy nearly 50 percent of the Soviet Union's population and nearly 80 percent of its industrial capacity—more than enough to achieve assured destruction. Besides, OSD was convinced that the Soviets sought nothing more than acquiring their own assured destruction capability.[17]

Many JCS protests about the dire consequences of losing U.S. numerical superiority proved to be overdrawn, but one warning was well taken. How, the chiefs asked, could the United States be sure that Soviet leaders were thinking and acting in the same way? The Soviets did in fact keep building well beyond an assured destruction level, thereby casting serious doubt on McNamara's action-reaction explanation of the arms race. By mid-1972, the Soviet inventory numbered 1,618 ICBM launchers (either operational or under construction) and 950 SLBMs, compared to U.S. totals of 1,054 and 656.[18] Yet McNamara proved to be correct in predicting that assured destruction would not only deter general war but also smooth the way toward strategic arms limitation talks, which began in 1969. The Richard Nixon administration basically retained McNamara's strategic nuclear force structure under the rubric of "sufficiency."

GRADUATED PRESSURE: THEORY AND PRACTICE

In January 1961, many of the new administration's civilian leaders believed they had inherited a strategy that left them no alternatives except holocaust or humiliation. Again, the work of academics and think tank analysts impressed Kennedy and McNamara. For instance, Thomas C. Schelling, a RAND analyst and subsequently a professor of political economy at Harvard, conceived war as a particularly violent form of bargaining. William W. Kaufmann, who held concurrent positions at RAND and on the political science faculty at the Massachusetts Institute of Technology (MIT), wrote that limited wars should be so managed as to send an opponent messages that would "have a good chance of inducing him to accept limitations of geography, weapons, and possibly time. The scope and method of the initial attack will tend to define . . . the possibility of controlling it." During the early 1960s, Kaufmann served as a consultant and speechwriter to McNamara. General Maxwell D. Taylor, USA, provided a professional imprimatur for the new strategy. After retiring as Army chief of staff in 1959, he argued in *The Uncertain Trumpet* that massive retaliation, having reached a "dead end," should be replaced by a "Strategy of Flexible Response: This name suggests the need for a capability to react across the entire spectrum of possible challenge . . . from general atomic war to infiltration and aggressions such as threaten Laos and Berlin."[19] Taylor came to the White House in June 1961 as military representative of the president and then moved to the Pentagon as chairman of the JCS from 1962 to 1964.

In February 1961, McNamara advised Kennedy that maintaining a capability to conduct nonnuclear warfare should be the primary mission of U.S. overseas forces. The president approved a directive giving first priority for defending Western Europe to conventional capabilities. An OSD draft of basic national security policy proposed that "in local war, we place main, but not sole reliance on non-nuclear weapons" and apply the amount of force appropriate to the situation. But exactly what, for example, constituted "local war?" The draft cited any war involving more than 300,000 to 350,000 troops as the transition point from a conventional to a nuclear response. NSC staff members, echoing Eisenhower's doubts about the ability to quantify hypothetical situations, asked: why was that the proper point? Criticizing the draft from another angle, the Joint Strategic Survey Committee of the JCS claimed that it was "negative and inhibiting in nature and tended to over-emphasize control of military forces, avoidance of casualties and damage, defense, survival, without comparable concern for combat effectiveness, the offensive, or the will to succeed."[20]

Gen. Maxwell D. Taylor, USA (*Oscar E. Porter*)

General Maxwell D. Taylor (1901-1987)

Born near Kansas City, Missouri, Maxwell Taylor graduated fourth in his class at West Point in 1922. During World War II, he fought with the 82nd Airborne Division in Sicily and Italy and then led the 101st Airborne Division from Normandy into Germany. He commanded the Eighth Army during the Korean War's last months and from 1955 until his retirement in 1959 was Army chief of staff—a tour made less satisfying by President Dwight Eisenhower's cutbacks in Army strength. *The Uncertain Trumpet*, a biting critique of reliance on massive retaliation that Taylor published soon after his retirement, earned praise from presidential candidate John Kennedy.

In April 1961, just after the failed Bay of Pigs invasion of Cuba, President Kennedy chose Taylor to head a study group to assess the shortcomings of the operation. Recalled to active duty in June as military representative of the president, he visited South Vietnam in the fall and proposed sending 5,000 to 8,000 support troops, which Kennedy deferred. Taylor became chairman of the Joint Chiefs of Staff just before the Cuban missile crisis broke in October 1962. Although Kennedy rejected Taylor's arguments for a surprise attack against Cuba, the president valued him for ensuring that the service chiefs loyally carried out the U.S. quarantine.

During spring 1964, Taylor attempted unsuccessfully to find a middle ground between civilians' belief in "graduated pressure" and the service chiefs' advocacy of a "hard knock" bombing campaign against North Vietnam. In August, he became ambassador in Saigon and endorsed applying graduated pressure for a few months against Hanoi. When the Johnson administration considered committing ground combat troops in early 1965, Taylor expressed serious reservations. But as ground troops poured in and graduated pressure continued, Taylor defended the steps he initially criticized.

Returning home in July 1965, Taylor headed the Institute for Defense Analyses from 1966 until 1969. *Swords and Plowshares*, his 1972 memoir, combined acknowledgment of costly miscalculations about Vietnam with an argument for staying the course there.[I]

A renewed Soviet threat to West Berlin led the administration to articulate how flexible response might be conducted by applying gradations of pressure. The Soviets appeared ready to sign a separate peace treaty with their satellite state of East Germany, ending the Western Allies' right to remain in West Berlin. During the summer and autumn of 1961, Kennedy authorized manpower increases for all of the services, called up reserves, and sent some U.S.-based units to Europe. On 20 October, with tension at its height, Kennedy prescribed how to challenge any new Berlin blockade through a sequence of graduated responses: First, test Soviet intentions by using a platoon-size probe on the ground and sending fighters to escort transports through the air corridors. If these were driven back, strive to win local air superiority while launching division-size or larger operations into East Germany. If those also failed, make selective nuclear attacks "for the primary purpose of demonstrating the will to use nuclear weapons." Finally, resort to general nuclear war.[21] As civilian leaders saw it, the conventional buildup was the key factor in showing U.S. determination to defend West Berlin.

During 1961, the biggest change in the conventional force structure came through increasing the number of combat-ready Army divisions from 11 to 16. McNamara learned that Army stocks could support less than two months of conventional combat in Europe. Accordingly, he allocated $2.5 billion for Army equipment in FY 1963, twice the average for FYs 1956–1960, and $3.3 billion in FY 1964—enough to keep 16 divisions in combat from the time fighting began until deliveries from production equaled consumption. McNamara gave first priority to correcting conspicuous shortages, limiting modernization to items that would deliver large improvements in effectiveness. He was convinced that extensive re-equipping too often had yielded only "marginal" gains in combat capability.[22]

For civilian leaders, the outcome of the Cuban missile crisis confirmed the wisdom of having large conventional capabilities available, finely calibrating any display of force, and keeping a negotiating track open. On 14 October 1962, American U–2s overflying Cuba photographed Soviet medium-range ballistic missile sites. By imposing a naval blockade but rejecting JCS recommendations for a surprise air attack, Kennedy and McNamara believed they had applied exactly enough pressure to bring about withdrawal of offensive weapons without resorting to an escalation that risked nuclear catastrophe. From this outcome, McNamara drew key conclusions about crisis management. How to apply usable power, he stated in a 1963 interview, proved to be "even more difficult than any concern with the type or quantity of power":

> A naval commander who blockades wants . . . to stop all ships. . . . What complicates his decision is that the actions he takes . . . are also telegraphic messages to the Soviet Union, a way of signaling our intentions in a world where both sides have the power to destroy a large part of civilization. This situation requires that the important signals come from the highest political power in the country. As a result, we've had a basic shift in the level where decisions on the application of power take place.[23]

Increasingly, after Berlin and Cuba, the administration shifted its focus toward the Third World. Seeing Communist-sponsored insurgencies as the main threat in Latin America, Africa, and Asia, senior civilians declared "winning hearts and minds" of the common people to be a top priority. Upon taking office and repeatedly thereafter, President Kennedy had pressed the Pentagon to pay more attention to combating insurgencies. Helicopters offered the means for projecting military power quickly and deeply into underdeveloped areas. In April 1962, Secretary McNamara bluntly told the Army that its helicopter procurement proposals were too low. He foresaw, in airmobile operations, a "revolutionary break" creating a quantum increase in effectiveness. McNamara appointed a task force to bring out "bold, new ideas" that would be "protected from veto or dilution by conservative staff reviews." As a result, production of UH–1 tactical utility helicopters rose from 441 during 1961 and 1962 to 700 in 1964. The 1st Cavalry Division (Airmobile), with a complement of 434 helicopters, was activated on 1 July 1965 and promptly deployed to South Vietnam.[24]

President Kennedy (center) and Secretary McNamara (far right) attend counterinsurgency capability demonstration at Fort Bragg, North Carolina, October 1961 (*John F. Kennedy Library*)

A snapshot of U.S. general purpose forces taken on the eve of the Vietnam War would have shown impressive capabilities. The Army had five divisions in West Germany, two in South Korea, one in Hawaii, and eight in the continental United States—all combat-ready. One Marine division/wing team was stationed on the East Coast, one on the West Coast, and one in the Pacific. Forty-eight Air Force tactical fighter squadrons were available for deployment overseas. The Navy operated 15 attack carriers, with 2 or 3 normally deployed in the Mediterranean and 3 or 4 in the western Pacific.[25] Applying this power effectively in Southeast Asia, however, proved to be far more difficult than civilian and military leaders expected.

The battleground was South Vietnam, where, by late 1964, the Saigon government's counterinsurgency campaign involving only U.S. advisors and special forces had failed. The administration wrestled with how, without provoking Chinese intervention, Communist North Vietnam could be stopped from sending men and supplies to strengthen Viet Cong guerrillas in South Vietnam. During November 1964, two courses of action were debated. The first, endorsed by McNamara and most of the president's other advisers, called for "a slow, controlled squeeze" on North Vietnam. Beginning with airstrikes against infiltration targets would allow the United States "to escalate or not, and to quicken the pace or not, all the while indicating a willingness to negotiate and being ready to settle for less than our full objectives." The second alternative, advocated by the JCS, was a "fast/full squeeze," taking out 94 targets in North Vietnam that included industrial sites; the sole purpose of any negotiation would be to preserve an independent, noncommunist South Vietnam. President Lyndon Johnson, Kennedy's successor, chose a slow squeeze.[26]

The air campaign against North Vietnam, Rolling Thunder, ran from February 1965 through October 1968. Graduated pressure, one civilian asserted, was "a complex and sophisticated" operation requiring "a high degree of control."[27] Target selections had to be reviewed by McNamara and approved by the president because to bomb was to send signals about U.S. objectives. But while Washington pursued limited aims, Hanoi dedicated itself to an all-out effort for total victory. Gradualism in bombing North Vietnam and building U.S. ground combat forces in South Vietnam passed the initiative to the Communists, who could decide whether to match or exceed the latest escalation. Increasingly, even as their signals went unanswered, U.S. civilian leaders looked upon bombing spurts as a prelude to negotiations. Thus, in 1967, seeking to satisfy both those who wanted more bombing and those who wanted less, President Johnson gave airmen two weeks to destroy bridges over the Red River and the Canal des Rapides around Hanoi, then allowed the North Vietnamese a two-month respite in which they were rebuilt.[28] The leadership in Hanoi was not sufficiently coerced, and the government in Saigon was not sufficiently strengthened. The war became a stalemate in which the North Vietnamese outlasted the Americans.

Secretary McNamara (second from left) and President Lyndon B. Johnson (third from left) meet with the Joint Chiefs of Staff at LBJ Ranch, December 1964 (*Yoichi Okamoto/Lyndon Baines Johnson Presidential Library*)

Clearly, flexible response and graduated pressure failed to meet expectations. Whether the fault lay with the ideas or their implementation is still debated. McNamara's efforts to refocus acquisition in support of this strategy fell short, sometimes for reasons that were beyond his control. The time element, in particular, was crucial. New weapon systems had to become available soon enough, and there were important instances in which that proved infeasible. Two examples illustrate the persistent mismatch between McNamara's objectives and the means available to achieve them.

The first example involves tactical aircraft. During the heyday of massive retaliation, the Air Force considered abolishing its Tactical Air Command. Although the command survived, its mainstay was the F–105 Thunderchief, designed primarily for low-level delivery of tactical nuclear weapons, in which pinpoint accuracy was unnecessary. Throughout Rolling Thunder, F–105s carried out more strikes against North Vietnam than any other Air Force aircraft and led in battle losses. Designed to deliver a nuclear weapon at high speed from a low altitude, the F–105 had to engage MiG jets without a fighter's maneuverability and survivability. Modifications were made during 1966 and 1967. Nonetheless, the Thunderchief has been described as "an excellent aircraft for the mission for which it was designed but a poor one for the mission it actually flew. . . . At best it proved to be a mediocre performer in difficult conditions."[29]

McNamara directed the Air Force to procure the Navy's F4H–1 Phantom (later the F–4B), an interceptor with ground attack capability. Slightly modified as the Air Force F–4C, it was assigned the whole range of tactical missions. When Rolling Thunder began in 1965, F–4Cs carried only air-to-air missiles because the Navy had developed the Phantom to protect carriers by engaging attackers at long range. Over North Vietnam, however, crowded skies often compelled pilots to identify aircraft visually, sometimes at distances too close for missiles. Gun pods added to newer model F–4Ds degraded the Phantom's performance. Phantoms also left highly visible trails of black smoke that would not have mattered for Navy F–4s firing air-to-air missiles beyond visual range. In daylight over North Vietnam, however, smoke betrayed the F–4's position. An upgraded model, the F–4E, with a built-in cannon and an improved navigation system, reached Southeast Asia too late for Rolling Thunder.

The second example concerns "smart" (precision guided) weapons. Required to carry out a carefully restricted bombing campaign, the Air Force made improved accuracy a top priority. Yet toward the end of Rolling Thunder, unguided iron bombs dropped by F–105s still were scoring direct hits only 5.5 percent of the time. Between May and August 1968 in the extreme southern part of North Vietnam, F–4s delivered small numbers of laser-guided bombs that performed impressively. But this Paveway system, requiring two aircraft for each strike, incurred too much risk for use against heavily defended targets in North Vietnam. A Pave Strike system requiring only one aircraft entered service in 1972 and achieved remarkable results. Between February 1972 and January 1973, 48 percent of the smart bombs dropped in North Vietnam scored direct hits.[30] By then, though, the end of U.S. military involvement was near.

THE INDUSTRIAL BASE: PUSHING "STATE OF THE ART"

Victory in World War II came in part through outproducing the Axis powers. Survival in the Cold War seemed to hinge upon out-innovating the Soviet bloc, offsetting the greater quantity of some of their weapons with the superior quality of U.S. systems. The Defense Department drew upon its own arsenals and laboratories, upon universities acting as federally funded research and development centers, and, most of all, upon the resources of the private sector. By mid-century, large, diversified corporations run by technically trained professionals dominated the U.S. economy. Administratively, what emerged from diversified enterprises were decentralized structures, consisting of autonomous divisions that handled all the functions involved in creating a line of products and a general office that evaluated performance and allocated resources. These multi-industry giants, according to distinguished business historian Alfred D. Chandler, Jr., employed "by far the largest number of people who carr[ied] out the technological innovation so central to economic growth" and spent "the greatest part of the massive funds that the federal government . . . allocated to research and development since World War II."[31]

The military depended increasingly during this period on academic and private-sector institutions for new technologies and research breakthroughs in computing and advanced electronics. In the 1950s, the Air Force collaborated with IBM and MIT in developing the Semi-automatic Ground Environment (SAGE), a system for continental air defense that tracked enemy aircraft and directed interceptors or surface-to-air missiles against them.[32] SAGE, which became fully operational in December 1961, required a high-speed, electronic digital processing machine at each radar site and a central computer to process the data flowing in from those sites. Relying on vacuum tubes placed major limitations on electric switching. Physicists at Bell Laboratories had developed the transistor, in which electronic devices replaced metal contacts. Until the late 1950s, however, transistors had to be connected to each other on a circuit board. A breakthrough came when Fairchild Semiconductor created an integrated circuit that incorporated transistors and resistors on a small sliver of silicon, then added microscopic wires to interconnected components.

The Army Signal Corps guided and substantially funded a changeover from vacuum tubes to semiconductors and integrated circuits in both commercial and military applications. In 1965, IBM introduced its "360" family of computers, which used integrated circuits and were designed to meet a wide range of needs. No matter what the size of the computer, all contained the same solid-state circuits and responded to the same set of instructions. Many military applications existed for the 360 computers. The Air Force, for example, leased one to serve as the centerpiece of an infiltration surveillance center in Southeast Asia.[33]

Throughout the 1960s and well into the 1970s, military, nuclear power, and space applications dominated the market for semiconductors.[34] Combat aircraft, for instance, had been designed under the slogan of "higher, faster, farther." Now, aviation electronics, or "avionics" (for example, data processors, radar warning receivers, and jamming devices), emerged as a critical factor in determining capabilities.

Missile guidance systems provide another example of how academia, industry, and the military collaborated to innovate. Achieving the accuracy needed to destroy targets at intercontinental ranges required gyroscopes and accelerometers of extraordinary precision. Most of the detailed design of guidance systems, and nearly all the research on systems and components, was accomplished outside the military services. The Instrumentation Laboratory at MIT concentrated on inertial guidance and navigation, designing the guidance systems for Polaris and Poseidon SLBMs. By 1968, the United States stood well ahead of the Soviet Union in this critical area.

In January 1961, President Eisenhower had warned in his farewell address that the "conjunction of an immense military establishment and a large arms industry is new in the American experience. . . . In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex." These words would resonate. Nearly two years later, a reporter asked President Kennedy whether he "felt this threat" from the military-industrial complex. Having weathered strong protests against canceling the Skybolt air-launched ballistic missile and pressure from Congress to spend funds appropriated for the B–70 bomber, Kennedy answered in a wry and ambiguous way: "Well, it seems to me there is probably more in that feeling perhaps some months ago than I would say today." Might it become impossible, another reporter queried, to discontinue a weapon system if doing so would put thousands of people out of work? That, Kennedy acknowledged, was "one of our toughest problems. On the other hand, we can't let our defense budget go out of sight [when] . . . these systems are always two or three or four more times more expensive than they look like they are going to be."[35]

Significantly, neither Eisenhower nor Kennedy doubted that the military-industrial complex was capable of safeguarding the nation's security. In fact, its run of achievements created a risk of calling for more innovation than could be delivered. The services wanted to push the state of the art as far as possible; industry wanted contracts and was ready to promise fulfillment at reasonable prices. The outcomes frequently involved performance shortfalls as well as cost and schedule overruns. Tradeoffs often came to mean not sacrificing one goal to achieve another, but accepting an even greater shortfall in one area to lessen the shortfall in another.

Defining the limits of technology and what constituted the state of the art posed increasingly serious problems. The record of the Autonetics Division of North American Aviation provides illuminating examples. Autonetics won the guidance contract for Minuteman I by claiming that it could keep an all-inertial system in continuous operation. Within two years, unexpected and increasing complexities drove the original estimate of $37 million up to $260 million. When the mean time between failures remained too short, subcontracts given to more than a dozen companies corrected the problem. For guidance in Minuteman II, Autonetics engineers decided to replace transistors with the brand-new technology of integrated circuits. But the circuits failed so frequently that 40 percent of Minuteman IIs went out of service. Air Force officers blamed Autonetics for taking miniaturized electronics too far. Managers were changed, engineers were seconded from TRW, Inc., and the problem was fixed, albeit with sizeable delays and cost overruns.

The Mark II avionics system was another Autonetics undertaking. Consisting of seven major components, it promised a huge improvement in conventional bombing accuracy. Almost every managerial reform was employed, but practically nothing went right. No matter how much time and money were added, performance fell well short. There was a basic incompatibility between air-to-air systems needing extremely fast rates of data processing and air-to-ground systems needing large capabilities for storing and processing data. Mark II revealed the limits of a "can-do" approach to acquisition.[36]

THE POLITICAL AND ECONOMIC ENVIRONMENT

In World War II's aftermath, the United States had the world's highest living standard and most productive economy. The fear of overstraining the economy with military spending that prevailed in the late 1940s diminished as the 1950s wore on. Between 1959 and 1968, the share of the gross national product devoted to defense remained about the same: 8 to 9 percent. During Kennedy's tenure, the defense budget grew by almost 20 percent, facilitated by a spurt in economic growth that minimized pressure on the civilian sector. But the economy had little idle capacity, and supplying the war effort in Vietnam overheated it. Inflation, which had averaged 1.2 percent during 1960–1964, reached 3.4 percent in 1966 and 4.7 percent by 1968. As the costs of the war and Johnson's Great Society programs grew, the combination of inflation and budget deficiencies placed new constraints on military spending.[37]

During the 1950s, the memory of unreadiness for World War II and Korea helped sustain bipartisan backing for a strong military establishment. In fact, President Eisenhower came under criticism for spending too little on defense rather than too much. In 1961, Congress promptly approved nearly all of President Kennedy's proposals, raising the defense budget by almost 20 percent. The military services had powerful allies in Congress. A seniority system put conservative southern Democrats into chairmanships of the Armed Services Committees: in the House, Carl Vinson of Georgia followed by L. Mendel Rivers of South Carolina, and in the Senate, Richard B. Russell, Jr., of Georgia. When Secretary McNamara differed with generals and admirals, conservative Democrats usually sided with the uniformed officers. As an Air Force officer working on missile development later observed, "We spent some $3 billion a year for six years. . . . [C]an you imagine operating for six years and not have any major litigation, major publicity incident, a Congressional review . . . [or] investigation, and spending all that kind of money? . . . [I]t was a different era; people thought differently in those days."[38]

The Vietnam War eventually changed everything. In the spring of 1965, when the first U.S. combat troops went to South Vietnam, President Johnson's actions drew fairly wide public support. As troop commitments grew and casualties rose, that support slipped steadily. By 1967, the administration faced anger from "doves" on the left for escalating the military effort and from "hawks" on the right for not escalating further and faster. Both hawks and doves perceived a credibility gap between what the administration predicted and what actually was occurring in Vietnam. Early in 1968, the enemy's Tet offensive turned the credibility gap into a chasm.

A broader change, though, was the American public's loss of confidence in its government's ability to act wisely. By 1968, there was a widespread feeling that good intentions had gone badly awry. Taking office in January 1969, Richard Nixon faced a public wary of security commitments and a Congress ready to clamp down upon military spending.[39]

* * * * *

A key dilemma for national leaders in the 1950s and 1960s was whether strategy should be harmonized with weaponry or weaponry should be harmonized with strategy. The Eisenhower administration settled upon a nuclear strategy for which weapon systems were either already or imminently available. B–47 bombers were being produced in large numbers, and intercontinental B–52s were nearing production. The Kennedy administration quickly imposed major changes in nuclear and conventional strategy, then set about creating the instruments needed to implement them, although the deployment of new systems lagged behind the shift in strategy.

Under the Eisenhower Defense Department, the acquisition process normally was service-driven. As subsequent chapters will illustrate, Secretary McNamara set out to centralize decisionmaking in OSD. He emphasized criteria like commonality, cost-effectiveness comparisons, and multiservice and multimission availability. Almost as disruptive as they were innovative, his reforms would have a sweeping impact on acquisition in the 1960s.

Endnotes

1. Robert J. Watson, *History of the Office of the Secretary of Defense*, vol. IV: *Into the Missile Age, 1956–1960* (Washington, DC: Office of the Secretary of Defense Historical Office [OSD/HO], 1997), 110–113; *Foreign Relations of the United States* [FRUS] *1958–1960*, vol. 3 (Washington, DC: U.S. Government Printing Office [GPO], 1996), 61, 86–88, 98–102 (quotations, 101–102).

2. *FRUS 1958–1960*, vol. 3, 292–296, 286–287 (quotations, 295, 286).

3. Ibid., 135–136, 327, 356–357, 373; Donald P. Steury, ed., *Intentions and Capabilities: Estimates on Soviet Strategic Forces, 1950–1983* (Washington, DC: CIA History Staff, 1996), 109–112.

4. While the M59 had welded steel construction, the M113's hull was made of welded aluminum plate. Aluminum cost less than steel and was, pound for pound, more resistant to shell fragments, allowing cheaper fabrication and a net saving in weight. Consequently, an M113 cost $22,000 compared to $28,000 for an M59. W. Blair Haworth, Jr., *The Bradley and How It Got That Way: Technology, Institutions, and the Problem of Mechanized Infantry in the United States Army* (Westport, CT: Greenwood Press, 1999), 28, 24.

5. *FRUS 1958–1960*, vol. 3, 504–506.

6. *FRUS 1961–1963*, vol. 8 (1996), 15–17.

7. Lawrence S. Kaplan, Ronald D. Landa, and Edward J. Drea, *History of the Office of the Secretary of Defense*, vol. V: *The McNamara Ascendancy, 1961–1965* (Washington, DC: OSD/HO, 2006), 83–85.

8. Ibid., 1–15.

9. Office of the Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2005* (March 2004), table 6–10, "Department of Defense Budget Authority by Service, FY 1945–FY 2009," 123–124. *Budget authority* is the authority to incur obligations that will result in the outlay of federal funds. Defense budget authority is provided almost exclusively through annual congressional appropriations. In the years covered by this volume, the federal government's fiscal year began on 1 July and ended on 30 June of the next calendar year and

was identified by the latter year. Beginning in FY 1977, the fiscal year began on 1 October and ended on 30 September of the next calendar year.

10. The Joint Chiefs of Staff prepared a National Strategic Targeting and Attack Policy. That document provided the basis for the National Strategic Target List and the SIOP, both prepared by the Joint Strategic Target Planning Staff working under the commander-in-chief, Strategic Air Command. This process is described in Byron R. Fairchild and Walter S. Poole, *The Joint Chiefs of Staff and National Policy: 1957–1960* (Washington, DC: Office of Joint History, 2000), 51–54, and Watson, *Into the Missile Age*, 473–494.

11. Fred Kaplan, *The Wizards of Armageddon* (New York: Simon and Schuster, 1983), 201–285; *FRUS 1961–1963*, vol. 8, 40–42, 82, 74–77, 196, 138–152, 181–187 (first quotation, 41; "spasm," 82); Scott D. Sagan, "SIOP–62: The Nuclear War Plan Briefing to President Kennedy," *International Security* 12, no. 1 (Summer 1987): 22–51.

12. Rhodri Jeffreys-Jones and Christopher Andrew, eds., *Eternal Vigilance? 50 Years of the CIA* (London: Frank Cass, 1993), 125; Graham Spinardi, *From Polaris to Trident* (Cambridge: Cambridge University Press, 1994), 72; J.C. Hopkins and Sheldon A. Goldberg, *The Development of Strategic Air Command: 1946–1986* (Offutt Air Force Base, NE: Office of the Historian, Headquarters Strategic Air Command, 1 September 86),154; Steury, *Intentions and Capabilities*, 217.

13. "Record of Decision" memo, SecDef McNamara to Pres Johnson, "Recommended FY 68–72 Strategic Offensive and Defensive Forces," 9 Nov 66, binder "DPMs, FY 68–72, Programs 1966," box 120; "Record of Decision" memo, SecDef to Pres, "Strategic Offensive and Defensive Forces," 15 Jan 68, binder "DPMs, FY1969," box 121, both in Henry Glass ASD (Compt) Papers (hereafter Glass Papers), Record Group (RG) 330, OSD/HO.

14. Donald MacKenzie, *Inventing Accuracy* (Cambridge: MIT Press, 1990); Spinardi, *From Polaris to Trident*, 76; draft memo, SecDef to Pres, "Recommended FY 69–73 Research and Development Program," 22 Sept 67, box 120, Glass Papers, RG 330, OSD/HO.

15. "Summary Minutes: Meeting of the Defense Industry Advisory Council," 10–11 Sept 65, 10, box 990, OSD/HO; Robert S. McNamara, *The Essence of Security* (New York: Harper and Row, 1968), 60–65 (quotation, 60); Robert S. McNamara, *Blundering into Disaster: Surviving the First Century of the Nuclear Age* (New York: Pantheon Books, 1986), 57–58.

16. Steury, *Intentions and Capabilities*, 225; memo, SecDef to Gen Earle Wheeler, 2 Aug 67, JCS 2458/272, 560 (2 Aug 67) sec 1 (IR 1952), RG 218 (Records of the Joint Chiefs of Staff), National Archives, College Park, MD (hereafter Archives II); memo, SecDef to Pres, "Strategic Offensive and Defensive Forces," 15 Jan 68; "Tentative Record of Decision" DPM, "Strategic Offensive and Defensive Forces," 9 Jan 69, both in binder "FY 1970 DPMs," box 122, Glass Papers, RG 330, OSD/HO; Alain C. Enthoven and K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program, 1961–1969* (New York: Harper and Row, 1971), 179–180.

17. Steury, *Intentions and Capabilities*, 240, 241, 246; Enthoven and Smith, *How Much Is Enough?* 177–178; memo, DepSecDef Nitze to Gen Wheeler, 29 Jul 68, JCS 2458/428, 560 (29 Jul 68), sec 1, RG 218; "Tentative Record of Decision" DPM, "Strategic Offensive and Defensive Forces," 9 Jan 69.

18. JCSM–481–67 to SecDef, 28 Aug 67, JCS 2458/272–2, 560 (2 Aug 67) sec 1, RG 218; Dept of State *Bulletin*, 3 Jul 72, 9–10.

19. Kaplan, *Wizards of Armageddon*, 330, 218 (quotation, 218; original quotation in William W. Kaufmann, ed., *Military Policy and National Security* [Princeton: Princeton University Press, 1956], 113). In 1964, Kaufmann published *The McNamara Strategy*. Maxwell D. Taylor, *The Uncertain Trumpet* (New York: Harper, 1959), 6.

20. *FRUS 1961–1963*, vol. 8, 42, 104 (para 4), 122, and vol. 14 (1994), 285–287. Ultimately, the president decided against approving a new statement of basic national security policy.

21. *FRUS 1961–1963*, vol. 14, 520–523.

22. Draft Memo, SecDef to Pres, "Recommended FY 1964–1968 General Purpose

Forces," nd (late Nov 62), 37–38, binder "FY 1964 DPMs," box 116, Glass Papers, RG 330, OSD/HO.

23. Theodore H. White, "Revolution in the Pentagon," *Look* 27, no. 8 (23 April 1963), 28. During the crisis, the commandant of the Marine Corps, General David M. Shoup, summed up the apprehensions of uniformed military leaders about how civilians might upset complex operational planning: "If somebody could keep them from doing the goddamn thing piecemeal. That's our problem." Ernest R. May and Philip D. Zelikow, *The Kennedy Tapes: Inside the White House During the Cuban Missile Crisis* (New York: W.W. Norton Co., 2001), 122.

24. Enthoven and Smith, *How Much Is Enough?* 100–104; Howard K. Butler, *Army Aviation Logistics and Vietnam, 1961–1975* (St. Louis, MO: Historical Office, U.S. Army Aviation Systems Command, January 1985), 403–404.

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31. Alfred D. Chandler, Jr., "The Structure of American Industry in the Twentieth Century: A Historical Overview," *Business History Review* 43, no. 3 (Autumn 1969): 274, 278–279 (quotation, 279).

32. The Air Force's Air Defense Systems Integration Division contracted with MIT's Lincoln Laboratory for electronic technical assistance. In 1959, one of the laboratory's divisions split off to become the nonprofit MITRE Corporation that would handle SAGE and later provide systems engineering expertise for a range of military and civilian customers.

33. Vernon W. Ruttan, *Is War Necessary for Economic Growth? Military Procurement and Technology Development* (New York: Oxford University Press, 2006), 95–96, 99–101, 104.

34. Ibid., 101–102.

35. *Public Papers of the Presidents: Dwight D. Eisenhower, 1960–1961* (Washington, DC: National Archives and Records Service, 1961), 1038; *Public Papers of the Presidents: John F. Kennedy, 1962* (Washington, DC: National Archives and Records Service, 1963), 895–896.

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37. Anthony Campagna, *The Economic Consequences of the Vietnam War* (New York: Praeger, 1991), 15, 35, 53, 64–65, 74.

38. USAF oral history interview, Maj. Gen. Osmond J. Ritland, USAF (Ret.), by Lyn R. Officer, 19–21 Mar 74, vol. 2, 316–317, K239.0512–722, Air Force Historical Studies Office (AFHSO), Joint Base Anacostia-Bolling, Washington, DC.

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CHAPTER II

Bidding for Control: Secretary McNamara and the Services

Upon taking office as secretary of defense on 21 January 1961, Robert McNamara quickly concluded that serious managerial shortcomings were hobbling the Defense Department. Military planning appeared unconnected to budgeting done by civilians. Planning was performed in terms of missions, units, and weapon systems; budgets were built around categories such as personnel, operations and maintenance, procurement, and construction. These procedures, McNamara believed, prevented the secretary from defining alternatives and choosing among them.[1] He and his comptroller, Charles J. Hitch, promptly created new mechanisms: a Planning, Programming, and Budgeting System (PPBS) and a Five-year Defense Program (FYDP).

Requirements, rather than the fiscal ceilings the Eisenhower administration had imposed, were supposed to determine the size of the defense budget. But how and by whom should requirements be determined? What McNamara saw as the parochialism of the services and lowest common denominator compromises by the Joint Chiefs of Staff convinced him that the Office of the Secretary of Defense could do the job best. He brought to the Pentagon a cadre of civilians who appraised alternatives by comparing them in terms of cost-effectiveness. They employed the techniques of "systems analysis," which in their eyes epitomized rationality and objectivity, to decide which weapon systems to buy and in what quantities.[2]

During his seven-year tenure, McNamara centralized decisionmaking to a far greater extent than any of his predecessors. According to John H. Rubel, deputy director of defense research and engineering, "We couldn't see how we were going to get a grip on the enormous programs we were supposed to supervise. . . . And you know what is the most significant observation I've made since McNamara came? Just the enormous difference one man can make, the tremendous changes in practice one can bring about with no effort at all to alter the laws."[3] But McNamara's prestige and influence peaked between 1963 and 1965 and slowly waned thereafter. He was never able to secure the willing support of most uniformed military leaders. Generals and admirals, seeing their prerogatives shrink and some of their favorite programs slashed, were alienated. That outcome may have been inevitable, given the nature of the changes McNamara made. Failures in the Vietnam War, with which the secretary was deeply involved, also gave his critics ample ammunition. By the end of 1968, McNamara had departed, and centralized decisionmaking was in retreat. Nevertheless, a good many of McNamara's reforms survived to guide Department of Defense budget and acquisition practices long into the future.[4]

CREATING THE PPBS AND FYDP

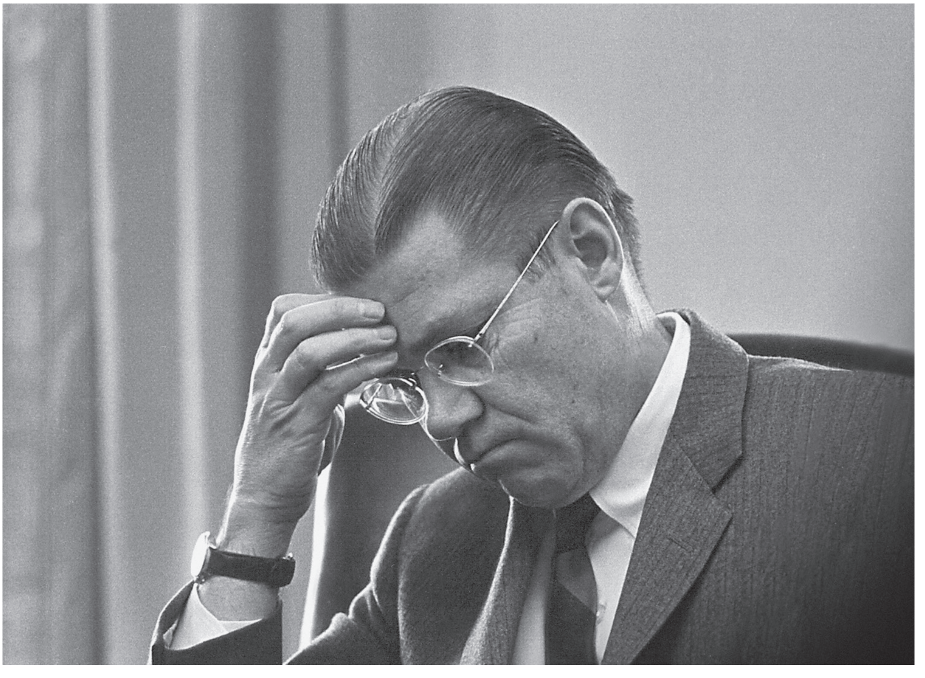
The Department of Defense Reorganization Act of 1958 gave the secretary of defense more authority, including greater control over the service secretaries. In developing weapon systems in the 1950s, the Army and Navy had relied on their semi-autonomous technical bureaus, while the Air Force worked through its Air Research and Development Command. Neil H. McElroy, who served as secretary of defense from 1957 until 1959, and Thomas S. Gates, in office from 1959 until 1961, depended on three subordinates to monitor the activities of the military services.

The first, Wilfred J. McNeil, supervised preparation of the defense budget as assistant secretary of defense (comptroller) from 1947 until 1959. Since holding down costs loomed large in President Eisenhower's thinking, McNeil was Wilson's and McElroy's most influential subordinate. McNeil, in fact, helped select weapon systems and force levels "to a degree that earned him the distinction of being targeted by legislation that would forbid him to exercise 'judgment' in military matters."[5] Under McNamara, however, the comptroller and his staff found ways to play an even larger role.

The second key subordinate, the director of defense research and engineering (DDR&E), a position created by the 1958 act, ranked above the assistant secretaries and just below the deputy secretary of defense. The DDR&E had authority to recommend an integrated research and development (R&D) program, review programs of the military departments and other DoD agencies, propose assignment of responsibilities for developing new weapons, and control any research and engineering activities that required centralized management.[6] Herbert F. York, who had headed the branch of the University of California Radiation Laboratory at Livermore (known after 1980 as the Lawrence Livermore National Laboratory), served as DDR&E until April 1961. His office quickly became the largest component of OSD and provided a separate element for reviewing the defense budget. The director also supervised the Advanced Research Projects Agency (ARPA), which undertook promising research efforts that no service had yet initiated. Thus, that agency took the lead in antiballistic missile and military satellite projects. York's successors, Harold Brown (1961–1965) and John S. Foster, Jr. (1965–1973), also had served as directors of the Radiation Laboratory.

The third subordinate, the assistant secretary of defense (supply and logistics), established procurement policies and procedures for the entire department. Perkins McGuire, who served in the position from December 1956 until January 1961, promoted the use of cost-plus-fixed-fee contracts. Following McGuire in a position that was retitled assistant secretary of defense (installations and logistics), Thomas D. Morris shifted that emphasis to fixed-price incentive contracts.[7]

McNamara later in life claimed to have arrived at the Pentagon without a preconceived approach to managing the Defense Department. There were, of course, shaping influences. At the Harvard Business School, he had learned about "financial control," crafting budgets to pursue an organization's goals and then monitoring changes as those goals evolved. During World War II, he rose to the rank of lieutenant colonel in the Army Air Forces on the strength of his accomplishments in calculating logistical requirements for the airlift over the Himalayan "Hump" and for supporting B–29 operations. As the Ford Motor Company's comptroller from 1949 to 1953, he greatly expanded the headquarters financial staff, increasing its reach beyond tracking manufacturing costs into marketing and purchasing, which included planning and forecasting. From that success, McNamara advanced to general manager of the Ford division in 1955 and group vice president of car divisions two years later. He achieved the presidency of Ford only weeks before John Kennedy chose him for the cabinet post.[8]



Secretary of Defense Robert McNamara during a quiet moment in the Cabinet Room of the White House, 28 January 1964 (*OSD/HO*)

McNamara approached acquisition with the conviction that decisions about weapon systems could not be based on technical merits alone but must reflect national security objectives and be tailored to meet the threats that stood in the way of achieving those objectives. A national military strategy had to be articulated, translated into force levels, and then turned into generalized requirements for weapon systems. Finally, those generalized requirements had to be refined into detailed specifications for each system. The Defense Department, McNamara believed, had done little to analyze how small shifts in specifications could improve a weapon's effectiveness or reduce its cost. From his experience at Ford, McNamara drew analogies that supported his conviction that minor product changes could yield major cost savings without compromising effectiveness. In 1957, for example, McNamara's division at Ford had brought out a very successful "stretch" Fairlane, 17 inches longer than the regular model and offering extra accessories (radio, whitewall tires, electric clock, and two-tone finish) but priced at only $15 more. To his dismay, McNamara saw no evidence that such a "thought process" was part of the Defense Department's culture.[9]

McNamara recruited bright young men, promptly dubbed the "whiz kids," who had refined the systems analysis approach while working at the RAND Corporation. Conceived as a mathematically rigorous means of choosing among alternatives, systems analysis worked as follows: First, analysts developed a set of possible courses of action derived from a thorough understanding of existing systems and their flaws. Then, they carried out an examination of each alternative that included cost-benefit analyses and comparisons based on relative cost and effectiveness. In the words of Alain C. Enthoven, who worked at RAND and later became assistant secretary of defense (systems analysis), "When a quantitative matter is being discussed, the greatest clarity of thought is achieved by using numbers . . . even when uncertainties are present. . . . [J]udgment and insight need, like everything else, to be expressed with clarity if they are to be useful."[10] A part of RAND's economics division had been working out ways to estimate life-cycle costs of weapon systems. These included future operating, maintenance, training, and other recurring expenses that were estimated year by year and then reduced to "present value" at an agreed discount rate. Once this analysis was complete, one weapon system could be compared against another in quantitative terms for both cost and effectiveness. This methodology provoked controversy mainly because McNamara used it to centralize decisionmaking in OSD.[11]

McNamara and Comptroller Charles Hitch, a Rhodes Scholar who had been chief of RAND's economics division since 1948, were most troubled by the apparent absence of any mechanism for correlating fiscal resources with military requirements. They decided to leave undisturbed the budget structure, which was organized by resource rather than by mission or functional categories, and to span the gap between military planning and civilian budgeting by creating a new "programming" function. To accomplish that task, Hitch established the Office of Programming headed by a deputy assistant secretary, with a Directorate of

Systems Analysis to "collect, evaluate and analyze information on both costs and objectives."[12] For each weapon or capabilities package, systematic analysis would determine the best and cheapest force mix. The functions of this office became key to McNamara's PPBS, which consisted of three phases: estimating requirements, or "planning"; determining the contents of program packages, or "programming"; and preparing the actual budget.[13]

Charles J. Hitch (*OSD/HO*)

In 1962, McNamara and Hitch instituted the Five-year Defense Program[14] plus a mechanism of Program Change Proposals by which any part of the FYDP could be amended at any time. These proposals could be submitted by the Joint Chiefs of Staff, the services, and OSD agencies; they would be reviewed by all concerned and then submitted to the secretary for decision.

The FYDP cycle began in early spring, when the JCS submitted a Joint Strategic Objectives Plan (JSOP) containing strategy and force-level recommendations. After a review, the secretary circulated preliminary decisions in the form of "tentative fiscal guidance" that gave the services a basis for presenting any force level and Program Change Proposals. OSD then grouped hundreds of program elements[15] according to their common missions and subjected them to systematic analysis.

The vehicles for conveying and explaining the results, Draft Presidential Memorandums written in OSD, were unprecedented in their detailed appraisals of alternatives and justifications of the force levels chosen. Circulated in early autumn, "for comment" DPMs were critiqued by the JCS and the services, revised as the secretary desired, and presented in final form to the president. At year's end, McNamara and the JCS would meet with the president for a final review. The DPMs grew in number from 3 in 1961 to 16 by 1968, becoming the central and culminating feature of the PPBS.[16]

McNamara's innovations—the PPBS and the FYDP—have been described as revolutionary. Although procedures were modified substantially in later years, the framework endured. Absent in the 1960s was anything comparable to either the Eisenhower-era reviews by the NSC or the activities of the Defense Systems Acquisition Review Council under the Nixon administration. McNamara, like the president he served, disliked decisionmaking by committees, believing that "a consensus of opinion is usually almost no opinion at all."[17]

CHANGING THE LOCUS OF DECISIONMAKING: 1961–1964

President Kennedy had determined to distance himself from what he saw as his predecessor's misguided emphasis on budget ceilings. Not surprisingly, then, McNamara's initial reviews led to some budget increases. International tensions, particularly the confrontation with the Soviet Union over West Berlin in 1961, triggered even larger increases. New obligational authority for FY 1962 came to $49.4 billion, compared to Eisenhower's original request for $43.7 billion.[18]

Larger budgets did not necessarily translate into smoother relations between OSD and the services. For example, although McNamara let the JCS have the first chance to shape a five-year program for strategic retaliatory forces, he turned to a DPM developed by the OSD comptroller's civilian analysts when he found JCS guidance lacking. Early in August 1961, the chiefs sent him a memorandum marred by disagreement among them over desirable levels for every major weapon system. At McNamara's request, they reconsidered the programs and then resubmitted the same split views, thereby losing perhaps their best chance to show that they could rise above parochial service interests. Accordingly, late in September, McNamara circulated a DPM written by Hitch's analysts. It applied optimistic, median, and pessimistic factors in assessing the survivability, reliability, and ability to penetrate protected targets of the various nuclear weapon systems. The "great weight of likelihood," according to the DPM, lay between the optimistic and median cases. There followed a detailed comparison of the target destruction capabilities of forces recommended by OSD and by the services, showing that the extra $10 billion that higher service budget levels would require "runs up against strongly diminishing returns and yields very little in terms of target destruction." In a comparison of bombers and missiles, analysis showed that "most targets, and all of those of the highest priority," were best attacked by missiles. Moreover, for the same cost as 45 more B–52 bombers, either 250 hardened and dispersed Minuteman ICBMs or 6 Polaris submarines carrying 16 missiles each could be procured.[19] McNamara continued to refine this methodology and capped major strategic retaliatory forces at 1,000 Minuteman ICBMs, 630 B–52 bombers, and 41 Polaris submarines. Air Force arguments for many more ICBMs and for new bombers struck him as lacking any objective analytical base.[20]

Monthly reports, prepared for McNamara by Deputy Assistant Secretary of Defense (Production Management) James N. Davis, helped to extend OSD's reach. Covering about 70 major weapon programs, these "score sheets" pointed out possible delays, financing problems, and forthcoming decision points. They placed details and figures literally at the secretary's fingertips. Paraphrased excerpts from the report for May 1963 illustrate the range of activities that McNamara oversaw in the Navy alone:

Polaris: The schedule of completing one fleet ballistic missile submarine per month left very little margin for error. The October date of readying USS *John Adams* (SSBN–620) for sea trials stood in "serious jeopardy." (*John Adams* would be commissioned in May 1964.) During April and early May, five A–3X intermediate-range ballistic missiles (IRBMs) with a 2,500-nautical-mile range had been tested; two were successful, two were partially successful, and one failed. Five of the six missiles test-fired from USS *Ethan Allen* (SSBN–608) landed in the impact area.

Antisubmarine warfare: Loss of equipment aboard USS *Thresher* (SSN–593), an attack submarine that sank in the north Atlantic in April, meant that the evaluation of improvements in ship silencing and the Submarine Rocket (a guided, submarine-launched, nuclear-armed, antisubmarine weapon system), among other things, would slip by six to eight months.

Amphibious Transport Dock (landing platform/dock [LPD]): The New York Naval Shipyard's heavy workload had caused completion of three ships to be postponed by four months each. Two LPDs programmed for FY 1963 were reassigned to private yards, with contracts awarded during May.

Talos: Design deficiencies in the Navy's cruiser-based surface-to-air missile remained "prevalent." Development was in "less than good shape" due to Talos's limited range, lack of electronic countermeasures capability, and inadequate performance during rainstorms. December 1964 had been set as the target date for completing measures instituted by a Navy "Get Well" team.[21]

Trying to control the purchase of machine tools illustrates the obstacles that McNamara sought to overcome. During the Korean War, the services had resisted OSD's efforts to create a centralized inventory. In 1961, Deputy Assistant Secretary Davis set up at Warner-Robins Air Force Base, Georgia, a computerized inventory of all machine tools owned by the Defense Department. If the Navy wanted to buy a dozen special milling machines, it first had to check with Warner-Robins to see what excess equipment was available. The services, Davis recalled, "fought like steers" before accepting this reform. After the administration reduced the B–70 strategic bomber to a prototype program, McNamara ordered Davis to inspect the B–70 plant at Palmdale, California, every three months. Unless Davis personally kept watch, McNamara told him, the Air Force would start buying hard tools to set up a full production line. In March 1963, the Defense Industrial Plant Equipment Center was established at Memphis, Tennessee. Requirements of the services and their contractors would have to be screened against the center's idle-and-excess lists before new procurements could be initiated.[22]

Applying systems analysis to the selection of conventional force levels drove a wedge between the secretary and the services. While all services immediately benefited from budget increases, each eventually came to feel that its prerogatives were being infringed. General Curtis E. LeMay, Air Force chief of staff, voiced concern early in 1962 that the Five-year Defense Program combined with guidance from Hitch might become a substitute for "mature military judgment." The JSOP written in 1963 adopted McNamara's methodology and format, even to the point of analyzing alternative packages for each program. General Maxwell Taylor, who became JCS chairman in October 1962, told McNamara that this analysis was "the most thorough of any JSOP within my experience."[23]

Nonetheless, McNamara and his whiz kids concluded that JSOP analysis was little more than a veneer concealing service biases. Alain Enthoven later explained why:

"Military officers as a group . . . have very limited intellectual and career independence. . . . The whole military ethos, conditioned by rank, hierarchy, and discipline, conflicts with the ideas of intellectual independence and objectivity." To Enthoven, civilian analysis was by definition much more objective: "Relatively unhampered by tradition or institutional restraints, free from the need to build consensus, without a predetermined position to sell, and without the need to be good soldiers, these analysts could more easily ask the hard questions and pose genuine alternatives, arriving at recommendations via a more rational and objective process."[24]

McNamara insisted that, under his leadership, requirements rather than arbitrary budget ceilings guided decisions on force levels. But if McNamara himself determined those requirements, some officers asked, wherein lay the difference? General Thomas D. White, retired Air Force chief of staff, claimed to speak for many military officers in declaring himself "profoundly apprehensive of the pipe-smoking, tree-full-of-owls type of so-called 'defense intellectuals'" who lacked "sufficient worldliness or motivation to stand up to the kind of enemy we face." Conversely, a service assistant secretary voiced civilians' feelings: "We resent the attitude of many generals and admirals that there is a special mystique about military experience which . . . alone makes one qualified to make important defense decisions."[25] Admiral David L. McDonald, chief of naval operations from 1963 to 1967, said that he "learned pretty soon not to raise the issue of experience before certain individuals because . . . that just made you parochial."[26] General Taylor enjoyed a much smoother relationship with McNamara than either his predecessor as chairman, General Lyman L. Lemnitzer, or his successor, General Earle G. Wheeler. Yet Taylor's feelings about the secretary were mixed. As Taylor related some years later, McNamara impressed him as intelligent, able, industrious, persuasive, and, "Boy, was he self-confident!"

> Decision-making was his favorite dish. The real problem with a man of that sort is not to let an issue get to him . . . until his staff has thoroughly digested it and prepared a well-considered recommendation. . . . He necessarily thought in figures. . . . Most of us are inclined to think in terms of broad concepts and then are quite happy to pass them to subordinates for detailed amplification. [Instead,] McNamara . . . personally followed an idea from concept all the way to the bottom line; furthermore, he put the figures in every step of the way.[27]

"SYSTEMS ANALYSIS" BECOMES A FIGHTING TERM: 1965–1968

The departure of Comptroller Hitch in 1965 presented McNamara an opportunity to institutionalize the systems analysis work that had been done within the comptroller's office by Alain Enthoven, the deputy assistant secretary (systems analysis). To succeed Hitch, McNamara brought in Harvard Business School professor Robert N. Anthony, an innovator in the field of accounting. As long as McNamara was secretary of defense, he could ensure that the comptroller's office paid sufficient attention to strategy and weapon systems. He presumed, however, that the comptroller in the next administration, like Anthony, would be an accountant and would spend the bulk of his time on routine financial management, such as auditing and budgeting. If that happened, McNamara believed, the job of providing the secretary with independent civilian analyses of requirements would not be institutionalized.[28] To enhance the importance of requirements formulation by OSD, McNamara created a new position of assistant secretary of defense (systems analysis) and appointed Enthoven to fill it. A September 1965 directive assigned the position functions that included developing cost and effectiveness measures that would permit quick and accurate analyses of alternative programs for force structures and weapon systems stretching over several years; presenting data showing the total implications of alternative programs in terms of cost, feasibility, and effectiveness; and analyzing and reviewing quantitative requirements relating to force structures, total manpower, transportation, communications, nuclear weapons, conventional weapon systems, and major end-items of materiel (for example, bombs, torpedoes, ships, vehicles, and ammunition). Enthoven's prescribed functions and authorities gave him extremely wide-ranging responsibilities.[29]

Systems analysts had been focusing on quantitative outcomes. Enthoven now reached out to take part in R&D decisions as well, addressing which systems to build and not simply how many to buy.[30] Unavoidably, the functions of Systems Analysis began to overlap those of Defense Research and Engineering. Deciding when to shift programs from R&D into production also concerned both offices.

From the standpoint of justifying civilian-led analysis, the timing of Enthoven's appointment proved to be unfortunate. The Vietnam War created a credibility gap for Systems Analysis, as it did for many other organizations. The war's steadily rising costs led McNamara to impose economies in other areas of the defense budget. He and Enthoven deployed a host of calculations, challenged by the JCS, to conclude that general purpose forces built around 18 Army and 4 Marine divisions, 23 Air Force tactical fighter wings, and 15 attack carriers could execute a "two-and-a-half war" strategy—fight in Southeast Asia, reinforce Allied Command Europe, and carry out a small contingency operation. Early in 1968, events undid their calculations. On 23 January, North Korea seized USS *Pueblo*, a lightly armed intelligence collection vessel operating off its east coast. The administration promptly decided on an aerial show of force. The 302 aircraft being sent to South Korea as reinforcements were "in very good shape," McNamara told the president, but the 332 being mobilized to replace them at home were "cats and dogs." On 29–30 January, in South Vietnam, the Communists launched the country-wide Tet offensive. What could the strategic reserve in the United States now supply? Only 1 airborne division, 1 1/3 Marine division/wing teams, and 12 tactical fighter squadrons, 8 of which were "cats and dogs" just called up.[31] Essentially, the active force could not deploy personnel and materiel for anything more than combat in Southeast Asia.

Alain C. Enthoven (*OSDHO*)

Alain C. Enthoven

Born in Seattle, Washington, on 10 September 1930, Alain Enthoven graduated from Stanford University, attended Oxford as a Rhodes Scholar, and earned his Ph.D. from MIT in 1956. He worked at RAND from 1956 to 1960 and entered government service in the Office of the Director, Defense Research and Engineering in the Eisenhower administration's final months. Early in 1961, he moved to the OSD comptroller's office, becoming director for systems analysis, advancing to deputy assistant secretary in 1963 and assistant secretary of defense (systems analysis) in September 1965, a position that he held until January 1969. During these last four years, his office applied cost-effectiveness calculations to virtually every area of force planning. Such analyses, he was convinced, imposed intellectual rigor and rationality, in the sense that numerical comparisons brought more objectivity into decisionmaking.

Systems analysis played the key role in making assured destruction of given percentages of the Soviet Union's industry and population the criterion for sizing strategic retaliatory forces. Systems analysts calculated, and McNamara agreed, that an effort to limit damage by deploying extensive ballistic missile defenses would be futile. With respect to Vietnam, Enthoven's statistics-based argument that escalating the bombing of North Vietnam would be ineffective provoked heated counterclaims that limitations imposed by civilians were the real problem.

For military and congressional critics, Enthoven and systems analysis became the embodiment of Secretary McNamara's alleged mismanagement. Military officers argued that operational efficiency, based on service doctrines drawn from experience, should determine acquisition and warfighting decisions, not impersonal, numerical calculations that excluded the impact upon human lives. Enthoven's rebuttal, *How Much Is Enough?* was published in 1971 after he had left Washington. Offering no apologies and few concessions, his book stands as the fullest defense of systems analysis methodology. As Enthoven predicted, cost-effectiveness calculations remained embedded in the decisionmaking process.

After leaving the Pentagon, Enthoven worked as an executive at Litton Industries until 1973. He spent the remainder of his career as a professor at Stanford University's Graduate School of Business, where he gained recognition for applying the techniques of systems analysis to health care policy.[I]

By the time Robert McNamara left the Pentagon in February 1968, every service had been alienated by his decisions about showcase projects. For the Air Force, it was cancelling the Skybolt ballistic missile, stopping the B–70 bomber, and deferring the Advanced Manned Strategic Aircraft. For the Army, it was his downgrading of the Nike-X antiballistic missile system. For the Navy, it was his insistence upon developing a carrier version of the Air Force F–111, a variable-sweep wing fighter-bomber, and cutting back on construction of nuclear attack submarines. Military leaders knew that the cost of the Vietnam War had placed limits on spending for acquisition, but they were deeply unnerved by McNamara's decisive influence on the fate of individual weapon systems. The cultural shock of increased OSD control was real and dramatic.

Vice Admiral Hyman G. Rickover, who was the father of the nuclear submarine and who had many friends on Capitol Hill, had become a frequent critic of McNamara's OSD. On 1 May 1968, testifying before members of the House Appropriations Committee, he castigated systems analysts as "social scientists" whose studies "read more like the rules of a game of classroom logic than a prognosis of real events in the real world." Their function, he charged, was one of acquiring "cheaper, not better military weapons." As an example of technical micromanagement, Rickover cited the rejection of Navy views that the DXGN nuclear-powered, fleet escort vessel should carry a second five-inch gun, the latest version of the SP–48 radar, and a command and control facility.[32]

When Enthoven testified before the House Armed Services Committee six days later, the knives came out. Enthoven argued that, as an assistant secretary, he did no more than submit recommendations; the power of decision rested with the secretary. Some congressmen charged that military advice, even when solicited, was rarely accepted. Responding to Enthoven's argument for limiting the number of nuclear attack submarines and stations, Rep. Samuel S. Stratton (D–NY) asked: "How is it that your office was able to say flatly that the Joint Chiefs of Staff and the Navy don't know anything about where to put [nuclear attack] submarines, and that you know better than they do where to put them?" Rep. Porter Hardy, Jr. (D–VA) complained: "My best information is that there are no significant military inputs into these analyses that he makes, and . . . if that is the case . . . then [Enthoven] is the most dangerous man we have in Government today."[33] Hardy's language was extreme, but influential members of Congress had grown skeptical of systems analysis.

During 1961–1962, civilian-military exchanges frequently proved fruitful, as DPMs opened new possibilities and forced the services into a more rigorous mode of analytical thinking. By 1967–1968, though, repercussions from the Vietnam War had blighted much of the process. To military leaders, many DPMs seemed designed more to justify force levels preselected by OSD than to provide objective analyses. The JCS and the services adopted Enthoven's methodology but often did so by creating categories into which they could fit whatever data would support their predetermined goals. As an Air Force general put it, "Our program is cost-effective no matter what the cost."[34] Distrust between military and civilian leaders by the end of McNamara's term prevented meaningful discussions on force levels and budgets.

DEFINING THE ACQUISITION CYCLE

In 1956, the Robertson Committee (named for its chairman, Deputy Secretary of Defense Reuben B. Robertson, Jr.) had recommended numerous steps to shorten the development time for weapon systems. Leaving implementation of the committee's recommendations to the services, however, meant that few real changes occurred.[35] In 1961, OSD again took the lead. McNamara sought to give lead time reduction and cost control equal priority with achieving performance requirements.

McNamara put Deputy Director of Defense Research and Engineering John Rubel in charge of this effort. Early in October 1961, Rubel sent his service counterparts "a preliminary and partial basis" for effecting changes. Among the reasons that lead times kept lengthening, he believed, were unrealistic funding, over-promising at the start of projects, and constantly introducing unnecessary changes. R&D costs had more than doubled over the last decade, much of which Rubel ascribed to "waste and little more." With proper cost accounting and management practices, he was convinced, a great deal of hardware could be procured through fixed-price instead of cost-plus contracts. In his view, the services, within and among them, were not formulating requirements in a uniform or consistent way. Large programs had been inaugurated with "totally inadequate" preliminary planning and design, using selection criteria that encouraged "brochuremanship" by bidders. Often, an aggregation of supposed improvements created "over-embellished, over-complicated" designs. Accordingly, Rubel set out "to establish more carefully the phases that make up a major development effort, to describe how the decision points are defined, who has the authority to make major decisions at these points and to match the definitions with the appropriate . . . management measurement and control mechanisms."[36]

As work on the FY 1963 budget moved forward, Rubel advised McNamara that the overruns on three Air Force projects equaled the Army's entire annual budget for research, development, and test and evaluation (RDT&E). He surmised that better management and financial control over a small number of projects could reduce cost overruns significantly, particularly since only one dozen weapon systems accounted for half the entire RDT&E budget. Accordingly, OSD created six categories for R&D projects: research having no clear military application; exploratory development aimed at solving specific problems; advanced development (moving projects into experimental or operational testing); engineering development; management and support; and operational systems development.[37]

Among the services, the Air Force appeared most advanced in its methods of systems management. Accordingly, OSD identified the service's Mobile Mid-Range Ballistic Missile (MMRBM) as the model project for a fresh approach. Before embarking on a large-scale MMRBM effort, several months would be spent preparing "a more precise definition of the system and its operational deployment." This "phase I" or "program definition" was broken into two parts. In phase IA, specifications would be drafted that were "representative . . . but not truly definitive," requests for proposals (RFP) issued, and contractors selected for program definition. The purposes of program definition were to make further funding contingent upon proof of the contractor's managerial and technical capabilities and to evaluate whether the project really amounted to applications engineering (engineering focused on the transition from development to quantity production) and not simply a pool of money for testing new technologies.[38] In phase IB, the Air Force would work with the winners in defining system designs and planning programs. A detailed development plan would be written, showing key milestones and decision points. After further evaluation, incentive contracts could be negotiated with one firm for each subsystem. Phase I also would be applied to the F–111 fighter-bomber, the Titan III space launch vehicle, and the Agena space booster programs. Subsequently, every service would be expected to copy this approach.[39]

Rubel remarked how frequently lower echelons asked for guidance even as they protested the trend toward overcentralization. Nearly every time, he noted, "the guidance documents have been bottled up at intermediate headquarters levels and it has been difficult or nearly impossible to discern any immediate effects from their issuance."[40] Air Force Systems Command, the Air Force's field development agency, quickly detected "a definite trend toward imposition of super-management organization at the top of current review and approval channels." General Bernard A. Schriever, who headed the command, advised the Air Force chief of staff that "[d]ecisions on matters that have never been previously reviewed are being withheld for inordinate lengths of time. . . . If we are to be held to this overly conservative approach, I fear the timid will replace the bold and we will not be able to provide the advanced weapons the future of the nation demands." Schriever's disenchantment with OSD would grow steadily.[41]

DoD Directive 3200.9 (Project Definition Phase), issued on 26 February 1964, imposed a three-phase approach to acquiring a weapon system. *Phase zero* would ensure that building block components and technology were sufficiently in hand, a thorough tradeoff analysis was conducted, and the best technical approach was selected. Next came a *project definition* phase, which involved engineering rather than experimental efforts, including identifying high-risk areas, validating technical approaches, and establishing firm and realistic specifications, schedules, and cost estimates. Assuming all went well, the third and final phase would be *full-scale development*.[42]

A revised Directive 3200.9, issued in July 1965, and renamed Initiation of Engineering and Operational Systems Development, slightly redefined and renamed the phases as *concept formulation*, *contract definition*, and *development*.

The first phase, concept formulation, included the following steps: After a military service and the DDR&E had validated a need, that service's headquarters would notify its field development agency. Then followed exploratory development, aimed at solving specific problems that fell short of being major projects. Next came advanced development, covering all the components and subsystem hardware that were undergoing experimental tests. After the service's headquarters settled upon a solution, the field agency would assemble data needed to support a funding request. The service then would submit a Program Change Request that included a Technical Development Plan.

Contract definition, the second phase, applied whenever R&D costs exceeded $25 million or projected procurement costs exceeded $100 million. Once the basic technology had been established, contractors would work out engineering development proposals and set standards of performance. The purpose of contract definition was to determine whether the conditional decision to go ahead with engineering development could be confirmed. A Technical Development Plan had to pass muster with the DDR&E. Once that had occurred, a decision by the secretary of defense to proceed with engineering development indicated strongly, but not surely, that full-scale development would follow. In some cases, though, simply starting contract definition could create an irresistible momentum. After McNamara terminated the B–70 bomber, the JCS pressed for $10 million to begin contract definition for an Advanced Manned Strategic Aircraft. The secretary disapproved, concerned that a seemingly trivial $10 million decision would turn into a de facto commitment to spend $1.5 billion to $2 billion for full-scale development, followed by $6 billion to $8 billion for procurement.[43]

Development was the third phase: After a project won full approval for production and deployment, operational development of systems, support programs, vehicles, and weapons began. Operational models underwent testing and evaluation, followed by production and issuance to units.[44]

The gains from these new procedures were unclear. For example, in September 1965, the DDR&E claimed that the mortality rate of new systems had been substantially reduced because technology had to be available or at least laboratory-proven before engineering development could be initiated. Another prerequisite was "reasonable expectation for potential effective use." He noted, though, that technological efforts worth $2 billion to $2.5 billion were proceeding even though no immediate uses for them had been identified.[45]

In practice, neither the secretary nor his senior people had time to master completely the voluminous documentation generated during concept formulation and contract definition. Moreover, the various service R&D organizations developed position papers independently, so that the secretary did not always see all pertinent views and arguments side by side. To remedy this, OSD prepared an annual DPM that covered research, development, and engineering programs. It was not a decisionmaking document, but mainly a status report and summary of decisions made in response to the services' program change requests.

Late in 1967, McNamara told the director of defense research and engineering to submit a Development Concept Paper (DCP) addressing the Army's SAM–D surface-to-air missile (subsequently named the Patriot Air Defense System). The secretary liked the result so much that he applied the procedure more widely. Running 10 to 20 pages, such DCPs laid out the financial, managerial, and technical risks incurred by each option, stated probable scheduling, and proposed thresholds that, if exceeded, would require a new decision. These thresholds concerned costs, appearance of new technological factors, and changes in threat assessments. But the DCP's main purpose was to eliminate unpromising programs at the earliest stage. Wherever possible, McNamara wanted to fulfill new requirements by modifying existing vehicles or adding new parts instead of buying whole new systems.

Each DCP had to be cleared by the assistant secretary for research and development of each military department involved, by the JCS, and almost always by the assistant secretary of defense (systems analysis). Enthoven's analysts appraised desirable characteristics from the standpoint of cost-effectiveness, ensuring that a perspective different from that of defense research and engineering was brought to bear. By December 1968, the secretary of defense had approved 15 DCPs, and 35 more were in various stages of preparation.[46]

REWORKING LOGISTIC GUIDANCE

Determining how many weapons and munitions to acquire was another function over which OSD exercised ever more detailed control. In 1960, the Eisenhower administration stopped planning a massive mobilization like that of World War II. For general war, its new objective was having enough materiel to fight for 90 days without relying on a resupply pipeline. For limited war, goals were based on what would be needed to fight in Korea: two divisions in place on M-day (the day mobilization for war began), and six divisions, six aircraft carriers, and six Air Force wings available by M+180 days. These levels, plus the rest of a peacetime establishment, conditioned the objectives for stocking materiel.[47]

Imposing a strategy of flexible response called for rethinking logistic standards. Soon after taking office, McNamara reported uncovering a serious imbalance in the inventories of all the services and among the items of any one service. In October 1961, he established a general planning base for the services of 180 days' worth of logistic support for waging a major conventional war. That meant having enough consumables to last from the time combat began (D-day) until production equaled combat consumption (P-day)—what was known as the “D-to-P” concept. Continuing to fight beyond 180 days would depend on deliveries from the production base.[48]

McNamara made a case that he was economizing even while objectives expanded. For example, the Army applied new factors for resupplying U.S. European Command. Instead of 120 days to move materiel through the pipeline to the battlefield, it would take 16 days to move items by air, 84 days for surface movement of munitions. D-to-P could be shortened by spending more in peacetime to accelerate the expansion of wartime production rather than by prestocking large quantities. Spending $10.4 million to expand the helicopter production base, for instance, would allow the peacetime inventory to be reduced by 263 helicopters worth $70 million.[49]

The Air Force, however, took issue with McNamara’s guideline. In its doctrine and acquisition, the Air Force was oriented toward strategic nuclear warfare and wanted to remain so. Adopting D-to-P objectives, it claimed, would add about $1 billion for munitions, $7 billion for combat aircraft, and $3 billion to $4 billion for transport and other support aircraft. Fulfilling D-to-P, therefore, was unaffordable.[50] McNamara decided that his objectives for the Air Force need not be attained until mid-1969.[51]

Waging the Vietnam War, of course, required new calculations. Early on, McNamara decided to keep inventories lean until the war ended, when the layoffs caused by defense cutbacks could be cushioned by retaining workers to rebuild stocks. Logistic guidance for FY 1968, completed late in 1966, changed most munitions requirements from D+180 days to D-to-P.[52] Switching to D-to-P could be seen as reducing requirements, but some interpreted it as calling for another several billion dollars’ worth of inventory. OSD’s solution, according to Comptroller Anthony, lay in a very liberal interpretation of the concept that a “hot” production base served as a substitute for inventory.[53] That ran counter to the experience of most wars, during which inventory requirements steadily expanded.

By autumn 1966, the JCS assumed that the Vietnam War would go on indefinitely and recommended financing everything, including combat attrition and consumption, through normal lead times. For example, aircraft acquired to replace losses, following the JCS recommendation, should have been financed for about 18 months beyond the end of the fiscal year being budgeted. The administration had ignored the recommendation and instead submitted a regular DoD budget in January 1966. It waited until the following January to ask for a supplemental appropriation covering war costs simultaneously with the presentation of the next year’s budget. That way, the administration expected to be able to put in the supplemental all the requirements that needed to be placed under contract before the next year’s funds became available—in effect, financing full lead times through the supplemental.[54]

Civilian analysts decided that forecasts of consumption should derive mainly from recent rates of expenditure. That was the basis for drafting, in

1967, much of the logistic guidance for FY 1969. Thus, for Southeast Asia, authorizations were not to exceed 135 combat days for air munitions, and operating and safety stocks were not to exceed a 90-day supply of ammunition.[55] McNamara directed his staff to seek more ways to reduce budgeted quantities of ammunition. Assistant Secretaries Enthoven and Morris concluded that a proper D-to-P computation called for accurately estimating the rate at which output would expand and analyzing the tradeoffs between larger peacetime stocks and expanded plant facilities. By November 1967, they claimed to have found major errors and omissions in service calculations of this "production offset."[56] Criticizing service estimates as unreliable and almost certainly excessive, they broke down requirements for 284 "Principal Controlled Items" into 5 categories, creating separate requirements for each.[57]

By the beginning of 1968, forces fighting in Southeast Asia were being supplied directly from the production base. The pipeline to ground forces was kept filled by taking equipment from the combat consumption reserves of divisions remaining in the United States.[58] McNamara decided to help offset the war's rising costs by tapping those accounts in which expenditures ran below projections. Accordingly, he asked Congress for what was called a zero supplemental, which meant authorization to shift funds from one appropriated account to another. There would be $6 billion worth of additions and $6 billion worth of reductions. Of that $12 billion, $10.3 billion involved shifts within accounts; he required authority to transfer only $1.7 billion.[59]

After the Tet offensive and the seizure of *Pueblo*, however, this carefully crafted zero supplemental had to be augmented with a request for $3.9 billion in new obligational authority, accompanied by another $2 billion of reprogramming among accounts. Moreover, Congress required FY 1969 expenditures to be cut by $6 billion; the Defense Department had to bear half that reduction, and more reprogramming followed. The upshot was that for the time being, the PPBS could not chart an orderly, long-term approach.

The strategy underpinning logistic guidance—graduated pressure or controlled escalation—assumed that the United States would hold the initiative and determine the tempo of operations. Instead, in January 1968, the enemy chose when, where, and how far to escalate. Just after North Korea captured *Pueblo*, critical munitions shortages emerged in Northeast Asia. The requirement for air munitions (in short tons) was 11,799, but only 2,986 were on hand; 4,450 short tons of surface munitions were needed, with only 2,800 on hand. Army ammunition was rushed from Japan and the United States. One ship en route to South Vietnam with 7,300 tons of Air Force munitions was diverted to Korea; another ship moved naval air munitions from the Philippines to Japan. But high expenditures in South Vietnam after the country-wide Tet offensive erupted prevented any further augmentation of munitions stocks.[60] During a 10-week period, moreover, B–52s and fighter-bombers dropped 100,000 tons of ordnance to defend the beleaguered Marine garrison at Khe Sanh. The administration ruled out military reprisal against North Korea and, after 31 March, curtailed airstrikes against North Vietnam. The stockpiles of materiel needed to fight two Asian wars simultaneously did not exist.[61]

To sum up, three sets of supply standards were applied: in 1960, 90 days for general war and enough to wage limited war on the scale of the Korean War; in 1961–1965, 180 days for some categories and D-to-P for the rest; in 1966–1968, for combat, consumption derived from previous rates of expenditure. These reflected decisions by Eisenhower not to fight a large-scale war without using nuclear weapons, by Kennedy to defend Western Europe by conventional means, and by Johnson to wage limited war without imposing major strains on the economy. Eisenhower's Korean scenario reduced stockpile needs. Kennedy's flexible response and Johnson's gradual escalation appeared to raise them; McNamara's cost-trimming measures, applied to both, worked better in peacetime than in war.

CONTRIBUTIONS OF THE DEFENSE SUPPLY AGENCY AND THE DEFENSE CONTRACT ADMINISTRATION SERVICES

Centralized control of acquisition scored a lasting gain in the area of common commodity purchasing. During and after World War II, the services often worked through joint entities to practice "coordinated procurement." Occasionally, they resorted to "cross procurement," in which one service would purchase most or all of another service's requirements for a particular commodity. The Hoover Commission in 1955 advocated a separate civilian-managed agency to administer all common supply and service activities.[62] The services successfully opposed going so far on the grounds that supply was a function of command and putting supply functions into an OSD agency could jeopardize operations.

Under pressure from Congress, Secretary of Defense Charles E. Wilson in 1956 started appointing service secretaries as "single managers" for selected groups of commodities or common service activities. Still, many congressmen were not satisfied. Three years later, the House Committee on Government Operations found the single manager approach to be "slow in formulation and limited in application."[63] By 1961, single managers were handling 39,000 kinds of items, but because each manager operated under the procedures of his parent service, customers had to use as many sets of procedures as there were commodity managers.[64]

On 23 March 1961, Secretary McNamara ordered a study of ways to integrate and improve supply management. "Project 100," as it was called, analyzed pros and cons of three alternatives: first, assigning more single managers; second, organizing a consolidated supply and service agency under a military department; or third, creating an agency that reported to the secretary of defense. This task was supervised by a committee consisting of DoD General Counsel Cyrus R. Vance, Assistant Secretary of Defense (Installations and Logistics) Thomas Morris, and the appropriate assistant secretaries of the three departments. The Navy pressed hard for alternative three, the Army less so for alternative two; the Air Force wanted alternative one.[65] McNamara chose the third alternative. He selected Lt. Gen. Andrew T. McNamara, who had been quartermaster general of the Army from June 1957 until June 1961, to be the first director of the new Defense Supply Agency (DSA).[66]

Established on 1 October 1961, DSA began operations on New Year's Day 1962. Formerly, a single manager had to report through an Army technical service or a Navy bureau, then to a military logistics chief at service headquarters, and finally to the secretary of defense. Now single managers reported to Lieutenant General McNamara, the executive agent of the secretary of defense. DSA had two objectives: first, to ensure effective and timely support for the services in the event of war, mobilization, or other emergency as well as in peacetime, and second, to furnish this support at the lowest possible cost. The agency was not a fourth service, congressmen were assured, and its director was not a supply czar. Wholesale purchasing and distribution between major depots would be DSA's main activity; retail distribution as well as setting requirements remained with the services.

The 1961 Berlin buildup highlighted difficulties in using funds flexibly and ascertaining true operating costs. Eight single-manager agencies, distributed among several technical services and bureaus, used different systems and procedures for requisitioning, pricing, billing, reporting, and cataloguing. For much of the supply field, the three services lacked even an agreed terminology; what, for example, constituted a "day of supply"?[67]

In 1962, the General Accounting Office (GAO) reported several cases where the services were delaying standardization even after being told to do so by Lieutenant General McNamara. Whatever progress had occurred, GAO argued, was accomplished at the direction of the deputy secretary of defense rather than by other officials. Even the smallest step could require top-level intervention. The Army and Air Force would not accept a common butcher's smock—a fact that Robert McNamara remembered in an interview 40 years later (without prompting by the interviewer). The services said that they needed six to nine months for smock negotiations. McNamara allowed them 30 days, at which time Lieutenant General McNamara settled the matter.[68]

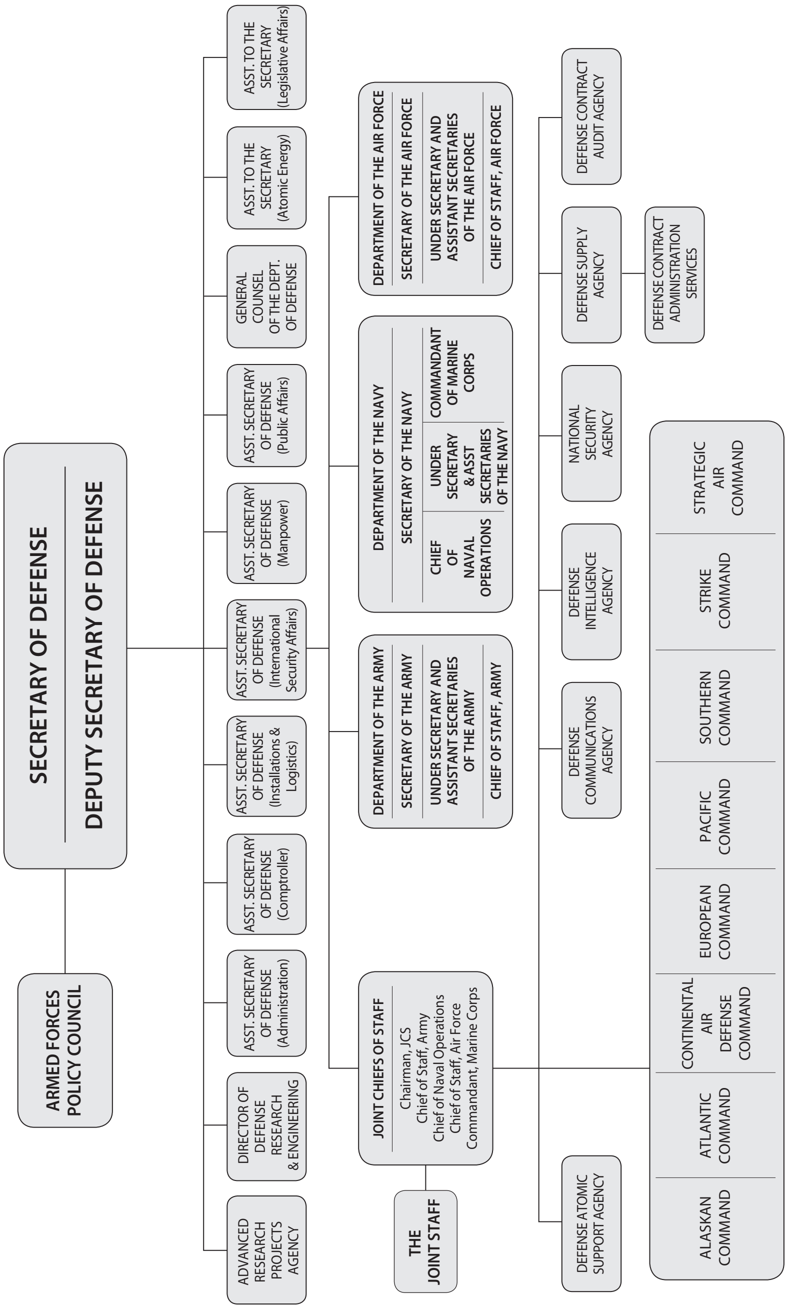
What changed DSA most began at a Procurement Management Improvement Conference convened by Assistant Secretary Morris at Williamsburg, Virginia, in February 1962. Conference participants included top-level procurement policy and operations people from DoD, the National Aeronautics and Space Administration (NASA), and the General Services Administration. The attendees agreed overwhelmingly that steps had to be taken to improve contract management as well as to eliminate overlap and duplication. Accordingly, Deputy Secretary of Defense Roswell L. Gilpatric initiated "Project 60," a detailed study of contract management.

The resulting report, dated June 1963, judged coordinated policy direction and enforcement tools to be lacking. Within OSD, it claimed, responsibilities for contract management were fragmented. Within each service, basic DoD instructions often were implemented successively by each command. Implementation thus depended on interpretations at various levels of command. Moreover, this multiplicity of procedures imposed requirements on industry that proved costly and confusing to administer. Many provisions in the "scope of work" for major weapons contracts translated into added controls over contractors. At North American's Rocketdyne plant, for example, the contractor had to cope with five quality assurance systems that required a doubling of personnel simply to prepare reports. The remedy proposed was a Defense Contract Management Agency, headed by a three-star flag officer (general or admiral) and reporting directly to Secretary McNamara. Also, directives were to be issued creating uniform contract management policies, and a single point in OSD would be established to coordinate policies for other matters, such as quality assurance, production, and industrial security.[69]

Lt. Gen. Andrew T. McNamara, USA (*OSD/HO*)

Secretary McNamara decided to start with a pilot project. In December 1963, he appointed Brig. Gen. Allen T. Stanwix-Hay, USA, to direct a unified Defense Contract Administration Services (DCAS) region with headquarters in Philadelphia, covering a five-state area that contained a cross-section of industry. This test addressed the post-award requirements of about 4,800 contractors with 13,000 contracts valued at \$6.5 billion. The trial was deemed successful. Consequently, in June 1964, McNamara ordered DCAS to oversee the consolidation of some 150 Army, Navy, Air Force, and DSA field contract offices over the next two years. A two-star officer headed the organization, which administered 11 regions created along the Philadelphia model. By FY 1968, DCAS was administering 246,000 contracts valued at \$52 billion, processing 2 million invoices, and paying more than \$16 billion to contractors. This new mission significantly altered the shape of the Defense Supply Agency. It had begun by devoting more than 90 percent of its resources to supply operations; it evolved into an agency divided almost equally between supply support and other logistical services. Yet the Army, Navy, and Air Force retained contract administration over state-of-the-art weapon systems.[70] Thus, the achievements of DSA and DCAS, while large, were limited in scope.

Figure 2-1: DEPARTMENT OF DEFENSE
September 1965



Source: Adapted from Chart 2 (Department of Defense, 1 August 1964) in Kaplan, Landa, and Drea, *The McNamara Ascendancy, 1961-1965*, 50.

The House Armed Services Committee, chaired by Rep. Carl Vinson and then by Rep. L. Mendel Rivers after 1964, was taken aback by the number of consolidations that expanded OSD's control. The Defense Communications Agency had begun functioning in May 1960, followed by the Defense Intelligence Agency in October 1961. A House Special Subcommittee on Defense Agencies concluded that "the groundwork is being laid for the very thing that Congress has repeatedly . . . attempted to prevent." Rivers and most committee members put a premium on service autonomy and military judgment. Under pressure from them, the secretary stopped creating common service agencies (see figure 2–1).[71]

* * * * *

Despite legislative changes from 1949 onward that strengthened the authority of the Office of the Secretary of Defense, McNamara had inherited a still largely decentralized Defense Department characterized by weak coordination on budget and strategy across the military departments. In addition to fractious relations among the services, internal dynamics and longstanding organizational arrangements impacted each one's distinctive approach to acquisition. McNamara quickly concluded that merely coordinating such disparate organizations was impossible, leaving centralized decisionmaking as the only solution.[72]

Over the course of the 1960s, all the services made major organizational changes. Air Force Systems Command, devised by General Bernard Schriever and created early in 1961, enabled Schriever to control everything from development to delivery. The following year, Secretary McNamara convinced President Kennedy to abolish the statutory positions of the Army's technical service chiefs, replacing them with Army Materiel Command, which oversaw the full range of acquisition just like its Air Force counterpart. The Navy, in 1966, replaced its four material bureaus with six systems commands under a Naval Material Command. The assistant secretary of the Air Force (materiel) kept the same title, but comparable assistant secretaries of the Army and Navy followed the lead of OSD and assumed the designation "installations and logistics."

McNamara was far more successful than his predecessors in shifting decisionmaking authority from the military departments to OSD. Although his personality and management style sometimes offended senior military leaders, the well-established custom of deference to civilian control remained paramount, and they did not mount major campaigns against him or his initiatives. But McNamara's success also was due in large part to his strong will and clarity of purpose, which enabled him to overcome the usual bureaucratic inertia of a large organization. The innovations McNamara brought to the Pentagon would ultimately shape budgeting, management, organization, and contracting for decades to come.

Endnotes

1. Charles J. Hitch, *Decision-Making for Defense* (Berkeley: University of California Press, 1996), 25–28.

2. Kaplan, Landa, and Drea, *The McNamara Ascendancy*, 72–75.

3. White, "Revolution in the Pentagon," 46. In 2008, John Rubel wrote that while McNamara suffered from "intellectual hubris . . . he was a most admirable figure. . . . I have met and known many CEOs and political figures and men of great talent in lesser jobs, but McNamara was *sui generis*. I continue to have great admiration for him." Ltr, John Rubel to Walter S. Poole, 14 Oct 08.

4. McNamara left his post on 29 February 1968 to become president of the World Bank. Clark M. Clifford served as secretary of defense until 20 January 1969.

5. Watson, *Into the Missile Age,* 785.

6. The functions of his predecessor, the assistant secretary of defense (research and engineering), had been more advisory in nature.

7. See chapter III in this volume.

8. Deborah Shapley, *Promise and Power* (Boston: Little, Brown, 1993), 20–57.

9. Interview, Robert S. McNamara by Walton S. Moody and Walter S. Poole, 2 Jul 01, 2–3, Washington, DC; Shapley, *Promise and Power*, 63.

10. Andrea Gabor, *The Capitalist Philosophers* (New York: Times Business, 2000), 138–141; Thomas P. Hughes, *Rescuing Prometheus: Four Monumental Projects that Changed Our World* (New York: Pantheon, 1998), 164 (Enthoven quotation).

11. See Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945–1965* (Washington, DC: Air Force History and Museums Program, 2001), 191–214.

12. Memo, Asst SecDef (Compt) Charles Hitch to Asst Secs of the Army, Navy, and Air Force (Financial Management), 3 Apr 61, fldr file #1 Programming, box 109, Glass Papers, RG 330, OSD/HO.

13. Creation of the PPBS is fully covered in Kaplan, Landa, and Drea, *The McNamara Ascendancy,* 75–87.

14. The original term was "Five-Year Force Structure and Financial Program."

15. An element was the combination of personnel, equipment, and facilities making up an integrated force or activity (for example, infantry divisions, attack carriers, tactical fighter wings).

16. Kaplan, Landa, and Drea, *The McNamara Ascendancy*, 118–122; Enthoven and Smith*, How Much Is Enough?* 48–55; interview, Alain Enthoven by Maurice Matloff, 3 Feb 86, Stanford, CA, 2–4.

17. "Committees Are of Value Only for Exchanging Ideas," *Armed Forces Management* 8, no. 2 (November 1961): 22–23.

18. Kaplan, Landa, and Drea, *The McNamara Ascendancy,* 130. New Obligational Authority remained around that level through FY 1965, mainly because of a rapid ICBM and SLBM buildup.

19. JCSM–521–61 to SecDef, 3 Aug 61, JCS 1800/445, sec 4A; Chairman's Memo (CM) 308–61 to SecDef, 7 Aug 61, 7000 (6 Mar 61), sec 3; JCSM–550–61 to SecDef, 15 Aug 61, JCS 1800/445, sec 4A, all in RG 218; *FRUS 1961–1963*, vol. 8, 138–152.

20. Interview, McNamara by Moody and Poole, 2 Jul 01, 8–9.

21. Memo, ASD (I&L) to DepSecDef and SecDef, "Monthly Highlights—Major Programs—May 1963," 30 May 63, fldr 020–I&L, Jan-May 63, control no. S–2100–63, box 32, 69–A–3131, RG 330, Washington National Records Center (WNRC), National Archives and Records Administration, Suitland, MD. Davis later recalled that the services became very forthcoming, wanting to paint the best possible picture. Therefore, "You had to . . . make sure

that they didn't overemphasize something or sweep aside some failed tests." Interview, James N. Davis by Elliott V. Converse III and Walter S. Poole, 2 Jul 01, Alexandria, VA, 33.

22. Interview, Davis by Converse and Poole, 31–32, 55–56, 38–41. The Defense Industrial Plant Equipment Center was an element of the Defense Supply Agency, which is described later in this chapter. Rear Adm. Joseph M. Lyle, "The Defense Supply Agency," lecture to the Industrial College of the Armed Forces (ICAF), Fort Lesley J. McNair, Washington, DC, 11 Feb 64, 10. Transcripts of this and hundreds of guest lectures given at ICAF from 1946 to 1965, including the question and answer periods, are available at the National Defense University (NDU) Library at Fort McNair or at <http://www.ndu.edu/Library/index.cfm?secID=210&pageID=126&type=section>. Davis also organized the first Defense-wide conferences on maintenance and weapons program management, which he later described as "noisy" but productive.

23. CSAFM–139–62 to JCS, 27 Apr 62, JCS 2143/152; JCSM–654–62 to SecDef, 27 Aug 62, JCS 2143/170, 3130 (24 Oct 61), sec. 3; CM–524–63 to SecDef, 17 Apr 63, JCS 2143/201, 3130 (14 Nov 62), sec. 2B; CM–109–62 to DJS, 14 Nov 62, JCS 2143/177, all in sec. 1, RG 218.

24. Enthoven and Smith, *How Much Is Enough?* 98–99.

25. The two quotations appear, respectively, in Enthoven and Smith, *How Much Is Enough?* 78, and *Business Week* (22 Jun 63): 30.

26. "The Reminiscences of Admiral David Lamar McDonald, U.S. Navy (Retired)," Naval Historical Center, Washington, DC, November 1976, 320. After reading a draft of this volume in 2008, John Rubel commented to the author that civilians, particularly those who had worked in the Livermore Laboratory, possessed whatever "experience" there was about nuclear weaponry. Rubel himself became "vastly" more knowledgeable about space-based systems. Ltr, John Rubel to Walter S. Poole, 14 Oct 08.

27. Maxwell D. Taylor, "Reflections on the American Military Establishment," in *Evolution of the American Military Establishment Since World War II*, ed. Paul R. Schratz (Lexington, VA: George C. Marshall Foundation, 1978), 20.

28. Interview, Enthoven by Matloff, 3 Feb 86, 9–10. McNamara sought a separate civilian source of requirements analysis because the service secretaries had disappointed him, falling short of his exacting standards and often appearing to become captives of their constituencies. The perceived shortcomings of Fred H. Korth, secretary of the Navy from 1961 to 1963, are mentioned in interview, Davis by Converse and Poole, 29 Jun 01, 79–81. Those of Elvis J. Stahr, secretary of the Army from 1961 to 1962, are mentioned in interview, Thomas D. Morris by Maurice Matloff, 6 Apr 87, 44–45, OSD/HO.

29. DoD Directive 5141.1 (Assistant Secretary of Defense, Systems Analysis), 17 Sep 65.

30. House, Cte on Armed Svcs, *Hearings on Military Posture*, rpt no 56, 90 Cong, 2 sess, 8916.

31. *FRUS 1964–1968*, vol. 29 (2000), 502; J–5 Talking Paper, "Forces Available for Emergency Deployment to Southeast Asia," 911/374 (5 Feb 68), RG 218; George C. Herring, *America's Longest War* (New York: McGraw-Hill, 1996), 211–228. In December, North Korea released *Pueblo*'s crew but kept the ship.

32. House, Cte on Approp, *DoD Appropriations for 1969*, 90 Cong, 2 sess, pt 6, 54–55, 114–115. Rickover was both deputy commander for nuclear propulsion, Naval Ship Systems Command, and director, Division of Naval Reactors, Atomic Energy Commission. In his latter capacity, he was free to criticize civilians in DoD.

33. House, *Hearings on Military Posture*, 8890 (Stratton quotation), 8891 (fn 1), 8898, 8883 (Hardy quotation). Enthoven later elaborated his case in *How Much Is Enough?* 225–234. Interestingly, on this issue, the Office of the Director of Defense Research and Engineering sided with the Navy and JCS against Systems Analysis. It labeled several of the effectiveness measurements employed by Systems Analysis "irrelevant," the tabulation "misleading," and the way that analysts proposed to use them tending toward a "simplistic, pseudo-quantitative view" of naval warfare. In general, according to DDR&E, the tables displayed "an often-seen

shortcoming of analysis," choosing a few measures that lent themselves to quantification while ignoring factors that were less readily quantifiable but sometimes more relevant. JCSM–286–68 to SecDef, "ASW Force and Effectiveness Tables," 8 May 68; memo, DDR&E to DepSecDef, "ASW Force and Effectiveness Tables," 23 Jul 68; both in fldr 381.35–tables, box 74, 73–A–1250, RG 330, WNRC.

34. Email, J. Ronald Fox to Walter S. Poole, 17 Mar 04.

35. See chapter VIII in Elliott V. Converse III, *History of Acquisition in the Department of Defense*, vol. 1: *Rearming for the Cold War, 1945–1960* (Washington, DC: OSD/HO, 2012).

36. Memo, Deputy DDR&E to Asst Secs of the Army, Navy, and Air Force (R&D), "Management of Research and Engineering," 9 Oct 61, fldr 1, Rubel, John H., Viewpoints, 1961–1962, box 19, General Samuel C. Phillips Papers (hereafter Phillips Papers), Library of Congress (LC).

37. John Rubel, comment on draft manuscript of chapter III, Oct 08.

38. Ibid.

39. Memo, DDR&E to Secs of the Navy and Air Force, "Mobile Mid-Range Ballistic Missile Program Plan," 19 Feb 62, fldr 1, box 19, Phillips Papers, LC.

40. Memo, Rubel to Asst Secs of the Army, Navy, and Air Force (R&D), 9 Oct 61, fldr 1, box 19, Phillips Papers, LC.

41. Memo, Col Jewell Maxwell, USAF, to HQ, USAF (AFSDC), "System Management and Program Initiation," 14 May 62 (AFSC quotation); ltr, Gen Schriever to Gen LeMay, 30 Apr 62 (Schriever quotation); both in fldr 1, box 19, Phillips Papers, LC; Stephen B. Johnson, "From Concurrency to Phased Planning," in *Systems, Experts, and Computers*, ed. Agatha C. and Thomas P. Hughes (Cambridge: MIT Press, 2000), 93–112; Johnson, *The United States Air Force and the Culture of Innovation*, 77, 206–208. The MMRBM became tied to creation of a Multilateral Force for NATO. When that project was terminated, so was the MMRBM.

42. DoD Directive 3200.9 (Project Definition Phase), 26 Feb 64; J.W. Grodsky, "Contract Definition," *Defense Industry Bulletin* 1, no 8 (August 1965): 3.

43. House, *DoD Appropriations for 1969*, pt 1, 737.

44. DoD Directive 3200.9 (Initiation of Engineering and Operational Systems Development), 1 Jul 65, attached to minutes, Executive Committee, Defense Science Board, 12 Apr 67, box 837, OSD/HO; Ralph Sanders, ed., *Defense Research and Development* (Washington, DC: ICAF, 1968), 10–15.

45. "Summary Minutes—Meeting of the Defense Industry Advisory Council, 10 and 11 September 1965," box 990, OSD/HO.

46. Sanders, *Defense Research and Development*, 180–181; "DCP—DoD's Anonymous Management Tool," *Armed Forces Management* 14, no. 3 (December 1968): 49–53; House, Cte on Armed Svcs, *Hearings on Military Posture*, 90 Cong, 2 sess, 8710; email, Alain C. Enthoven to Walter S. Poole, 5 Aug 04.

47. Watson, *Into the Missile Age*, 742.

48. *FRUS 1961–1963*, vol. 8, 169–170; House, Cte on Approp, *DoD Appropriations for 1963*, 87 Cong, 2 sess, pt 4, 488; House, Cte on Approp, *DoD Appropriations for 1964*, 88 Cong, 1 sess, pt 5, 3, 74.

49. House, *DoD Appropriations for 1964*, 172, 171; House, *DoD Appropriations for 1966*, 89 Cong, 1 sess, pt 4, 244.

50. House, *DoD Appropriations for 1964*, 838–839. The Air Force's inventory of high-value spare parts and assemblies did not exceed 45 days. Ibid., 836.

51. Logistics Review Board, *Logistic Support in the Vietnam Era*, May-June 1970, monograph 2, "Ammunition," app H, p H–3, box 321, OSD/HO.

52. Since NATO allies were stocking 15 days or less for some key items, McNamara decided that supplying U.S. forces in Europe for 180 days would be "futile" until they did more. Record of Decision Memo, SecDef McNamara to President Johnson, "General Purpose Forces," 27 Dec 66, binder DPMs, FY 1968–72 Programs, 1966, box 120, Glass Papers, RG 330, OSD/HO.

53. Memo, AsstSecDef (Compt) Anthony to SecDef McNamara, "Proposed Changes to Logistic Guidance," 15 Mar 67, box 41, 72–A–2468, RG 330, WNRC. A "hot base" facility was one that operated at its maximum sustainable production rate. A "cold base" facility was available but not producing. A "warm base" facility produced below its maximum sustainable rate.

54. Edward J. Drea, *McNamara, Clifford, and the Burdens of Vietnam, 1965–1969* (Washington, DC: OSD/HO, 2011), 97, 101–102, 106, 146, 150–153; memo, Henry E. Glass to Sec McNamara, "Basic Approach to the Financing of the Vietnam War Effort," 3 Oct 66, fldr History of Ammunition Procurement Policies Prior to Vietnam Buildup (Jan '61–Jan '65), box 95, Glass Papers, RG 330, OSD/HO.

55. Record of Decision Memo for President, "General Purpose Forces Requirement and Logistic Guidance," 5 July 1967, fldr 400 Logistics Guidance, Jan-Jun 1967, box 41, 72–A–2468, RG 330, WNRC. Other objectives included 90 days of combat support for NATO-committed forces and 180 for those in the "indefinite combat" category (i.e., when the place and length of hostilities could not be predicted). *FRUS 1964–1968*, vol. 10 (2002), 637–638.

56. Computations were made by calculating the gross requirement, predicting how long after hostilities started the materiel would be needed, and then taking a credit—the "production offset"—for how much materiel would be produced after the war began.

57. Principal Controlled Items, most of them Vietnam-related, were those for which sophisticated protocols had been developed to track production, storage, and expenditure. Memo, AsstSecDef (I&L) Morris and AsstSecDef (SA) Enthoven to SecDef McNamara, "Possible Changes in FY 1969 Logistics Guidance," 7 Nov 67; memo, ASD (Compt) to SecDef McNamara, 9 Nov 67; "Statement of Policy to be Followed by OSD in Review of Service Submissions," approved by SecDef on 16 Nov 67; all in fldr 400 Logistics Guidance, Jul 67, box 41, 72–A–2468, RG 330, WNRC.

58. Draft memo, SecDef McNamara to President Johnson, "General Purpose Forces and Logistics Guidance," 9 Jan 68, in binder DPMs FY 1969, box 121, Glass Papers, RG 330, OSD/HO.

59. Some of the major changes, justified in language that made a virtue of necessity, were: cutting back FB–111 production by bringing output into better alignment with production of the short-range attack missiles they would carry; arranging a more orderly phase-in of the F–111D carrying the Mark II avionics system and buying fewer F–111As without it; slipping the operational availability of Minuteman III to allow a more efficient modernization schedule; delaying the start of one Polaris-to-Poseidon conversion without delaying its delivery date; cancelling the start of six destroyer escorts because an entirely new program was in prospect; and reexamining the usage rates and average ages of the noncombatant vehicle inventory. House, Cte on Approp, *DoD Appropriations for 1968*, 90 Cong, 1 sess, pt 2, 521; *DoD Appropriations for 1969*, pt 1, 348–351.

60. *Logistic Support in the Vietnam Era*, app G to monograph 2, "The Northeast Asia Crisis of January 1968," G–5, box 321, OSD/HO.

61. John Schlight, *The War in South Vietnam: Years of the Offensive, 1965–1968* (Washington, DC: Office of Air Force History, 1988), 285. Khe Sanh was besieged from late January until the beginning of April 1968.

62. See Converse, *Rearming for the Cold War*, 41–43, 55–57, 405–406.

63. House, Cte on Govt Ops, *Military Supply Management (Progress in Single Manager Agencies)*, 86 Cong, 1 sess, 80–85; Lyle, "The DSA," 3–5.

64. House, Cte on Govt Ops, *Defense Supply Agency*, 87 Cong, 2 sess, 57, 60; Lyle, "The DSA," 5–8.

65. Secretary of the Air Force Eugene M. Zuckert said later that he had been "very much opposed" to creating DLA "because I could see the erosion of the service role." Interview, Eugene Zuckert by Maurice Matloff, 21 Aug 85, 30, OSD/HO.

66. House, Cte on Govt Ops, *Defense Supply Agency*, 87 Cong, 2 sess, 57, 60; Lyle, "The

DSA," 5–8. In July 1961 the secretary had sent McNamara (no relation) to Korea as deputy commanding general, Eighth Army, so he would have a third star and thus be eligible for the director's position. He was succeeded by Vice Adm. Joseph M. Lyle on 1 July 1964, who was followed in turn by Lt. Gen. Earl C. Hedlund, USAF, on 1 July 1967.

67. House, Cte on Govt Ops, *Defense Supply Agency*, 58, 64, 110; DoD press briefing by SecDef on DSA, 31 Aug 61, 5–6, OSD/HO.

68. House, *Defense Supply Agency*, 10, 22, 62; interview, McNamara by Moody and Poole, 2 Jul 01, 17.

69. DoD, *Secretary of Defense Project 60, Contract Management*, vol. I, Summary, June 1963, NDU Library.

70. *Army, Navy, Air Force Journal and Register*101, no. 43 (27 Jun 64), 18–19; *The Review* 44, no. 6 (May-June 1965): 14–17; "Background," *Introduction to the Defense Supply Agency*, Jan 69, 6; Defense Logistics Agency, *Defense Logistics Agency: 40 Years of Logistics Excellence* (Fort Belvoir, VA: Defense Logistics Agency, 2001), 3.

71. R.F. Futrell, *Ideas, Concepts, Doctrine,* vol. II, *1961–1984* (Maxwell AFB, AL: Air University Press, 1989), 156 (quotation); interview, Leonard Niederlehner by Alfred Goldberg and Maurice Matloff, pt III, 19 May 87, OSD/HO. DSA became the Defense Logistics Agency on 5 January 1977.

72. "The services by themselves," McNamara remarked years later, "are incapable of determining what should be procured. How can the Air Force decide what missiles to procure when they don't know what the Navy is procuring or what the total strategy will be with respect to confronting Soviet nuclear forces?" Interview, McNamara by Moody and Poole, 2 Jul 01, 6–7. It might be said, more precisely, that the Air Force knew what the Navy was procuring but thought the Navy was distorting total strategy by procuring too much, taking funds that the Air Force was convinced it could put to better use.

I. Drea, *McNamara, Clifford, and the Burdens of Vietnam*, 6–7, 10, 132–133, 138, 141, 190, 348, 353, 371, 380; interview, Enthoven by Matloff, 3 Feb 86, 1–4.

CHAPTER III

The Shortcomings of Fixed-price Contracting

In the negotiation of defense contracts, a tension has existed between controlling costs and allowing companies the opportunity to earn reasonable profits. From the start of the Cold War, the drive for each new generation of a weapon system to far exceed the capabilities of the previous one forced contractors to go beyond existing technical knowledge, introduced great uncertainty into weapons development, and made price competition in contracting impractical. Consequently, the type of contract most frequently employed, cost-plus-fixed-fee, reimbursed firms for their legitimate contract costs (as approved by government auditors) and paid them a predetermined fee or profit. Efforts to overcome technical challenges, however, frequently drove development and production costs well beyond original estimates. For example, a B–50A piston-engine bomber of the late 1940s cost $1.14 million; a B–52G jet bomber of the late 1950s cost $7.69 million. Defense officials came to worry not about how many weapons could be produced but how many the United States could afford.[1]

Hoping to reverse these trends, Secretary McNamara shifted emphasis to fixed-price incentive contracts, which were designed to hold down costs by rewarding contractors for their efficiency. Broadly, the contractor and the government would negotiate a target price; the contractor would receive a percentage of the savings below that price or pay a percentage of the costs above it. Assistant Secretary of the Air Force Robert H. Charles created another version of fixed pricing, total package procurement, to prevent firms from "buying in" with unrealistically low bids. Under total package procurement, a single contract with a firm cost ceiling would cover the acquisition cycle from prototype development to series production.

Surprisingly, at least to their creators, these reforms fell short of expectations. Cost control worked no better under fixed-price than under cost-reimbursable contracts. The profit motive, presumed by DoD officials to hold a central place in contractors' calculations, proved to be only one factor in the equation.

CONTRACTING IN THE 1950s

The 1948 Armed Services Procurement Regulation (ASPR) prescribed uniform policies and procedures for the military departments, provided guidance for complying with executive orders and statutes, and set procedures for pricing, contracting, and oversight. The regulation was periodically reviewed and revised by a committee comprised of two representatives from each service plus a chairman provided by OSD. The assistant secretary of defense (supply and logistics) published revisions after consulting with his counterparts in each of the services. Each service issued its own supplemental regulations, but these steadily declined in scope during the 1950s as the ASPR extended its coverage.[2]

During 1959–1960, E. Perkins McGuire, assistant secretary of defense (supply and logistics), acted as the secretary of defense's principal staff assistant for procurement, inventory management, materiel requirements, and production planning. Under him, Graeme C. "Jim" Bannerman served as director of the Office of Procurement Policy. Bannerman's task was to guide the development of DoD-wide policies, programs, systems, and procedures, as well as assure their effective implementation. Each military department tasked an assistant secretary with overseeing its own procurement activities.[3]

While nearly all contracts fell into two broad categories—fixed-price and cost-reimbursement—variations existed within each category.

Fixed-price Contracts

Firm fixed-price required a contractor to furnish supplies or services at a designated price not subject to change. Whenever possible, OSD preferred this type above others because it was the easiest and least costly to administer. For contractors, firm fixed-price offered the greatest possibility to reap profit or suffer loss. Naturally, this type worked best when reasonably definite specifications were available, price competition and production experience existed, and costs could be predicted with reasonable certainty. In FY 1959, 32.8 percent of procurements above $10,000 were obligated under firm fixed-price contracts.

Fixed-price with escalation, allowing the price to be moved up or down, was applied where market and labor conditions were considered unstable. Such contracts—6.3 percent of FY 1959 procurements above $10,000—permitted an overall increase if a specified contingency, such as additional taxes or increases to a labor and materials price index, took place.

Fixed-price redeterminable was used when the lowest price that a prospective contractor would accept proved to be higher than the contracting officer was willing to obligate the government to pay. The parties agreed to reconsider, at a point specified in the contract, whether the price initially negotiated was reasonable and adjust it based upon the experience gained. Usually, this type was employed for relatively small amounts and short deadlines, accounting for merely 4.7 percent of procurements above $10,000 obligated in FY 1959.

Fixed-price incentive called for initial negotiations to set a target cost, a target profit or fee, a ceiling price, and a final profit formula, usually allowing the contractor to keep between 10 and 20 percent of savings achieved below the target cost, with the government retaining the rest. For example, a target cost of $100,000 with a target profit of $8,500 would have a base or target price of $108,500. Assuming a ceiling price is set at $120,000 and a profit ceiling set at $13,000, if the final cost ran below the $100,000 target cost, the contractor would collect the target profit of $8,500 plus a 20 percent share of cost savings up to $13,000. The purpose was to have the contractor spend as if operating in a market dominated by vigorous price competition, critically analyze probable costs, and keep false starts and changes to a minimum. Setting the target price was sometimes delayed until production was about to begin; a "successive-target" contract would fix a production point at which the profit formula would be applied. Government officials believed the crucial point lay in keeping the target price and ceiling price as low as possible. Consequently, incentive contracts were intended for use only when cost experience appeared sufficient to determine a realistic base or target price. During FY 1959, such contracts accounted for 15.3 percent of procurements above $10,000.[4]

Cost-reimbursable Contracts

In *cost-reimbursable contracts*, the government undertook to defray all essential costs, assume all major risks, and guarantee a profit. Such contracts rose from 12.7 percent of procurements above $10,000 in FY 1952 to 40.9 percent by FY 1959. The steep rise in cost-reimbursement contracts reflected the growing emphasis on retaining a qualitative technological lead through the development of complex weapon systems, the final costs of which proved literally incalculable. Purchasing production quantities for inventory was no longer the major activity. According to Assistant Secretary McGuire, "Where we are demanding tomorrow what was unheard of yesterday and where the passage between the two is filled with many unknowns, the costs of performance cannot be measured with reasonable accuracy."[5]

Two variations of cost-reimbursable contracts were used. *Cost-plus-fixed-fee* (CPFF) claimed 34.3 percent of procurements above $10,000 obligated in FY 1959. Used more widely than any of the fixed-price types, CPFF contracts allowed the government substantially more visibility and control over contractors' work. Because it offered only minimal inducements to contain and cut costs, McGuire characterized CPFF as the least preferable type, to be used not just sparingly, but grudgingly. A contractor was assigned a dollar figure amounting to a ceiling cost beyond which the government bore no responsibility. The contractor had to notify the government when 90 percent of the funds up to the ceiling had been spent. Going beyond that ceiling required the government either to raise the ceiling or write a new contract. The Armed Services Procurement Regulation, in its 1958 revision, added cost control mechanisms. Generally, the regulation deemed a contractor's cost unreasonable if it exceeded what an ordinarily prudent firm should incur in conducting a competitive business. By law, fees under CPFF contracts were limited to 15 percent of costs for research and development, 6 percent for architectural or engineering services, and 10 percent for all other cost categories. Since fees usually could be negotiated below these legal maximums, the regulation required secretarial approval for any fees exceeding 10 percent of research and development costs and 7 percent for all other costs, architectural and engineering services excluded. [6]

Cost-plus-incentive-fee (CPIF) was a variation in which the government and the contractor would agree on a target cost and then determine the target fee in relation to it, along with a fee adjustment formula similar to that found in a fixed-price incentive contract. Target and maximum fees were subject to the same percentage limitations prescribed for CPFF contracts. Used in aircraft and missile programs, CPIF accounted for only 3.2 percent of procurements above $10,000 obligated in FY 1959.

A revision to the ASPR on 20 April 1959 authorized two types of special incentive contracts. The first, a *performance incentive* contract, incorporated fixed-price incentive and cost-plus-incentive-fee pricing formulas with the aim of improving performance as well as cutting costs. "Performance" covered timeliness of delivery, product capability and serviceability, ease and simplicity of operation, and economy of maintenance. Thus, the "incentive" feature applied to desired rather than mandatory performance, to performance goals rather than minimal requirements. This type of contract was best suited for complex weapon systems having either substantial development goals or great potential to improve performance.[7] The second type, *value engineering*, had been pioneered by the General Electric Company and adopted by the Navy's Bureau of Ships in 1954. A value engineering study would appraise all elements in the design, manufacture, installation, and maintenance of an item and its components. By giving the contractor a stated percentage of the resulting savings, value engineering encouraged him to maintain a staff dedicated to eliminating "gold plating" and ensuring that every cost element made a proportionate contribution.

Several different types of contracts would be used for the acquisition of a sophisticated weapon system. A CPFF contract would cover the early research work. The contract for hardware development and early prototype work would stipulate cost-plus-incentive-fee. For late development work and the first stages of production, fixed-price incentive fees proved to be common. For the final production run, firm fixed-price contracts were normal. As an example, to cover long lead-time items and production of the first 13 B–52A bombers, the Boeing Company won a contract allowing costs plus a fixed fee of 6 percent. For B–52Ds, the first model to go into large-scale production, fixed-price contracts with redeterminable incentives were applied.[8]

PROFIT OPPORTUNITY: SPUR TO EFFICIENCY OR TO DECEPTION?

In the wake of Sputnik, many businessmen characterized the arms race as a contest between statism and free enterprise, which the nation could win only if industry was unshackled from government controls. The executive vice president of General Electric, C.W. LaPierre, argued in 1958 that although "the American system of competition and incentives . . . is the most dynamically effective producer of technological goods and services. . . . defense work is being carried out with a minimum of incentives and highly centralized governmental control of detailed plans and operations." A Raytheon Company executive claimed that contractors for integrated weapon systems had to borrow large amounts of working capital and place major subcontracts, then supervise and coordinate the subcontractors' performances. Yet the government disallowed reimbursement for interest on borrowed funds, and many government negotiators apparently felt that the more a prime contractor subcontracted work, the less risk the prime contractor assumed and the less profit allowance it deserved. The Raytheon executive argued, however, that technical leadership, management, production, procurement skill, assembly, and test were each worth a profit. Each was a different profit, and no one could take the place of all or of another.[9]

What about "unearned" profits, those made when estimates overstated what contractors' actual costs proved to be? The General Accounting Office kept finding cases of overcharging, which it attributed to poor pricing mechanisms, and the government recouped what it deemed excess profits, most notably in a long legal battle against the Boeing Company. Pressed by the GAO, the Air Force began compelling contractors to certify that all available cost data had been considered and disclosed. An October 1959 amendment to the Armed Services Procurement Regulation required contractors to make the same certification for procurements exceeding $100,000 when the negotiated price was based more on estimates than on either competition, catalog prices, market prices, or prices set by law.[10]

The chairman of the House Armed Services Committee, Rep. Carl Vinson, was convinced that incentive contracting invited deception and padding, permitting profit on profit. On 31 May 1960, a House subcommittee on procurement practices held a revealing and sometimes combative hearing. Vinson and the GAO had drafted legislation requiring contractors to submit complete, accurate, and timely cost data, providing price adjustments for defective data, and prohibiting "increased fees or profits for cost reductions or target cost underruns resulting from causes other than those which the contractor can clearly and completely demonstrate are due to his skill, efficiency, or ingenuity." Defense Department spokesmen objected, arguing that if savings were limited to cases where such proof was possible, many reductions never would occur because contractors would have nothing to gain by making them. Yet Vinson insisted that incentives allowed a contractor to collect undeserved profits because the target price was so uncertain that it could be underrun "by something beyond his skill and efficiency." In response, Graeme Bannerman, the director of procurement policy in OSD, cited statistics about the Navy's fixed-price incentive contracts placed for aircraft and missiles during FYs 1957 through 1959. Their average final cost ran only 2.7 percent below the initial target costs, indicating that the average targets negotiated had been reasonably accurate. The contractors' final profit rate on fixed-price incentives was 9.8 percent, compared to 18.3 percent for firm fixed-price contracts. But congressmen remained unconvinced.[11]

Debating the Merits of Incentive Contracting

Rep. William G. Bray (R–IN): On the same theory [about incentives bringing out better performances], you hire a surgeon and pay him so much, but you are going to pay him so much more if you live. . . . And if you can't trust him to do his best, he oughtn't to have the job.

Rep. Carl Vinson (D–GA): Mr. Bray, you hit the nail on the head.

Graeme Bannerman (OSD): I think this goes to the heart of all questions of types of contracts. There isn't any question but that you achieve a higher degree of industrial efficiency under fixed-price contracting and competitive circumstances than you ever do under cost-reimbursement types of contracting. . . . At the end of the last war, it took several years for good companies to get back to habits of efficiency and economy and ability to compete in commercial markets. . . . I think that your comments with respect to incentives are applicable, Mr. Bray, quite as forcefully to fixed-price contracts.

Bray: If there is one instance where that contractor hasn't done his best to do a job and save the taxpayers money, you certainly ought not to give him another contract.

Bannerman: I completely agree. But how do you know he has done his best?

Bray: If you can't trust him, how can you trust the target you arrive at with him?

Bannerman: If that were true, Mr. Bray, we should never make fixed-price contracts. We should only make cost-type contracts [because the government could audit spending].

Vinson: Why is it that commercial concerns do not use this [incentive] type of contract? This contract . . . was only born in the fertile brains of naval procurement officers and then followed by . . . the Air Force.

Bannerman: I think the answer . . . is that commercial industry is not . . . buying missiles or aircraft that have not been previously run on a production line. Commercial industry, by and large, knows costs far better than we can possibly know them. . . . [W]e don't make incentive contracts at the beginning of the concept of a new weapon. We develop weapons under cost-type contracts, and we do get cost information from those contracts.

Vinson: If the target price was based upon a complete audit, there might be more justification to have incentive-type contracts. But when it is based upon an estimate, you are on weak grounds when you make your target price.[1]

In fact, Bannerman's claim about the accuracy of average negotiated targets was open to question. The targets may have been inappropriately high because contractors wanted the higher contributions to their overhead costs resulting from higher payments, not the relatively small profit increases gained by underrunning target costs. Conversely, low targets undermined incentives because the increase in profits would be more than offset by the decrease in contributions to a contractor's overhead. Also, if actual cost ran significantly below target cost, the government's contracting officer would appear to have accepted too high a target, reflecting poorly on his abilities and spurring him to prove otherwise in the next contract.[12]

The issue remained unsettled. The House passed Rep. F. Edward Hébert's version of Vinson's bill (HR 12572) by voice vote, but the Senate Armed Services Committee pigeonholed it. Late in July 1960, Defense Department officials published a fact sheet confirming that negotiated costs accounted for 85 percent of procurement dollars but denying that negotiation automatically signified the absence of competition. About 88 percent of negotiated procurements resulted from competitive situations, they maintained, with much of that competition of the design or technical variety. The House Armed Services Committee, however, issued a report claiming that the ability of cost-plus-fixed-fee and fixed-price incentive contracts to control costs remained "shrouded in the gravest doubts." Such contract types relied on advance cost estimating, rather than in-progress cost auditing, and so appeared "fraught with dangerous possibilities of 'unjust enrichment' at public expense." The committee concluded that firm fixed-price combined with advertised competitive bidding offered the best possibility of cost reduction, with the redeterminable variant providing "probably the soundest and more exact approach."[13]

There was considerable variation. By FY 1960, in the rapidly evolving missile field, DoD had concentrated three-quarters of the dollars in CPFF contracts. Firm fixed-price contracting was being used most widely for ships and tank-automotive equipment, where the technology was relatively well known, and also for semistandard items of electronic equipment. Aircraft contracts relied much more heavily on fixed-price incentives because they included many models that had moved into full production.[14]

A RAND study published in June 1962, but using Air Force samples from the middle and late 1950s, showed that about 55 percent of CPFF contracts had resulted in overruns while almost 75 percent of incentive contracts recorded underruns. Admittedly, CPFF contractors often would win contracts with unrealistically low bids. But costs and fees might rise because the scope and character of the job underwent significant changes—and the RAND analyst could not discern whether a low target price or later modifications had caused the overrun. Similarly, incentive underruns might result from either superior performances or poor estimates of target costs that even average contractors easily could undercut. Replacing fixed fees with incentive fees, the RAND analyst wrote, "ought to improve outcomes and efficiency in a measurable way." Incentive contracts, on average, yielded sizably higher profits. However, the analyst warned: "The notion that businessmen willingly accept risks in order to obtain higher profits has been very commonly believed, but to find actual instances in military procurement is rather difficult. If anything, 'play it safe' is the rule."[15]

THE TURN TO FIXED-PRICE INCENTIVE CONTRACTS

Secretary McNamara did not give contract reform the same detailed oversight that he applied to strategy and force requirements. Instead, he allowed subordinates to shoulder more of this task. Assistant Secretary of Defense (Installations and Logistics) Thomas Morris managed the transition from cost-plus-fixed-fee to fixed-price incentive contracting.[16] Morris began his tour on 29 January 1961, having served previously as deputy assistant secretary under Perkins McGuire and then as assistant director for management and organization at the Bureau of the Budget. McNamara met with Morris at 8:00 A.M. every Friday. Reflecting years later on their relationship, Morris said that the secretary was always courteous and supportive. A spirit of teamwork, Morris was convinced, pervaded his field. He detected little of the interservice rivalries and OSD-service tensions that bedeviled other areas.[17]

Morris left the Pentagon in December 1964 but returned 10 months later, first as assistant secretary of defense (manpower) and then in September 1967 as assistant secretary of defense (installations and logistics) once again. With hindsight, Morris characterized his first tenure in that position as innovative and his second as one of maintenance dominated by the demands of the Vietnam War.[18] For the interval between December 1964 and September 1967, Paul R. Ignatius held the installations and logistics position. At Morris's urging, Ignatius had left his management consulting firm of Harbridge House in 1961 to be assistant secretary of the Army (installations and logistics). He became under secretary in January 1964.

Thomas D. Morris *(OSD/HO)*

Thomas D. Morris (1913–1994)

Thomas Morris was born in Knoxville, Tennessee, on 19 April 1913. After graduating from the University of Tennessee, he worked in industry for five years and then as an office systems analyst with the Tennessee Valley Authority. Between 1942 and 1945, he served in the Navy as a member of the Navy Management Engineering Staff. Following the war, he participated in both Hoover Commissions studies (1949, 1955) and conducted management surveys for several federal agencies and private organizations.

Morris began his initial tour with the Office of the Secretary of Defense in 1956 as deputy assistant secretary for supply and logistics. Between 1958 and 1960, he was the assistant to the president of the Champion Paper and Fiber Company, and then served as assistant director for management and organization, Bureau of the Budget. Secretary of Defense McNamara selected Morris to be assistant secretary of defense (installations and logistics); he took office on 29 January 1961.

At the Pentagon, Morris championed measures to reduce contract costs, such as price competition, incentive contracting, inventory management, and direct purchase of spare parts from manufacturers rather than through prime contractors. Competitively awarded contracts increased while Morris was assistant secretary, from 32.9 percent in 1961 to 38.6 percent in 1964. The McNamara Pentagon, during this time, also placed restrictions on cost-plus-fixed-fee contracts, which were widely blamed for cost overruns in major weapons programs. As the military services shifted to incentive contracting, the use of cost-plus-fixed-fee contracts dropped significantly, from a rate of 38 percent in 1961 to 12.3 percent by July 1964.

Morris left the installations and logistics post in December 1964 but soon returned to the Pentagon as assistant secretary of defense (manpower), a position he held from October 1965 until August 1967. Between September 1967 and February 1969, Morris was, once again, assistant secretary of defense for installations and logistics. He left the Pentagon for the final time in February 1969 to become vice president of Litton Industries. In the 1970s and 1980s, Morris held several high-level positions in the General Accounting Office, Department of Health, Education, and Welfare, and the General Services Administration.[II]

Secretary McNamara outlined his views on contracting and the government-contractor relationship in a speech on acquisition reform in June 1961 at a cost-reduction symposium sponsored by the National Security Industrial Association (NSIA), a trade and lobbying organization. Past efforts at economy, McNamara argued, had concentrated entirely too much on identifying unallowable costs after they had been incurred. Instead, improving the cost-to-benefit ratio up front should be given central importance. McNamara proposed seven ways to do this:

- simplify specifications, rationalize tolerances, and look upon a performance standard as a range of alternatives rather than a fixed point
- reduce development times by real analysis and by sometimes drastically overhauling the decisionmaking process, particularly avoiding the dollar traps of open-ended work statements that invited exploration of endless technical alternatives
- obtain more reliable cost estimates
- limit the engineering changes after an item enters production
- simplify procurement procedures down through every tier of the subcontracting structure
- streamline DoD reporting requirements
- eliminate uneconomic and inefficient conditions while recognizing the human costs of plant or base closings.[19]

Early in October 1961, Deputy Secretary of Defense Roswell Gilpatric told the NSIA that contractors merited a mixed verdict: "Over-all, your industry's performance has been good, but 'good' is not enough in these times. There have been far too many failures." Three cases of mismanagement stood out. First, the carrier USS *Kitty Hawk* was undergoing sea trials 22 months behind schedule. The Navy admitted that its design changes accounted for 12 of those months but held the New York Shipbuilding Company's inefficiency responsible for the other 10. While the contractor was saving about $1 million annually in housekeeping costs, for example, metal shavings and other debris that littered the deck had found their way into fuel, water, and chemical lines. Second, production of the Army's new M–14 rifle faltered so badly that McNamara publicly labeled the contractor's performance "a disgrace." Third, OSD officials learned without prior warning that engine deliveries for Navy fighters were 5 months behind schedule. Responsible managers in General Electric had not even been aware that problems existed; flight tests were set back 6 months.[20]

During World War II and the Korean War, cost control was willingly sacrificed to speed. Now, though, the administration aimed to control costs while meeting schedule and performance standards. Previous secretaries of defense assumed that there had to be tradeoffs among these three factors. McNamara and Morris hoped that incentive contracting, combined with other initiatives, would make such sacrifices unnecessary. An interagency review led by Bureau of the Budget Director David C. Bell and completed in April 1962 supported their view. The Bell report denigrated cost-plus-fixed-fee as probably raising costs when deadlines were tight and inducing contractors to prolong deliveries when no deadlines existed. Conversely, it cited ample evidence that giving adequate incentives to reward outstanding performance could save both time and money.[21]

OSD held that many of the CPFF contracts awarded for R&D work mainly concerned applications engineering, involving no research and little or no development. Test and evaluation, for example, involved largely routine undertakings. By introducing better management and cost accounting practices, such services could be procured on a fixed-price basis.[22]

Assistant Secretary Morris voiced OSD's bedrock belief that a company's incentive to earn more was the keystone of its effort to produce better products at lower prices.[23] Implementation of that conviction began on 15 March 1962. Revision No. 8 of the Armed Services Procurement Regulation limited CPFF contracts to basic research, study, and a few involving development where the unknowns were so great that feasibility was uncertain. Incentive contracts would replace cost-plus contracts in most cases in which the development and production of new weapons overlapped. Fixed-price incentive and cost-plus-incentive contracts would establish target costs, performance factors, and reward formulas. They also would specify cost, time, and performance goals, making the penalties as great as the rewards, which would range from zero profit (meaning an out-of-pocket cost to the contractor) up to the legal maximum of 15 percent. During the early stages of a missile's development, for example, performance factors such as range, payload, accuracy, and reliability might comprise one-half the incentive fee, completion time one-third, and cost reduction one-sixth. When production for testing began, however, performance and time might determine about half the fee and cost the remaining half. Contractors would be invited to specify the incentive plan under which they would work. Since a virtually risk-free proposal would endanger a bidder's competitive position while an unduly optimistic offer courted financial loss, resorting to incentives should "compel more clarity and integrity" from contractors. In fact, the ASPR specified that "to the extent practical, firms not willing to negotiate appropriate incentive provisions may be excluded from consideration for the award of development contracts."[24]

The *DoD Incentive Contracting Guide,* issued in August 1962, claimed that incentives, when properly conceived and applied, could do more than any other factor to maximize technological progress. According to the *Guide*, both government and industry would have to break new ground since no reliable way had been found to determine whether a performance incentive arrangement was working well or badly. Consequently:

> all the traditional elements of procurement planning must be carried out in even greater depth when an incentive contract is contemplated. For the government, this means more careful evaluation of potential sources, and a serious endeavor to make solicitation documents more definitive. . . . For the contractor, it means stronger emphasis on realistic and objective preparation of proposals and greater willingness to examine the job in minute detail. . . . A too-heavy incidence of changes, modifications, and misunderstandings during contract performance will severely damage the effectiveness of the incentive provisions.[25]

Some contractor concerns and priorities differed from those of OSD. According to a survey published in the journal *Armed Forces Management*, many statements of military requirements struck industry suppliers as "less than reasonable formulations." At the working level, DoD's handling of fixed-price redeterminable contracts, its extensive documentation of costs and estimates, and its penchant for overmanagement left some contractors with "the clear, and frightening, impression" that DoD believed "free enterprise can't hack it." Even for contracts negotiated at cost-plus-7 percent, some claimed, a company negotiator had to be "virtually a genius" to keep as much as 5 percent, no matter how efficient the performance proved to be.[26] In June 1962, the National Security Industrial Association heartily endorsed incentive contracting but warned against using renegotiation to take back "excess" profits. Claiming that detailed official supervision wasted "undetermined, but vast, sums," the association argued for making such oversight the exception.[27]

Early in 1962, McNamara, Gilpatric, and Morris decided to organize a government-industry forum. The Defense Industry Advisory Council (DIAC), established on 23 May 1962, started out with Gilpatric as chairman and E.V. Huggins of Westinghouse Electric Corporation as vice chairman. Its mission was twofold. First, it would allow McNamara and his subordinates to present their objectives before a cross section of industry leaders, inviting their suggestions and criticisms. Second, it would provide a focal point to review the findings of study groups run by industry. Twenty-one top executives attended the DIAC's first meeting on 30 June.[28]

Between January and May 1963, the council identified what it considered the fundamental issues affecting government-industry relationships and created working groups to analyze them. Early in September, the council reviewed the groups' recommendations. First, how could proposals for weapons development programs be made more realistic? The DIAC decided that many of the efforts under way, such as stressing incentive contracting and widening the use of Program Evaluation Review Technique (PERT), a methodology for integrating and evaluating progress, would attack the causes of this problem and render further study unnecessary.[29] Second, and harder to address, how could industry's slide in profits, or earnings as a percentage of sales, be stopped? Since only generalized and limited data were available, the "causes, effects, true meaning and future projections of this apparent trend" needed more analysis. Third, how could cost estimates be made more reliable? Despite "truth in negotiations," the GAO still uncovered cases where known costs were not submitted accurately. The DIAC labeled underestimating costs a matter of great concern, causing severe criticism of both government and industry as well as creating friction between them, but the council had no solution.[30]

Pursuing other possibilities, Assistant Secretary Morris created a cost-plus-award-fee contract, the first of which was awarded in 1964. Following Army and Navy experiments, this innovation came into use for such technical services as design, architecture, programming, and engineering. Risks and rewards were greater than those under CPFF but less than those under CPIF. A producer could be penalized as much as 5 percent of costs or earn a fee as high as 15 percent, exceeding even the 8 to 12 percent gross profit range normally allowed in fixed-price contracts. In these cases, both parties agreed to minimum and maximum fees as well as criteria for judging the contractor's performance. A government board carried out monthly or quarterly appraisals. Profits were determined upon completion, when the board assessed the product's quality and reliability, the amount of financial risk assumed, and the efficiency of operations. This proved to be the most durable contract innovation of McNamara's tenure.[31]

Another effort to strengthen incentive contracting came through the use of "contractor's weighted average shares" (CWAS), endorsed by the Defense Industry Advisory Council in May 1965 and approved by Secretary McNamara six months later. CWAS offered a better way of distinguishing high-risk from low-risk environments. Under its provisions, a contractor's risk would be measured by applying weights to the type of contract being performed (varying from 0 percent for cost-plus-fixed-fee to 100 percent for competitive fixed-price) by a company and by each smaller "profit center" within it.[32]

Two-step formal advertising offered another way of trimming costs. Assistant Secretary Ignatius began applying it to the Army, and Secretary McNamara approved its use DoD-wide. In the first step, bidders would respond to requests for proposals by submitting designs that met specified performance criteria but without the cost estimates previously required. Unqualified firms would be weeded out. In the second step, bidders with approved designs would submit sealed bids, with the low bidder winning the contract.[33]

Army officials believed that switching from annual to multiyear contracts would improve some procurements significantly, especially those for vehicles. Under one-year contracts, for example, jeep production temporarily stopped whenever the winning bid shifted from the Ford Motor Company to Willys Motor Company or vice versa because Army-owned machine tools had to be moved from one plant to another. Such a stoppage occurred in October 1962—a particularly inopportune time—in the midst of the Cuban missile crisis. One month later, OSD approved using multiyear procurements in which the complete contractual period along with each year's requirements would be specified, but funding obligations would cover only the first year. A cancellation clause provided that if funds were unavailable in later years, the contractor would receive compensation for production expenses that would otherwise have been spread across the entire production run for the full, multiyear procurement.[34]

During the next 18 months, according to a study by the Logistics Management Institute (LMI), multiyear procurement worked well.[35] In 38 of 42 cases, the low multiyear bid ran below the low single-year bid. Since the consequences of losing a multiyear contract were far more severe, contractors devoted strenuous efforts to cutting bid prices to the absolute minimum. But 90 percent of multiyear contracts were Army, and they remained a small percentage of the DoD total. Many contracting officers were reluctant to use it, concerned about whether a requirement would remain firm over several years.[36]

In past years, companies sometimes had received letters outlining contract terms (that is, "letters of intent" or "letter contracts"), allowing them to start work immediately with a promise of reimbursement as soon as Congress appropriated the money. In OSD's judgment, too much reliance on loosely worded letter contracts and long delays in defining their terms constituted "one of the most wasteful procurement practices." Accordingly, between November 1962 and June 1963, the dollar value of such contracts was slashed by almost half. Deputy Secretary Gilpatric then signed a policy statement encouraging the relaxation of unnecessarily tight delivery dates, which had been a frequent reason for using letter contracts. In June 1963, 365 letter contracts worth $1.85 billion were in force; 105 were over six months old and worth $1.153 billion. By June 1964, there were 186 valued at $644 million; only 30, worth $366 million, were over six months old.[37] During the autumn of 1965, however, urgent requirements for the Vietnam War brought letter contracts back into heavy use (see chapter XI).

STRIVING FOR "TRUTH" IN COST ESTIMATES

The switch to fixed-price incentive contracting came at a price. In March 1961, Rep. F. Edward Hébert introduced a bill (HR 5532) based on the earlier bill by Vinson that required complete, accurate cost data and limited profits. OSD General Counsel Cyrus Vance stated DoD's opposition, contending that regulations could adapt to circumstances but a statute was inflexible. Nonetheless, on 7 June 1962, the House overwhelmingly approved the bill. The GAO supplied crucial evidence that ended Senate opposition to it. Upon reviewing 276 negotiated pricing actions by the Army and Navy during 1960–1961, the GAO found that 121 had been completed without certifications that cost data appeared to be complete and accurate. (The Air Force, anticipating the problem, had obtained certifications for its 88 actions that the GAO had reviewed.) According to Vinson, the GAO's audit showed that "in many instances we bought only a superior guess." Pleading his case before the Senate Armed Services Committee, Vinson said that "if it is good regulation, it will be good law." Assistant Secretary Morris objected to singling out incentive contracting. Why not make the ASPR cover all types? The committee chairman, Sen. Richard Russell, agreed. So, reluctantly, did Vinson.[38]

The "truth in negotiations" bill, as it was termed, became law (Public Law [PL] 87–653) on 10 September 1962 and took effect on 1 December. It required a contractor to certify as accurate, current, and complete, to the best of its knowledge and belief, cost and pricing data submitted during negotiations exceeding $100,000. Significant increases would be disallowed if the contractor's data had failed to meet certification requirements. Before applying a formula for sharing profit or loss, an audit would determine whether costs claimed by the contractor were in fact accurate, complete, and current. If not, the incentive target price would be correspondingly reduced and the shared profit would be smaller.[39]

As early as 1958, outside consultants had been urging the Defense Department to establish a single contract audit agency. Public Law 87–653 provided added impetus. The Defense Contract Audit Agency (DCAA), collocated with the Defense Supply Agency in Alexandria, Virginia, and headed by a civilian who reported to the assistant secretary of defense (comptroller), began functioning on 9 June 1965. It audited all cost-reimbursement types of contracts but was not authorized to examine records relating to firm fixed-price and fixed-price with escalation contracts.[40]

Assigning responsibility for changing costs proved to be difficult. After a 1966 review, GAO claimed that auditors often had found cases of overpricing hard to pinpoint. The U.S. comptroller general recommended establishing standards by which contractors could improve and formalize their cost estimating methods. In January 1967, now-Deputy Secretary of Defense Vance issued a circular setting out tighter guidance and criteria. That year, the DCAA reviewed 244 contracts worth $1.735 billion and found possibly defective pricing in 46, amounting to only $12.8 million. Nonetheless, GAO kept alleging instances of inadequate agency audits, prompting an irritated OSD to raise questions about the objectivity of such findings. However, Vance directed that noncompetitive, firm fixed-price contracts contain a clause allowing auditors to assess records and determine compliance with PL 87–653. Some members of the Defense Industry Advisory Council voiced strong reservations, but OSD Comptroller Robert Anthony stressed how very limited such reviews would be.[41]

CHALLENGING THE RATIONALE FOR INCENTIVES

Might "truth in negotiations" have been a solution to a disappearing problem? In 1962, Merton J. Peck and Frederic M. Scherer of the Harvard Business School published a seminal study, *The Weapons Acquisition Process: An Economic Analysis*. Their findings flowed from case histories of 12 major weapon systems.[42] On average, development costs had run about 3.2 times greater than the original estimates—a figure that would be cited frequently by critics of CPFF contracts.

Why were the overruns so high? Put very broadly, cost had been sacrificed to save time and particularly to assure quality. What Peck and Scherer learned about economizing through incentives was sobering. In the commercial market, they noted, consumers imposed time and price limits. But the military services wanted high performance above all and were willing to pay for it. Consequently, incentives often had a perverse effect:

> Profits are in one way or another roughly related to costs, and so incurring high costs through quality-increasing activities is usually profitable. . . . Of course, in theory this is not so, since the fee on a development contract is usually fixed in advance. But in practice profits often increase with costs through the use of engineering changes, letter contracts, and short-term contracting practices.[43]

In 1964, Scherer's sequel, *The Weapons Acquisition Process: Economic Incentives,* waved more warning flags. Looking at development phases of the same 12 weapon systems, Scherer found that incentives frequently were undercut by "user costs," which he defined as sacrificing future profit for some immediate benefit. During 1958–1959, Scherer concluded, companies focused more on performing contracts in ways that would attract future business than on trying to maximize the relatively modest incentives by keeping costs as low as possible. Under CPFF contracts, research and development as well as bid and proposal costs were reimbursed by the government. By 1963, as outlays climbed for research, development, and test and evaluation, firms set out to maximize their reimbursable expenses in those categories. Time and quality almost always took priority over cost control. Thus, contract provisions that attempted to correlate profit with price reduction were overwhelmed by rising overall costs.[44]

In Scherer's view, recent DoD directives requiring extensive use of multidimensional contracts combining time, cost, and quality incentives "must be found wanting."[45] His analysis indicated that competitive incentives usually preserved quality and compressed time much better than they controlled cost. Scherer cited the supersonic B–58 bomber as the first use of multidimensional contracting. Final profit could vary between 4 and 7 percent of the target cost; one-half of that variation was allocated to performance, one-third to deadlines, and one-sixth to costs.[46] Yet by almost any yardstick, the B–58 was not a success. Development problems resulted in cost overruns, schedule delays, and major reliability problems. The Air Force ultimately purchased fewer than half the total number of B–58s it intended to buy and retired the aircraft after less than a decade of service.[47]

A 1963 study by the firm Arthur D. Little, Inc. (ADL) found conclusive evidence that the defense industry's profits, at least as a percentage of sales, had declined steadily between 1957 and 1961. ADL called this trend a natural result of swiftly cutting back fixed-price redeterminable contracts while vastly increasing CPFF contracts. However, the ADL report continued, the Defense Department's view of profit as the energy that kept American business running applied only in an entrepreneurial economy. In the defense industry, by contrast, innovators and managers who promoted efficiency depended largely on salaries for their reward. While defense firms' profits as a percentage of sales were falling, ADL noted, their return on equity or invested capital compared to all businesses remained high. Because the government was providing less capital, however, contractors had to increase their own investment "by an indeterminate but very substantial amount." ADL continued: "For the large corporations, upon which the bulk of our defense effort must rest, the most important implicit cost is that of capital. The cost of capital may be defined as the return which must be provided to [attract and] secure capital from investors. . . . Profits must clearly be related to the return required to generate the investment." Since contractors had been financing their own growth primarily by taking on debt, their cash requirements rose faster than their sales.[48]

Meantime, Assistant Secretary Morris's staff reviewed recent incentive contract negotiations and claimed an achievement: realistic cost targets were being established for high-dollar awards. But incentives for exceeding technical performance targets were not being used enough, and profit-sharing arrangements neither gave contractors superior rewards nor imposed severe penalties on them. Further studies showed that incentive fees tended to cluster around given percentage rates, depending on the type of contract and industry, and remain there year after year. ADL had discerned that many government negotiators, through experience, would arrive at a profit or fee rate well below the maximum permitted but high enough for contractors to accept. They would apply those rates constantly for a time and then lower them slightly, thereby establishing themselves as good bargainers.[49]

Morris's remedy, which the Defense Industry Advisory Council endorsed and DoD began applying during 1963, was weighted guidelines. Their purpose was to distinguish between low-risk ventures, where profits ought to run substantially below current norms, and high-risk ventures, where target profits might reach the maximum allowed by law or what was considered sound business practice. Specific numerical weights would be assigned to quality, time, and cost factors, each having a range of percentage points to reflect possible variations. For example, points assigned to the contractor's assumption of risk could vary from zero, in the case of a CPFF contract, to several points for a tightly negotiated firm fixed-price contract. To prevent pyramiding profits on large contracts, subcontracted work was generally assigned a lower level of profit than work done in the contractor's own house. Weighted guidelines would force contracting officers to discriminate among many factors. The ASPR stated profit policy simply as a narrative, so contracting officers had fallen into a habit of assigning the same profit rate to all contracts of the same type.[50]

Evidence accumulated indicating that certain basic assumptions about incentive contracting were mistaken. Peck and Scherer had found that, from the contractors' standpoint, the pursuit of higher profits had "diminishing marginal utility."[51] A study by George Washington University researchers published in

December 1965 made the point more bluntly. According to the *DoD Incentive Contracting Guide*, a contractor "should be motivated in calculable mathematical terms" concerning fees or profit. Not so, said the researchers. A substantial amount of recent literature held that managers and executives did not behave like entrepreneurs, who concentrated on maximizing their profits. Rather, procurement personnel interviewed by the researchers had "unequivocally verified . . . that contractors strive to improve efficiency when confronted with a loss but are indifferent to a reward for such efforts." Assuring future sales and marketplace dominance had higher priority. Moreover, there was:

> a fundamental inconsistency in incentive contracting. The contractor's efficiency is not a factor to be associated with risk. . . . Therefore the contractor's choice between inefficient procedures or profits (the choice that the fee schedule attempts to influence) is a choice which can only be made under conditions of cost certainty. But the cost uncertainties associated with incentive contracting are patent. . . . Therefore, at the time of negotiation, the contractor is more concerned with establishing a favorable position with respect to the cost uncertainties involved in the contract than [with] the possibility of rewards for future efficiency.[52]

STREAMLINING PROCEDURES

DoD Directive 3200.9 (Initiation of Engineering and Operational Systems Development), dated 1 July 1965, required that completion of three phases—concept formulation, contract definition, and development—precede a decision about production. Broadly, concept formulation would provide the technical, economic, and military basis for a conditional decision to begin engineering development; contract definition would determine whether to ratify or reject that decision. A study by the Peat Marwick Company illustrated the necessity of starting with a strong effort at concept formulation, which included the preparation of a technical development plan. Of the five projects examined in the study that underwent contract definition prior to February 1964, only two proved to be ready for that phase as it came to be described in July 1965. Analyses, plans, and decisions about the other three that were made *during* contract definition should have been made *before* it. As for those three contracts, one was canceled, the second was substantially changed after a technical assumption proved invalid, and the third had to be reoriented when its mission was redefined.[53]

Contractors complained about an explosion of management systems and a growing number of reporting requirements, calling them inconsistent with the promised simplicity of fixed prices and incentives. If the government chose to exercise detailed oversight, they argued, should it not also share in the contractor's failures as well as successes? In May 1966, a study group organized by the Aerospace Industries Association protested the "increasing proliferation of divergent and incompatible management systems" being imposed on industry, particularly multicustomer companies. Government, the group claimed, imposed rigid rules even as it promised competitive programs—creating an environment that tended largely to negate the advantage of fixed-price incentives.[54]

Already, Secretary McNamara had instructed Comptroller Anthony to combat Defense Department overmanagement with some "disengagement." In response, Anthony devised resource management systems that would keep information requirements at a minimum, relying on contractors' internal systems and reporting procedures, provided they met DoD standards. Industrial associations also collaborated with DoD in developing a selected acquisition information and management system (SAIMS), starting in December 1965. Based on information extracted from the contractors' control systems, SAIMS presented information in a form that DoD managers could use to support planning and evaluate progress.[55] Contracting for Poseidon, the submarine-based ballistic missile system that succeeded Polaris, showed how difficult it could be to apply phases and incentives as OSD defined them. Some of those who made Polaris a success during 1955–1960 argued that they would have been hamstrung by the policies instituted during 1961–1965. The concept of Polaris had not been clearly defined before its development began; subsystems were definitized as needs arose. Incentives were not applied until Polaris's production phase, after prototypes had been procured and priced under annual CPFF contracts. During the development of Poseidon's subsystems, only the rocket motor contract was opened to competition; all others were sole-source awards. In some subsystems, contrary to DoD Directive 3200.9, as much as half the design work was completed before contracts were definitized. Government engineers objected that incentive contracts forced decisions too soon, cost more, created extra paperwork, and boosted contractors' profits. In time, their antagonism toward incentives mellowed because they learned how to turn such contracts to their advantage. For example, according to Harvey M. Sapolsky, author of the classic study of the Fleet Ballistic Missile system, Navy program managers used multiple incentives for Poseidon but "consistently and openly placed the greatest weight on system performance targets with delivery and cost targets usually following behind them in that order."[56]

THE HERSHEY PRICING CONFERENCE

All was not lost by any means for advocates of incentive contracts. A study initiated by the Defense Science Board claimed that incentives could prove beneficial, especially for engineering and operational systems development. But the study also judged that incentives had been used improperly during research, exploratory, and some advanced development situations, where uncertainties precluded any prior definition of meaningful incentive tradeoffs. The study identified as a major cause the bias in regulations toward using high-risk contracts without giving adequate consideration to their exploratory nature.[57]

When the Defense Industry Advisory Council met in mid-October 1967, Secretary of the Air Force Harold Brown argued that "today's methods of acquiring major weapon systems were far superior to those of the past and were continuing to improve." Ruben F. Mettler, president of TRW Systems and vice chairman of the council since 1964, countered that "despite much effort and considerable improvement, there were still serious flaws," some of which might become "more significant in future programs."[58]

Sharper criticisms were voiced at a DoD-wide Procurement Pricing Conference, held from 30 October through 2 November 1967 in Hershey, Pennsylvania. The Hershey meeting was, in effect, a super-DIAC convened to identify problem areas, emphasize the importance of pricing as a part of procurement, and establish communications links between OSD echelons, the military departments, and field pricing personnel. Two addresses—one by Barry J. Shillito, president of the Logistics Management Institute (and a future assistant secretary of defense for installations and logistics), and the other by Robert A. Frosch, assistant secretary of the Navy (research and development)—are illuminating. Shillito gave conferees a synthesis of how senior executives from over 100 private companies saw matters. Many maintained that DoD was failing to practice what it preached about pricing. They believed that contracting officers and price analysts, under pressure from the Defense Contract Audit Agency, had grown reluctant to include even the most logical contingencies in cost estimates. Industry wanted long-term contracts but found DoD unwilling to give what companies considered reasonable protection against unforeseen or uncontrollable price increases. Often, they contended, fixed-price incentives limited their profits while allowing the government to reduce prices. In sum, cost reduction by a contractor did not translate into an equivalent rise in profit.[59]

Shillito reported that the ratio of profits to invested capital among larger contractors had declined about 35 percent since 1958. In fact, for every year since 1960, price/earnings ratios for defense-oriented firms were lower than those for predominantly commercial firms. Shillito recalled that in 1962, he had labeled competitive fixed-price the ideal type of contract, offering the greatest profit incentive. Now he thought the pendulum had swung too far that way. Unlike fixed-price commercial contractors, fixed-price defense contractors had no opportunity to recoup the unanticipated costs arising from miscalculations or poor estimates. Still, Shillito considered the movement away from simple cost-reimbursable contracting to be beneficial to suppliers because it pressured them into greater efficiency.[60]

Assistant Secretary of the Navy Frosch was more outspoken. As far as most R&D people were concerned, he began, "the procurement empire has no clothes." A "very remarkable number" of projects, ostensibly conceived with care, were coming up against "terrible troubles," mainly because the result of the development phase was not an *object* but an *objective*. The outcomes of contract definition were being treated as if they were pieces of sensible, tangible hardware, yet their unsolved problems made changes unavoidable. Those changes were what “generally cause all the trouble,” but contracts read as if there should be no changes, and the pricing system rested on an assumption that none would occur.

Commenting on fixed-price incentive contracts, Frosch doubted the underlying presumption that incentive equaled motivation. Instead, incentives provided a manufacturing firm with “a rather more complicated framework inside which it can optimize its problems.” In some recent contracts, Frosch related, the contractor’s best move would have been to default and never deliver—but the government wanted the objective so badly that it would not let the contractor escape.[61]

Frosch rated a cost-type contract as the most advanced, creating the best chance for successful development. Yet it also allowed continuous changes that DoD’s research and development management system could not control. The development phase might prove that a weapon could be fabricated but not that it could fit into a production plan. “Fly before you buy” impressed Frosch as the right way to go, although the time required to take that approach would double, and risk money would have to be paid out sooner. Instead of cutting back on parallel developments by two or more contractors, he wanted competing prototypes from which well-tested weapon systems could be purchased.[62]

Little came of the 220 recommendations the Hershey conference produced. Panels studied 13 items singled out for early consideration. In March 1968, the panel on profit reported that it saw no way to measure how government policies affected contract performance. None of its subgroups could even agree about whether contractor profits were adequate. The panel on incentive contracting reported that multiple incentives had grown more complex, yet the underlying belief that maximizing profits on each contract was a prime motive had proved to be wrong. Such contracts should be deemphasized and cost-plus-award-fee contracts used, particularly in the R&D field.[63]

To improve pricing techniques for sole-source procurements, Comptroller Anthony inaugurated a “should-cost” procedure. The purpose was to move away from elastic historical cost to a more stringent standard. A government team would visit a plant, examine the contractor’s assumptions, and negotiate what a performance “should cost,” assuming reasonable economy and efficiency. In February 1968, Anthony started releasing quarterly Selected Acquisition Reports (SARs) that summarized performance, schedule, and cost information about major projects, allowing DoD management to identify problem areas by comparing actual with planned accomplishments in technical characteristics, schedules, quantities, and costs. SARs could be required when financing for research, development, and test and evaluation surpassed $25 million or when cumulative production investment exceeded $100 million.[64]

DISSOLVING THE LINK BETWEEN INCENTIVES AND PROFITS

By 1968, a consensus was forming that demolished much of the original rationale for incentive contracting. The Logistics Management Institute in May described virtually unanimous agreement among managers and analysts that contractors were willing to sacrifice profits, in the short run, to achieve company growth and increase market share. Managers' salaries and prestige, after all, depended more on sales than on profit rates. Even for research, exploratory development, and advanced development, scientists and engineers as well as procurement specialists looked upon incentives as little more than a gamble. Thus, LMI concluded, there was:

> no compelling evidence that cost incentives are working. Contractors have such strong motivation to emphasize performance attainment that performance incentives may be unnecessary. The use of incentives has, however, produced more thorough government acquisition planning and more complete and precise communication of procurement objectives to contractors.[65]

The aircraft industry supplied ample evidence of these findings. A RAND analyst, Irving M. Fisher, studied 1,007 Air Force contracts completed between fiscal years 1959 and 1966. He found cost underruns—projects completed for less than the target cost—more common among fixed-price incentive contracts than among other types. But he could detect no proof that incentive profit-sharing arrangements led to costs that ran below the target price. Rather, such underruns resulted from a general upward shift in target costs. As long as the development contractors could win the production and follow-on contracts without facing effective competition, there would be:

> no guarantee that the negotiated target cost [for production] is sufficiently close to the contractor's anticipated actual cost to provide a meaningful incentive for greater efficiency and reduced costs. In short, incentive contracts cannot be expected to provide the motivation for which they were intended without some means for establishing realistic target costs.[66]

Peck and Scherer, in their seminal 1962 study, believed that aircraft manufacturers' profit as a percentage of capital investment began falling when the government stopped investing in plants and tooling, forcing contractors to make up the difference. Decades later, in a history of the U.S. aircraft industry, Donald Pattillo wrote that smaller production runs, contract cancellations, and heavy development expenses for commercial jets created grave financial troubles for the industry. The Douglas Aircraft Company in 1959, the Lockheed Corporation in 1960, and General Dynamics in 1961 led the list of money losers among *Fortune* magazine's list of the top 500 industrial firms. Rising R&D expenses and heightened financial risk eliminated all but the largest and strongest firms, and even those became increasingly vulnerable.[67]

Profit, defined as a percentage of total capital investment, was stagnating for almost all defense contractors. LMI found that between 1958 and 1967, highly profitable defense firms earned less (around 7 percent) than highly profitable commercial companies (above 10 percent). Thus, OSD suspected that the Pratt and Whitney Aircraft Company was trying to postpone deliveries of TF30 engines for F–111s so that it could fill more profitable orders for commercial jet engines.[68] Low-profit commercial and defense businesses ran at about the same rates. Defense profits had fallen steadily from 1958 to 1964, risen slightly during 1965, then stayed level over 1966–1967. Indeed, according to LMI, the Defense Department's increasing use of competition largely accounted for the lower profit-to-sales ratios of defense businesses. During 1968, when accusations of war profiteering came from Congress and the media, Secretary of Defense Clark Clifford cited these findings in rebuttal. True, he informed congressional committees, estimated "going in" profits on noncompetitive contracts rose 22 percent between 1964 and 1967. The final realized profit, however, depended upon whether actual costs proved to be the same as the estimated going-in costs. The LMI study, he stressed, showed that "realized" profits remained at 1959–1963 levels. However, his refutation of war profiteering also constituted a condemnation of incentive contracting. In sum, then, an array of incentives had failed to produce the higher profits that would translate into greater industrial efficiency.[69]

TOTAL PACKAGE PROCUREMENT

Total package procurement (TPP) was a bold bid with a plausible rationale and a promising beginning. Robert Charles came to the post of assistant secretary of the Air Force (installations and logistics) in 1963 after 18 years with McDonnell Aircraft Corporation, where he had risen to be executive vice president. Charles's experience left him "appalled," he said later, by "the lack of meaningful competition in defense work, particularly in the big systems." The high cost of aircraft development, he believed, usually ruled out building two or more models for a competitive fly-off. Development contracts thus were concluded "without competition in terms of meaningful commitment." In their place came what he called "brochuremanship: unrealistically low estimates of cost and florid estimates of technical performance for which there were no significant penalties if not met." When the time to start production approached, "the contractor was so far into the program, and . . . had built up such a store of technical knowledge and data and equipment . . . that it was virtually impossible to change contractors or to inject competition." When Charles worked for McDonnell, he recalled, "I would clap my hands with glee and shed a tear for the taxpayer. . . . This technique of buying icebergs on the installment plan [that is, concealing the much larger ultimate cost] . . . amounted to an open government invitation to contractors to buy in on the development work by overstating technical performance and understating costs." His answer to the unrealistic buy-in was total package procurement. A single contract covering design, development, and test and evaluation (DDT&E), production, spare parts, and ground equipment would apply the discipline of competition to the complete acquisition cycle.[70]

A vigorous debate took place within the Air Force regarding what would happen if a contractor failed to perform, but Charles carried the day.[71] He chose the C–5A, a long-range jet transport with a cargo volume four times greater than that of the C–141, to be the pioneer project for TPP.[72] Charles's superiors concurred. In December 1964, the Air Force asked Lockheed, Boeing, and Douglas to present detailed technical and cost proposals; General Electric and Pratt and Whitney were invited to submit power plant proposals. The Air Force admonished each competitor:

> In order that competition . . . be meaningful, the target cost contained in the winning competitor's contract will remain firm . . . throughout the program and his proposed performance will become the contract minimum requirement to be assured by a Correction of Deficiencies clause. These provisions will be strictly adhered to and you should bear this in mind as you prepare your proposal.

During 1965, TPP became a formal part of the Defense Department's acquisition process. In June, adopting a recommendation by LMI, DoD Directive 4100.35 (Logistic Support) required that cost estimates cover the entire life cycle of a weapon system. In October, Lockheed and General Electric were declared winning bidders for the C–5A. Lockheed's contract for DDT&E and production of 115 aircraft stipulated a target price of $1.945 billion; GE's engine contract had a target price of $624 million.[73] These prices included a 10 percent profit. If the actual cost underran the target, the contractor's profit would increase by 15 percent of that underrun. Similarly, if an overrun occurred, the profit would be cut by 15 percent of the overrun. Most important, the contract fixed a *ceiling* price of 130 percent of the target cost. The government could adjust Lockheed's share in any overrun or underrun by 50 and 30 percent respectively, with the stipulation that the target cost, target price, and ceiling price then would rise by about 3.2 percent.[74]

Charles felt sure that TPP surpassed standard contracts in several ways. First, a conventional contract defined requirements largely through detailed specifications approved by the government. Consequently, when a system failed to perform as advertised, the government had to shoulder some responsibility. But the C–5A's requirements were expressed largely in terms of performance, for which the contractor accepted full responsibility. Second, under the old system, commitments regarding technical performance, delivery schedules, and production price were made only after the development phase was substantially completed and, even then, usually only for one year's run at a time. Under TPP, such commitments took place prior to development.[75]

There were other significant differences. The government usually furnished many components and therefore did not hold the prime contractor responsible for the total system's performance. If the reason for faulty performance could not be clearly allocated, the government bore the cost of corrections. On the C–5A, however, Lockheed accepted responsibility for the entire system. In addition, in fixed-price incentive contracts, the targets for measuring rewards and penalties usually were based on the past performance of that particular contractor. Since the contractor's inefficiencies as well as efficiencies entered the calculation, there was little penalty for failing to improve and economize. In contrast, the C–5A contract contained powerful incentives that were arrived at competitively to find better, cheaper ways of doing business. Finally, while a normal contractual commitment lasted about two years—and in many cases, particularly for engines, less than one year—the C–5A contract ran for seven.[76]

Even though experience was meager, the services promptly adopted total packaging. The Air Force started applying TPP to the AGM (air-to-ground missile)–69, a short-range attack missile (SRAM) carried on B–52s and FB–111s, the Army to a light observation helicopter's avionics system, and the Navy to a Fast Deployment Logistics (FDL) ship. Like the C–5A, these systems were deemed suitable for TPP because they were assumed simply to be extending proven technology, avoiding leaps into the unknown.[77]

During 1966, the Defense Industry Advisory Council made assessing TPP a top priority. Speaking to council members on 18 February, Assistant Secretary Charles addressed their concerns. Would the low bidder always win, tempting the contractor to lower quality? On the contrary, Charles answered; C–5A awards were made after considering all factors, and "both primes are contractually required to meet, at their peril, the specified performance . . . that is simply what they proposed during the competition." Could the price discipline inherent in TPP stifle innovation? An incentive for increasing productivity gave contractors "maximum latitude, and great motivation, for the application of creative effort. Innovation is thus fostered, not discouraged." Would a contractor be granted ample freedom of action to fulfill commitments? "This is critical," Charles noted. "Responsibility and authority are twins." Had the Air Force required too much data, or had competitors supplied too much? Probably both, Charles believed: "We wanted a transport which has only a few basic requirements, such as cargo area, cruise speed, range, payload, takeoff and landing distances and conditions, and navigational capabilities. But it took us over 1,500 pages to say this. In reply, the five competitors sent in . . . 240,000 pages."[78]

At that same meeting, now-Assistant Secretary of the Navy Bannerman stressed that applying total packaging to FDL ships represented "quite a radical change," because the contractor would design the ship and likely build "a completely modern shipyard designed for mass production." Lockheed's Daniel J. Haughton voiced concern about a clause that restricted the pricing of C–5A changes but stated that TPP "should be workable if all parties give it their best." Finally, the DIAC rated TPP and its expected results "highly desirable from the standpoint of Industry as well as the Government." It reemphasized, however, "the need to watch this program very closely as it develops and is applied, in view of the many present or potential problems apparent."[79]

Already, Charles had established a task group to evaluate TPP from the standpoints of the Air Force's 375 series of acquisition regulations and the demands placed on prime contractors and subcontractors. Reporting in March 1966, the group praised TPP as compatible with management techniques and constituting a quantum jump in procurement methods. Negotiating definitive contracts concurrently with source selection did add considerably to the initial effort and the volume of data—but such concurrency was TPP's most important feature.[80]

The DIAC organized a working group to study problem areas. At a June 1966 meeting, members again addressed the issue of whether TPP would stifle creative technology. As Charles acknowledged, the history of aircraft and missiles revealed constant improvement within a given program. While group members did not think that competition discouraged innovation—in fact, many thought just the opposite—they disagreed sharply about what would happen *after* selection of the winner. Some felt strongly that making a long-term commitment on production would induce the contractor to gear himself to a standardized product. Others thought this danger could be controlled by expressing requirements in terms of performance but leaving the contractor free to achieve them in his own way. However, many voiced serious reservations about whether the government would keep a hands-off attitude or provide large enough financial incentives.[81]

A subgroup chaired by Dr. Finn J. Larsen, deputy director of defense research and engineering, studied how TPP was affecting design changes. In February 1967, it reported tentatively that TPP had stimulated "within-scope" innovations (that is, those staying within the scope of the contract) promoting simplification, cost reduction, and schedule assurance. The subgroup found no evidence, as yet, that "growth-type" innovations (that is, outside the scope of the contract) were being inhibited or that contractors were introducing them as a means of raising prices and extending schedules.[82]

A June 1967 appraisal by the Logistics Management Institute gave TPP a strong boost—but with caveats. It analyzed the C–5A, the fast deployment logistic ship, the short-range attack missile, the avionics package for the light observation helicopter, and the Navy's A–7 attack aircraft. The institute then assessed TPP's pros and cons. The advantages, according to LMI, lay in substantial dollar savings and a shortening of development schedules because a good deal more development work would be done at an earlier point. Contractors also had considerable incentives to design for ease of production. Total packaging increased design and price competition, so that the five programs noted above contained proposals that far exceeded most of the minimum performance requirements.[83]

Even so, LMI detected significant disadvantages. Contractors took on greater financial risks. Poor estimating alone could eliminate virtually all of a contractor's profit and cut into available capital for even the largest aerospace firms. The longer the contract definition phase, the higher a contractor's bid and proposal expenses; on the other hand, firming up design details, performance specifics, and logistic support fairly early could make it extremely difficult to exploit later technological advances. Finally, severe competition might cause a contractor to cut his price to an uneconomical point and then try to recoup by reducing his obligations or increasing the scope of work.[84]

In conclusion, LMI judged TPP effective for programs within the state of the art, but a verdict about those requiring technological jumps remained uncertain. TPP restricted government oversight of the contractor, but DoD still needed a system that would integrate its requirements for financial, technical, and management information. Since total packaging locked in specific performance requirements for a fairly long time, adjusting to changing needs could prove to be harder for TPP than for conventional contracts. If one system depended on another, or a subsystem had to be integrated into a complete weapon system, government-mandated modifications could seriously impair and even destroy TPP's advantages.[85]

Larsen's subgroup, finishing its work in mid-October 1967, informed the DIAC that on balance, within-scope innovations were not being retarded but growth-type improvements were discouraged. Two weeks later, Charles gave the Hershey conference a positive report about TPP. The C–5A, he said, was patterned after the C–141, which had proved to be one of the best-managed programs ever. Remarkably, the C–5A was setting a record for the minimum number of changes—one-twelfth of those for the C–141 at the same point, despite much greater advances in the state of the art. Compared with contract requirements, Charles related, the C–5A's predicted performance ran better than that of the C–141.[86]

In 1968, however, the balloon of cost control burst. Exactly when senior Air Force and OSD officials realized that C–5A costs were skyrocketing became the subject of bitter controversy. Was it as early as July 1966, when the C–5A system program office (SPO) reported a 33⅓ percent increase over the planned costs of work accomplished? Or was it by December 1967, when, according to the GAO, the Air Force could reasonably have predicted overruns resulting from rising labor and materials costs? Charles later told congressmen that a briefing he received from the SPO on 5 June 1968 "showed for the first time that Lockheed's costs might rise above the ceiling specified in the contract." That September, Lockheed estimated that design, development, and test and evaluation, and production of 58 aircraft would cost $2.335 billion, a figure that was $1.057 billion above the target cost. The C–5A system program office forecast an even higher figure: $2.436 billion. On 13 November 1968, A. Ernest Fitzgerald, deputy for management systems in the Office of the Assistant Secretary of the Air Force (Financial Management), made the problem public knowledge. Sen. William Proxmire (D–WI) asked him whether reports of a $2 billion overrun that included spares, ground equipment, and 57 more aircraft were true. Fitzgerald replied that "your figure could be approximately right."[87]

TPP's showcase project fared poorly for several reasons. Charles and some of his colleagues attributed the C–5A's problems to special circumstances. First, escalation of the Vietnam War deluged suppliers with urgent requirements. Lockheed encountered great difficulty acquiring the precise items needed for ongoing test programs; substitute materials had to be retrofitted and retested at considerable cost. Second, commercial airlines' orders jumped from $1.1 billion in 1964 to $11.4 billion during 1965–1967, sharpening the competition for resources and actually outstripping military production orders. Third, inflationary pressures exceeded expectations.[88]

But TPP itself created problems. When the C–5A's design ran 12,000 pounds overweight, Lockheed engineers recommended having General Electric increase the thrust in each of its four engines from 41,000 to 45,000 pounds. Charles, backed by his superiors, insisted upon enforcing the contract as written; otherwise, the contractor would simply assume the Air Force was continuing on its cost-plus ways. Accordingly, engineers thinned the wings by chemical milling of structural parts. Soon after C–5As entered service, however, cracks appeared in the wings, and expensive modifications had to be made. Boeing, facing a similar weight problem with its 747 commercial airliner, responded by having Pratt and Whitney increase engine thrust. Although the bigger engines suffered early problems, these were quickly and cheaply corrected.[89]

By January 1969, TPP had widened to embrace other major projects, including the Navy's F–14 fighter and its LHA amphibious assault ship. Yet only a few systems, such as Raytheon's Maverick AGM–65, lived up to expectations. Most TPP projects were plagued by delays, performance problems, and, most of all, overruns as high as those under CPFF contracts. Maverick, it was said, succeeded because it was mainly a straight-line extrapolation from proven technology. Yet the C–5A, at inception, was seen as an extrapolation of the C–141. When it became clear that was not the case, Lockheed already had boxed itself in.[90]

Because TPP's reach so often exceeded its grasp, the basic fault lay more with the concept than with particular circumstances. Contractors simply could not estimate the cost of a complex project with the degree of accuracy required by a fixed-price contract. TPP would work only if the government was willing and able to enforce contract terms. Before the C–5A contract was signed, Charles remarked that he saw no chance of Lockheed defaulting because if it did, he would meet Lockheed executives on the courthouse steps. However, when Lockheed proved to be unable to perform without relief, no courthouse confrontation took place.[91]

PROGRAM MANAGEMENT AND THE PROGRAM MANAGER

Switching emphasis from cost-plus to fixed-price contracting in the early 1960s called for a more demanding style of program management and, thus, more qualified and capable program managers. OSD policy and instructions were aimed at improving the quality of both program managers and the acquisition workforce in general. But like similar initiatives taken during the previous decade, the measures largely failed to realize their objectives because OSD left implementation to the services, which pursued their own, sometimes differing, personnel priorities.[92]

Early in the 1950s, the Air Force began to employ a specialized management structure at the field level for specific weapon systems. Known initially as the "joint project office" (later as the weapon system project office and then as the system program office), the new organizational form had two purposes: to address the difficulties created by the division of responsibility between the service's two acquisition field commands, the Air Research and Development Command (ARDC) and the Air Materiel Command (AMC), which handled production; and to provide centralized direction and coordination for new systems developed and produced within the context of the functionally organized field commands. Thus, the project or program office drew together functional specialists in aerodynamics, armament, electronics, propulsion, and flight test from ARDC as well as budgeting, contracting, production, maintenance, and supply experts from AMC, all under the command of the project officer or (later) the program manager.[93] Speaking to an audience at the Industrial College of the Armed Forces in 1963, Paul W. Cherington, professor of business administration at Harvard University and a DoD consultant, noted what distinguished such project or program structures from past horizontal and functional arrangements. In the latter, he pointed out, a coordinator rather than a central authority ran acquisition programs. In Cherington's experience, functionalists tended to become parochial in their outlook. A program manager, by contrast, wielded broad authority and had a fairly large staff. He was not a technician but a planner, salesman, decisionmaker, and controller.[94]

The services' ICBM and IRBM programs represented the ultimate expressions of vertically organized, project-type structures in the 1950s: Maj. Gen. Bernard Schriever's Western Development Division, charged with developing and fielding the Atlas and Titan ICBMs and Thor IRBM for the Air Force; the Special Projects Office, headed by Rear Adm. William F. Raborn, Jr., for the Navy's Polaris IRBM system; and the Army Ballistic Missile Agency, under Maj. Gen. John B. Medaris, for the Jupiter IRBM. Although highly successful, these programs enjoyed special advantages that made them unique among weapon system programs of the day. All had been accorded the nation's highest priority by the president and had been provided generous budgets. Moreover, each of their directors possessed wide-ranging authority that enabled them to bypass traditional reporting echelons.[95]

Throughout the 1950s, the services used project offices to greater or lesser degrees. In the Air Force, they were standard for major weapon system programs. At the end of 1956, the Air Force had 62 of varying size.[96] Initially, the Navy did not apply the project office form, used for the Polaris system, to its other programs. The service's Libby Board, directed by the chief of naval operations in 1955 to examine the adequacy of the bureau structure with respect to weapon system development, concluded that the SPO approach should be employed "only in exceptional circumstances" due to its "inherently disruptive effect" on the Navy's regular organization for acquisition.[97] In 1958, however, following a recommendation of the consulting firm of Booz, Allen, and Hamilton, the Bureau of Aeronautics formed a modified project office for its new attack aircraft, designated the A2F–1 (later the A–6 Intruder). But early proposals to expand use of project offices in the Bureau of Naval Weapons (created in 1959 with the merger of the Bureau of Aeronautics and the Bureau of Ordnance) produced opposition at high levels in the new bureau.[98] With the exception of some programs of the Army Ballistic Missile Agency (beginning in 1958, Army Ordnance Missile Command), the Army did not employ project offices during the 1950s. But in mid-1961, Secretary of Defense McNamara indicated that he wanted the Army to appoint a project manager to head a project office for each of its major weapon system programs.[99]

Whether program managers directed a weapon system office or operated as a coordinator in the context of a larger functional organization, many urged that they be granted increased organizational status and greater authority. These were among the principal recommendations in 1956 of the Robertson Committee, headed by Deputy Secretary of Defense Reuben Robertson to investigate ways to reduce the length of the acquisition cycle for manned aircraft weapon systems.[100] But whatever the individual service responses, five years later, the program manager's circumstances had not improved much. In October 1961, John Rubel, the deputy director of defense research and engineering, asserted to the services' assistant secretaries for R&D that "frequently our DoD organizations place restrictions on the project officer which degrade the responsibility that he ought to have. . . . The rewards and penalties for success or failure should be better devised."[101]

In the spring of 1963, Deputy Assistant Secretary of Defense James Davis and Professor Cherington arranged a three-day DoD conference on program management in New London, Connecticut.[102] About 40 percent of the 231 attendees were generals or admirals or their civilian equivalents. They broke into panels, where five topics drew the most attention: how program offices related to traditional service organizations; how those offices ought to exercise technical direction; how to ensure the quality of personnel; the nature of the government-industry relationship; and the "feedback" by which managers assessed progress and revised programs.[103]

Simon Ramo, vice chairman of the board of directors at Thompson Ramo Wooldridge, Inc., offered insights. Typically, he told the New London conferees, a program management activity involved a dozen or more individuals or agencies, each sharing some of the responsibility and some of the authority. Organization charts appeared to depict clear delegations of authority and responsibility. Often, though, the position of program manager was only a symbol, distinguished by the title. In Ramo's experience, numerous parallel operators acted as consultants, judges, redirectors, delayers, debaters, investigators, coordinators, and vetoers. Seemingly elegant systems, he predicted, would merely produce well-documented failures.

A manager could stimulate stellar performance, Ramo argued, by rewarding outstanding work with follow-on contracts. To make that incentive credible, though, there had to be a direct connection between the new award and the past performance. Ramo recommended applying large incentives during a project's definition phase if a contractor demonstrated convincingly that he could meet or exceed cost, schedule, and performance objectives. Ramo's fundamental point was that using incentives depended on running a controlled operation with excellent communications to the point of control. A highly experienced, outstanding manager had to act as that point of control.[104]

Conferees at New London agreed on broad principles. First, program management should be applied with discretion to tasks involving high priority, large resources, and great technological complexity. Second, superimposing program offices on functional organizations invariably created jurisdictional problems that called for some flexibility and cooperation, not predetermined formulas or ironbound regulations. Third, a program manager needed the widest possible latitude, a carefully drawn charter, and a staff comprising the most talented military and civilian personnel.[105]

New London's downside was that few conferees could agree on how those generalizations translated into specifics. How many program offices, for instance, could operate within an organization? What should be a program manager's rank, level of reporting, main function (for example, line or staff), and authority in matters of contracting, technical direction, programming, and budgeting? How many full-time personnel, and at what grades, should be assigned to a program office and be responsible solely to the program manager? Conferees did agree that OSD should issue a policy statement clarifying the conduct of program management. Representatives from OSD and the services then would draft a blueprint for its implementation.[106]

On 19 September 1963, Deputy Secretary of Defense Gilpatric directed Assistant Secretary Morris to draft policy guidance concerning the management of all high-value, high-priority service programs. Saying that New London had "convincingly demonstrated that the essential problems and skills are common to all weapons managers irrespective of Service," Gilpatric also called for the early creation of a central training establishment.[107]

DoD Directive 5010.14 (System/Project Management), signed by Cyrus Vance (Gilpatric's successor) on 4 May 1965, articulated a DoD-wide policy for project management. The essential step was creating "a designated, centralized management authority who is responsible for planning, directing, and controlling the definition, development, and production of a system/project." Such a manager must head every system or project rated as being of high urgency or estimated to cost more than $25 million for research, development, and test and evaluation, or more than $100 million in total production investment. The project manager would have responsibility for preparing and maintaining a master plan approving contractual actions; making all technical and business management decisions; approving the scope, schedule, funding, and cost control of in-house activities; and delivering progress reports. He and his staff were to possess a high degree of technical and managerial competence, supplemented whenever possible by special training and recent experience. They should be available for at least three-year tours.[108]

Simultaneously, Secretary McNamara signed instructions aimed at improving the professional caliber of procurement personnel. He directed each military department to create a broader base of procurement billets for its junior officers and to establish minimum tour lengths as well as minimum experience and educational requirements at every level of responsibility. For key billets, qualifications should include 3 years of direct acquisition experience during an individual's 10 prior years of service, 3 additional years within any related or direct procurement duty, and attendance at a refresher course. For the civilian workforce, he outlined initiatives requiring mandatory training at the entry, intermediate, and senior levels as well as mandatory registration and referral of career employees for critical positions. Many years would pass before these measures showed real effect. A disparity persisted in qualifications, stature, and experience between industry representatives and their DoD counterparts, aggravated by the differences in service cultures.[109]

Career development, as McNamara had articulated it, faced obstacles within each service. The Navy claimed its unique requirements meant that all officers had to achieve a requisite balance of sea duty, shore duty, functional specialization, advanced education, and staff and command experience. Within that framework, according to the Navy, current policy and procedures were making the best use of individuals with procurement experience. Minimum lengths had been established for normal tours. Claiming that many officers in procurement billets had served more than three years, the Navy planned to determine what would constitute optimum length.[110]

The Army proved to be more malleable. General Frank S. Besson, Jr., head of the Army Materiel Command, created 65 project management offices. The Army's Office of Personnel Operations, working with a senior civilian at AMC headquarters, nominated candidates for positions as project managers; Besson's two-star deputy then made the selections. As things turned out, Army project managers spent most of their time traveling and briefing. Hence, their training as managers emphasized briefing skills, an area in which Army officers lagged behind their Air Force counterparts. At first, Besson released from project management any officer who had been selected for a school or a command slot. Only when that practice led to many short tours did he insist that managers remain for three years unless an overriding need could be identified. Also, the Army began awarding command credit for project manager assignments. At the outset, every manager reported directly to General Besson. Later, though, this reporting requirement applied to only a few managers. Who should have contracting authority became a frequent point of contention because commanders in the field wanted to retain that right.[111]

In May 1965, J. Ronald Fox, deputy for management systems under the assistant secretary of the Air Force (financial management), visited 7 of the 37 system program offices reporting to Air Force Systems Command. Those SPOs, Fox reported, faced extreme difficulty in obtaining military officers with training and experience in managing large development and production contracts. No more than a handful of civil servants, particularly in the higher grades, appeared to be qualified; active participation with contractors was particularly lacking. Courses at the Defense Weapon Systems Management Center, established in 1964 to train service program managers, Fox reported, dealt with regulations and processes but devoted scant time to contact with contractors. Moreover, turnover among those holding responsible positions in the SPOs was rapid. In the 7 program offices that he visited, program managers rarely served more than one year. Not surprisingly, many contractors reacted to the inexperience of these officials by "humoring the Air Force personnel . . . so that they [would] keep out of the contractor's way and allow him to move ahead with business as usual."[112]

Among Air Force SPO personnel, Fox found a widespread conviction that the contractor had been hired to manage the program while the SPO's main task lay in planning and controlling the *rate* of spending. Consequently, no SPO had created formal methods for relating costs to progress achieved, identifying or projecting cost overruns, and appraising the reasonableness of contractor estimates (particularly those related to program changes) and indirect costs. Such omissions, Fox believed, were "entirely out of place in an environment where change is a way of life and where the Air Force is serious about negotiating changes with a contractor." Writing a good contract could not "substitute for a comprehensive, formal management system that includes reliable techniques for planning and controlling schedules, costs, and technical performance parameters throughout the life of a program."[113]

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Defense Weapon Systems Management Center

One of the outcomes of the New London conference on program management was a directive, issued in September 1963 by Deputy Secretary of Defense Roswell Gilpatric, to establish a systems/project management education and training institution in the Department of Defense. James Davis, deputy assistant secretary of defense for weapons acquisition and industrial readiness, was in charge of the organizational effort. He assigned the Air Force responsibility for setting up and administering the new Defense Weapon Systems Management Center (DWSMC) in early 1964.

The joint service DWSMC began operation at Wright-Patterson Air Force Base, Ohio, at the end of September 1964. The center was unique among joint defense institutions as it was the only school to address acquisition of weapon systems from the perspective of the project manager. Its first commandant was an Air Force colonel who was assisted by a Navy and an Army deputy. Faculty included military and civilians from the three military departments, as did its first class, comprised of 18 students, which graduated in December 1964. The initial 10-week course consisted of a 3-week introduction to project management, a fourth week covering concept formulation, a fifth week examining contract definition, and four weeks examining project activities associated with development, test and evaluation, production, contracting, and logistics support. The course's final week was spent on a simulation exercise in which teams tried to field weapon systems that met specific requirements while optimizing cost, schedule, and performance.

In September 1970, following an intensive review of the center's program management course, Deputy Secretary of Defense David S. Packard approved transfer of oversight of the school to the director of defense research and engineering and providing it with a flag officer commandant.

In 1971, the center was renamed the Defense Systems Management College and moved to Fort Belvoir, Virginia, under the administration of the Army.[III]

A GAO report completed in 1970 concluded that DoD's effort to stimulate and strengthen careers, whether military or civilian, had fallen short.[114] Difficulties with respect to civilian career development began at the entry level, where few positions were filled by young trainees. Emphasis instead was on hiring older persons from other agencies or from industry. Thereafter, DoD had no means for measuring individuals' career development against projected goals and learning the reasons for voluntary or premature departures. A Career Management Board consisted of two representatives from DoD, two from each military department, and three from the Defense Supply Agency. Crippled by lack of data as well as by lack of authority to direct service activities and unable to deal with broader issues, the board concerned itself with curriculum issues, leaving procurement activity commanders to run civilian career programs as they saw fit.[115]

A master development plan outlined the mandatory and desired training available through 61 courses. While responsibility for course content lay with the assistant secretary of defense (manpower and reserve affairs), the services ran the schools and created the courses. But most of the civilians had not attended any of the courses required at their grade levels. Many had held those grades before the courses became mandatory and therefore were exempt. Others had not completed the courses before being promoted and neither finished them nor passed equivalency tests.[116]

Military officers, the GAO found, were better educated than civilian procurement careerists but had, on average, less than one-third of the course training and one-fifth of the acquisition experience. For example, a Navy captain who held the position of assistant executive director for purchasing had attended only one five-week course. Service standards were vague enough that officer selections often resulted from personal connections or availability for assignment.[117]

As matters stood, the GAO concluded, neither civilians nor military officers could pursue full and satisfying careers in the acquisition field. Civilians usually entered as trainees or journeymen but rarely reached top management because responsible positions were reserved for political appointees and military officers. Conversely, officers often entered at the supervisory level but then were passed over by promotion boards and forced into early retirement. Operational command, not acquisition management, was the normal path to flag rank.[118]

The weakness of the acquisition workforce, military and civilian alike, helped perpetuate several shortcomings. First, program managers frequently found themselves facing problems more difficult than their training equipped them to handle. Second, military officers often lacked the depth of experience possessed by their industry counterparts. A lieutenant colonel with 1 or 2 years' experience in acquisition might have to deal with a Boeing executive who had more than 20, held a higher position, and was much better paid. As Simon Ramo observed at the New London conference, "If the military is to be used as a prime structure for program managers, then much has to be done to bring up the stature of program management within the military. There needs virtually to be a military management 'corps'."[119] Third, government personnel no less than contractors were tacitly encouraged to underestimate technological challenges. Military officers often were transferred and promoted before problems that had been postponed became widely known. These conditions help explain why schedule slippages, cost growth, and performance shortfalls remained common occurrences.

Of course, managerial inadequacies were not the only source of troubles. Coming from the private sector, Secretary McNamara failed to anticipate the difficulty of implementing his reforms within government. He might have been more successful had he compelled the services to place greater emphasis on training and skill building. Clearly, he overestimated the willingness of military and civilian personnel to implement his modus operandi. In the end, his limited ability to promote and reward acquisition personnel and to create comprehensive career management for this field prevented him from achieving his desired reforms. Thus, the McNamara revolution in acquisition was incomplete.[120]

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During a 1971 DoD-industry symposium, Raytheon's president remarked that all parties must try "to <u>never</u>, <u>never</u> make the mistakes of the sixties again." What were those mistakes, and who bore the blame for them? DoD's bedrock assumption had been that emphasizing competition and fixed-price incentives would improve performance while meeting deadlines and controlling costs. At the symposium, a Radio Corporation of America executive spoke of having experienced "the thrills of weighted guidelines (which defy the laws of gravity) and total package procurement (that wasn't really total or properly packaged)." An Avco Corporation vice president prompted applause by describing target cost as "the absolute minimum cost that could possibly be attained and most likely will not be."[121]

Meshing Secretary McNamara's reforms with contractors' management methods proved difficult.[122] Many of the *DoD Incentive Contracting Guide*'s prescriptions went unfilled by both government and industry. McNamara did not foresee that setting realistic target costs, vital to the success of fixed pricing, would prove to be well-nigh impossible. Richard M. Anderson, a director of the H.R. Land consulting firm who previously had worked for Litton Industries, wrote that when cost-plus-fixed-fee predominated, managers:

> learned to run the program "out of their heads," without use of formal management systems. . . . Unfortunately, in a disorganized situation, the "fire fighter" who energetically struggles with problems after they have developed is judged to be a better contributor than the manager who is able to foresee and prevent problems. . . . In short, contractors often signed fixed-price, total package contracts at prices below the expected costs, containing risks that were not thoroughly appraised, and

for which they lacked the management discipline necessary to perform the work in an efficient manner.[123]

But a senior manager at North American Aviation, Inc., Hudson B. Drake, laid much of the blame on DoD. He cited, as a major failing, the lack of precision in requests for proposals. Cost-effectiveness evaluations and tradeoff analyses often proved inadequate, Drake argued, because "the ground rules from the DoD Component . . . are too broad and the data provided [by competing contractors] too narrow."[124] Uncertainties at the outset were such that contractors expected to increase their target prices, no matter how firmly fixed, by negotiating numerous contract changes. Between 1962 and 1965, the cost-reimbursable portion of one large contractor's business fell from 75 to 25 percent, replaced by fixed-price arrangements. However, while the nature and volume of that business remained about the same, the number of contract changes *quadrupled*.[125] In those circumstances, just as the *Guide* warned, the effectiveness of incentives was severely damaged and fixed pricing did little to contain costs. The Nixon administration would turn from fixed-price back to cost-reimbursable contracts, discard total package procurement, and launch a major effort to improve acquisition management and education.

Endnotes

1. Knaack, *Post–World War II Bombers*, 174, 281.

2. Converse, *Rearming for the Cold War*, 43–46.

3. At the end of the Eisenhower administration, the assistant secretary of the Army (logistics) delegated portions of his authority to the deputy chief of staff for logistics. That officer, in turn, directed procurement activities of the technical services: the Chemical Corps, the Corps of Engineers, the Medical Service, the Ordnance Corps, the Quartermaster Corps, the Signal Corps, and the Transportation Corps. The assistant secretary of the Navy (material) had oversight of the chief of naval material, who in turn had responsibility for procurement tasks performed by the Bureaus of Personnel, Ships, Supplies and Accounts, Weapons, Yards and Docks, the Marine Corps, and the Office of Naval Research. The assistant secretary of the Air Force (materiel) delegated necessary authority through the deputy chief of staff, materiel, to the Air Materiel Command, which was responsible for that service's centralized buying program. A separate Air Research and Development Command ran procurement for some basic and applied research as well as some equipment prototypes.

4. The following paragraphs closely paraphrase information in DoD Procurement Presentation by the assistant secretary of defense (supply and logistics) to the Procurement Subcommittee of the Senate Armed Services Committee, 86 Cong, 2 sess, 8–9 Feb 60, 3–5, 22–26, 30. The description of CPFF contracts draws upon email, Fox to Poole, 14 Jul 04, and that of value engineering from Richard Mankelhorn, "Who Needs Value Engineering?" *Armed Forces Management* 5, no. 5 (February 1959): 21–26.

5. DoD Procurement Presentation, 86.

6. The Atomic Energy Commission viewed cost-plus-fixed-fee as "the administrative contract par excellence." Richard A. Tybout, *Government Contracting in Atomic Energy* (Ann Arbor: University of Michigan Press, 1956), 175.

7. Performance incentive contracts were first used in the B–58 strategic bomber program.

See Converse, *Rearming for the Cold War*, 485–486.

8. "What's Ahead in Procurement?" *Armed Forces Management* 7, no. 2 (November 1960): 98; Knaack, *Post–World War II Bombers*, 219, 250–251.

9. J. Sterling Livingston, "Decision Making in Weapons Development," *Harvard Business Review* 36, no. 1 (January-February 1958): 136 (quotation); Ernest F. Leathem, "What Price Procurement Integration?" *Armed Forces Management* 5, no. 2 (November 1958): 19–20.

10. Herbert Roback, "Truth in Negotiating: The Legislative Background of P.L. 87–653," *Public Contract Law Journal* 1, no. 2 (July 1968): 5–7.

11. House, Cte on Armed Svcs, report no. 67, *Special Subcommittee on Procurement Practices in the Department of Defense Consideration of H.R. 12299*, 86 Cong, 2 sess, 6046, 6070, 6071, 6074, 6079 (quotations, 6070, 6074); Roback, "Truth in Negotiating," 10–12.

12. Email, Fox to Poole, 17 Mar 2004.

13. Roback, "Truth in Negotiating," 13–16; "Pentagon and Congress Lock Horns in Divergent Views on Procurement," *Army, Navy, Air Force Journal* 97 (30 July 1960): 28–29 (quotations, 29).

14. As an example, B–52Gs were produced during 1958–1961 under three contracts: the first, under a cost-plus-incentive-fee with a sliding percentage topped at 6 percent, for 53 aircraft; the second, a fixed price with a firm incentive for 101; and the third, a fixed-price incentive for 39. Knaack, *Post–World War II Bombers*, 274–275.

15. Frederick T. Moore, *Military Procurement and Contracting: An Economic Analysis*, RM–2948–PR (Santa Monica, CA: RAND, June 1962), 13, 14, 15, 21, 49, 50, 26 (quotations, 68, 58).

16. In January 1961, the positions of assistant secretary of defense (supply and logistics) and assistant secretary of defense (properties and installations) combined to form the position of assistant secretary of defense (installations and logistics).

17. Interview, Morris by Goldberg and Matloff, 6 April 1987, 3, 19, 45, 19, OSD/HO.

18. Ibid., 37.

19. "Remarks Before the National Security Industrial Association Cost Reduction Symposium," 15 June 1961, in *Public Statements of Secretary of Defense Robert S. McNamara, 1961*, vol. II (Washington, DC: OSD/HO). The National Security Industrial Association was a nonprofit organization of about 500 defense contractors. E.V. Huggins, executive vice president of Westinghouse Electric Corporation, was president of the association in June 1961.

20. "Weapons: The Struggle to Build More of Them Better and Faster without Undue Costs or Profits," *Newsweek* 58, no. 16, 16 Oct 1961, 90–91, 93 (quotation, 90); Knaack, *Post–World War II Bombers*, 265.

21. Bureau of the Budget, *Report to the President on Government Contracting for Research and Development*, 30 Apr 62 (Washington, DC: GPO, 17 May 1962), doc no 94, 87 Cong, 2 sess.

22. Memo, Deputy DDR&E Rubel to Asst Secs of the Army, Navy, and Air Force (R&D), "Management of Research and Engineering," 9 Oct 61, 6, fldr Rubel, John H., Viewpoints, 1961–1962, box 19, Phillips Papers, LC.

23. Quoted in George C. Wilson, "Defense to Emphasize Incentive Contracts," *Aviation Week* 27, no. 20 (20 November 1961), 27.

24. ASPR revisions are described in OASD (I&L), *DoD Incentive Contracting Guide* (Boston: Harbridge House, August, 1962), 3–4, 7–8 (quotations, 4). Paradoxically, one of Secretary McNamara's efficiency moves tripled the size of the ASPR. In 1963, to eliminate confusing or contradictory instructions, he consolidated the services' supplemental instructions and the Defense Supply Agency's publications in the regulation. By 1974, to contractors' consternation, the ASPR had jumped from 1,000 to 3,000 pages. James F. Nagle, *A History of Government Contracting*, 2d ed. (Washington, DC: George Washington University, 1999), 481–486. OSD, "DoD to Incorporate All Procurement Instructions into ASPR," press release, 2 Jan 64, OSD/HO.

25. "Statement of Thomas D. Morris before the Permanent Committee on Investigations, Committee on Government Operations, U.S. Senate," 25 May 62, 2, 7–8, OSD/HO; *DoD Incentive Contracting Guide*, 30, 9, 46 (quotation, 9).

26. C.W. Borklund, "Where Industry Suppliers Think Defense Buyers Should Shape Up," *Armed Forces Management* 8, no. 5 (February 1962): 14–18. The article was based on a questionnaire sent to 225 defense-oriented suppliers, 83 of whom responded.

27. In 1961, at McNamara's request, the NSIA had formed 10 task groups that drew 200 people from 62 companies to explore ways to trim procurement costs. NSIA News Info, 19 June 1962, OSD/HO. "Task Force Urges Greater Use of Incentives," *Army, Navy, Air Force Journal* 99, no. 44 (30 June 1962), 22 (quotation). Excerpts are printed in Stanford Research Institute, "The Government-Industry Aerospace Relationship," report, May 1963, vol. II, 62–65, NDU Library.

28. DoD, "DIAC to Be Formed," press release, 24 May 62, OSD/HO; "DIAC Permits Dialogue with Industry," *Armed Forces Management* 14, no. 9 (June 1968), 61–63. DoD Directive 5030.22 (Defense Industry Advisory Council) established the DIAC. Members in mid-1968 included Ruben F. Mettler (president, TRW Systems), William M. Allen (president, Boeing Company), Daniel J. Haughton (president, Lockheed Aircraft Corporation), Roger Lewis (chairman and president, General Dynamics Corporation), and Charles B. Thornton (president, Litton Industries). In April 1968, the DIAC shortened its title to "Industry Advisory Council."

29. According to the *DoD Incentive Contracting Guide*, 30, "The greatest value of PERT lies not so much in the use of computers and probability distributions as in its requirement that the job be analyzed in minute detail before work is started." For an analysis of PERT as applied in the Polaris program, see chapter VIII.

30. DIAC, "Fundamental Issues Affecting Defense-Industry Relationships," Sep 63, fldr "DIAC," box 990, OSD/HO (underlining in original). To improve the government's ability to assess costs and to compare outcomes and performance across R&D programs, the Bell Report suggested establishing "some central and fairly formal means of reporting methods and experience and recording them permanently." U.S. Bureau of the Budget, "Report to the President on Government Contracting for Research and Development" (Bell Report), 30 Apr 62, 33–34. OSD responded by establishing, on 1 August 1963, a "Program of Contractor Performance Evaluation" with DoD Directive 5126.38. Project managers would submit evaluation reports at six-month intervals and at the termination of a development effort on all engineering and operational systems development contracts whose value exceeded $5 million for one year or $20 million overall. Their reports would be reviewed by military department groups, returned to contractors for comment, and then forwarded to OSD for storage in a centralized data bank. OSD, "Guide to the Performance of Major Development Contracts," 26 Jul 63; OSD, "DoD Program to Evaluate Contractor Performance," press release, 8 Aug 63, OSD/HO.

31. Stuart J. Evans et al., *Procurement* (Washington, DC: Industrial College of the Armed Forces, 1968), 133–134. NASA pioneered the use of cost-plus award fee contracts.

32. Memo, AsstSec (I&L) Ignatius to SecDef McNamara, 11 Nov 65, "CWAS in Risk Concept," fldr 400.13, box 64, 70–A–4443, RG 330, WNRC.

33. *Business Week*, 24 June 1961, 40; interview, Paul R. Ignatius by Walton S. Moody and Walter S. Poole, U.S. Army Center of Military History, Fort Lesley J. McNair, Washington, DC, 20 Jan 03, OSD/HO, 45–46. In March 1961, DoD rescinded a 1957 directive withholding, until work was completed, 20 percent of the costs incurred while performing certain categories of cost-reimbursement contracts. The theory had been that requiring contractors to invest their capital until deliveries took place would promote economy and efficiency. Instead, contractors often borrowed and added the interest charges to their fees. The government's borrowing cost would have been less than that of the contractor, making the practice inefficient. DoD, "Payment Procedure Revised in Cost-Plus-Fee Contracts," press release, 15 Mar 61, OSD/HO.

34. Shannon A. Brown, ed., *Providing the Means of War: Historical Perspectives on Defense Acquisition, 1945–2000* (Washington, DC: U.S. Army Center of Military History and Industrial College of the Armed Forces, 2005), 373–374. Paul Ignatius described the Army's jeep problem during the Cuban missile crisis at a session of the Defense Acquisition History Project symposium, Providing the Means of War, held at the campus of Science Applications International Corporation in Tyson's Corner, Virginia, on 11 September 2001.

35. The Logistics Management Institute, incorporated on 2 October 1961, was the brainchild of Assistant Secretary Morris. Small, nonprofit, and federally funded, LMI existed to study and analyze logistics problems, identify areas where major gains in effectiveness and economy seemed possible, and recommend ways to accomplish such improvements. Barry J. Shillito became LMI's president; Charles H. Kellstadt of Sears Roebuck and Company chaired the board of trustees. Charles E. Wilson, former president of General Electric and director of the Office of Defense Mobilization during 1950–1952, was an original board member.

36. Logistics Management Institute, "Implementation Status—Multi-Year Procurement," February 1965, 2, 3, 10, 20, 21, 49, 42, 65, NDU Library.

37. Memo, Asst Sec Morris, "Agenda for Discussion with Secretary Gilpatric on 2 August 1963," fldr 020 I&L, June-September 1963, box 32, 69–A–3131, RG 330, WNRC; "Installations and Logistics," *Armed Forces Management* 11, no. 2 (November 1964): 80.

38. Roback, "Truth in Negotiating," 16, 18–21.

39. Ibid., 24–27 (quotation, 27). The certification requirement could be waived when the negotiated price was based on adequate competition, catalog or market prices of commercial items sold in substantial quantities to the public, law or regulation, or exceptional cases determined by the head of an agency. Vinson's provision prohibiting increased profits that were not demonstrably due to a contractor's "skill, efficiency, or ingenuity" did not survive.

40. DoD Directive 5105.36 (Defense Contract Audit Agency), 9 June 1965, established the Defense Contract Audit Agency.

41. Report to Congress by the Comptroller General, *Survey of Reviews by the DCAA of Contractors' Price Proposals Subject to P.L. 87–653*, February 1967, NDU Library; Willard O. Vick, "Role of DCAA Under P.L. 87–653," *Public Contract Law Journal* 1, no. 2 (July 1968): 58, 66; memo, Asst Sec (I&L) Ignatius to Compt Gen Staats, 29 Jul 67, fldr 160 Contracts, box 9, 70–A–3493, RG 330, WNRC; Executive Secretary of the DIAC, "Summary Minutes, DIAC Meeting, 13–14 October 1967," fldr 334 DIAC, box 32, 72–A–2468, RG 330, WNRC; Roger R. Trask, *Defender of the Public Interest: The GAO, 1921–1966* (Washington, DC: GPO, 1996), 505–527, describes the 1965 congressional hearings that highlighted DoD–GAO tensions.

42. These were the B–58 strategic bomber, F–105 tactical fighter-bomber, Navy F–4H interceptor, Atlas ICBM, Jupiter and Polaris IRBMs, Bomarc, Nike-Ajax, Nike-Hercules, and Talos surface-to-air missiles, Sparrow III air-to-air missile, and Nike-Zeus antiballistic missile. Merton J. Peck and Frederic M. Scherer, *The Weapons Acquisition Process: An Economic Analysis* (Boston: Harvard University Press, 1962), 12–13.

43. Ibid., 22, 458, 477 (quotation, 477).

44. Frederic M. Scherer, *The Weapons Acquisition Process: Economic Incentives* (Boston: Harvard University Press, 1964), 158–159.

45. Ibid., 136–137.

46. Ibid., 159, 168–169, 189, 236, 289, 325–326.

47. See Converse, *Rearming for the Cold War,* 479–489.

48. Arthur D. Little, Inc., *How Sick Is the Defense Industry?* 52–54, 57, 83 (quotations, 54, 57).

49. Ibid., 39, 42–46.

50. Asst Sec Thomas D. Morris, statement before the House, Subcte on Govt Ops, 23 May 63, OSD/HO; Little, *How Sick Is the Defense Industry?* 39; House, Cte on Approp, *DoD Appropriations for 1964*, 88 Cong, 1 sess, pt 5, 127; *DoD Appropriations for 1968*, 90 Cong, 1 sess, pt 4, 415. During 1961–1968, Bannerman served as deputy assistant secretary of defense

(procurement) and then as assistant secretary of the Navy (installations and logistics).

51. Scherer, *Weapons Acquisition Process: Economic Incentives*, 243.

52. C.E. Bradley and C.C. McCuistion, *Contractor Decision Making and Incentive Fee Contracts* (Washington, DC: George Washington University, 1965), 14, 15, vi, ii (quotations, 14, 15). NASA funded the report. Two subsequent studies reinforced these findings. A RAND review of 94 Air Force contracts concluded that cost growth was not influenced by the type of contract used. Report WN 7117, *A Preliminary Analysis of Contractual Outcomes for 94 Air Force Systems Command Contracts* (Santa Barbara, CA: RAND, December, 1970). An Army study revealed that there was no difference in cost overruns between incentive and cost-reimbursable contracts and that incentive contracts tended to have higher targets and administrative costs than cost-reimbursable contracts. Army Procurement Office, *An Analysis of 200 Army Incentive Contracts* (Fort Lee, VA: Army Procurement Office, March 1971).

53. Grodsky, "Contract Definition," 3; Peat Marwick Co., *Lessons Learned from Contract Definition*, 16 August 1965, 5.

54. David D. Acker, *Acquiring Defense Systems* (Fort Belvoir, VA: Defense Systems Management College Press, 1993), 14; "A Presentation on Government Management Systems by the Systems Management Committee of the AIA Aerospace Manufacturers' Council," 12 May 1966, fldr 334 DIAC (Jan-May 66), box 52, 70–A–4443, RG 330, WNRC.

55. Acker, *Acquiring Defense Systems*, 15–16. The criteria listed in DoD Instruction 7000.2 (Performance Measurement for Selected Acquisitions), 22 December 1967, established standards of acceptability for contractors' data.

56. Harvey M. Sapolsky, *The Polaris System Development* (Cambridge, MA: Harvard University Press, 1972), 205–213 (quotation, 212).

57. Memo, Act DDR&E Larsen to Asst Sec (I&L) Ignatius, "Recommendations of the Defense Science Board Concerning Incentive Contracting for RDT&E," 13 Jan 67, fldr 160 Contracting, box 9, 70–A–3493, RG 330, WNRC.

58. "Summary Minutes, DIAC Meeting, 13–14 October 1967," 1 Nov 67, fldr DIAC, box 990, OSD/HO.

59. Memo, Dep Asst Sec Malloy to Asst Sec Ignatius, "DoD Procurement Pricing Conference," 20 Feb 67, Pricing Conf, file 1, box 3; "Proceedings of the 1967 DoD-Wide Procurement Pricing Conference, Hershey, PA," box 1, both in 72–A–4524, RG 330, WNRC.

60. "Proceedings of the 1967 DoD-Wide Procurement Pricing Conference, Hershey, PA."

61. Memo, Dep Asst Sec Malloy to Asst Sec Ignatius, "DoD Procurement Pricing Conference," 20 Feb 67; "Proceedings of the 1967 DoD-Wide Procurement Pricing Conference, Hershey, PA."

62. Memo, Dep Asst Sec Malloy to Asst Sec Ignatius, "DoD Procurement Pricing Conference," 20 Feb 67; "Proceedings of the 1967 DoD-Wide Procurement Pricing Conference, Hershey, PA." It should be noted that Frosch often shared the views of industry, and industry always preferred "best effort" contracts over those with specific performance criteria. Email, Fox to Poole, 14 Jul 04.

63. "Proceedings of the 1967 DoD-Wide Procurement Pricing Conference, Hershey, PA." Apart from this, the DIAC was relatively inactive during 1968.

64. Acker, *Acquiring Defense Systems*, 16–17. The quotation is from Defense Procurement Circular no. 12, 16 Oct 64, cited in A. Ernest Fitzgerald, *The High Priests of Waste* (New York: W.W. Norton & Co., 1972), 137–138. Fitzgerald became disillusioned with what he saw as the emasculation of "should cost" by senior DoD officials. DoD Instruction 7000.3 (Selected Acquisition Reports), 23 Feb 68, created the Selected Acquisition Reports.

65. LMI Task 66–7, *An Examination of the Foundations of Incentive Contracting* (Washington, DC: LMI, 1968), 8, 9, 13, 14 (quotation, 14).

66. Irving M. Fisher, *A Reappraisal of the Incentive Contracting Experience*, RM–5700–PR (Santa Monica, CA: RAND, July 1968), 4–5, 21, 41–42 (quotation, 41–42).

67. Peck and Scherer, *Weapons Acquisition Process: Economic Analysis*, 168; Donald M.

Pattillo, *Pushing the Envelope* (Ann Arbor: University of Michigan Press, 1998), 205, 250, 261–262.

68. Michael H. Gorn, *The TFX: Conceptual Phase to F–111B Termination, 1958–1968* (Andrews Air Force Base, MD: Office of History, Headquarters, Air Force Systems Command, 1986), 50–51.

69. LMI Task 69–1, *Defense Industry Profit Review* (Washington, DC: LMI, March 1969), 15, 13, 17, NDU Library. The survey covered 40 companies—23 high volume and 17 medium volume. Clifford's letter is printed in "Profit on Defense Contracts," *Defense Management Journal* 4, no. 3 (Summer 1968): 34–37.

70. Robert H. Charles, interview by Lyn R. Officer, U.S. Air Force Oral History Program, 21–22 Jan 74, Washington, DC, 6–7, 31–32, AFHSO.

71. This is the recollection of J. Ronald Fox, who was then deputy for management systems under the assistant secretary of the Air Force (financial management).

72. Chapter VI gives a detailed account of the C–5A's travails.

73. A contract price for spare parts could not be determined until types and quantities had been decided upon and prices for them negotiated. The DDT&E contract included $26 million for enough spare parts to support the flight test program.

74. The contract is described in *GAO Report on the C–5A Program*, 11 Jun 69, printed in House, Cte on Approp, *Government Procurement and Contracting*, 91 Cong, 1 sess, pt 4, 1283–1284. The Air Force admonition comes from "Summary Minutes—Meeting of the DIAC—18 and 19 February 1966," attch 1, 6, fldr DIAC, box 990, 1962–66, 1968, OSD/HO; LMI Task 4C–5, *Life Cycle Costing in Equipment Procurement* (Washington, DC: LMI, 1965), 10–11.

75. House, Cte on Armed Svcs, *Military Posture*, 91 Cong, 1 sess, pt 2, 3072–3073, 3075–3077.

76. Ibid.

77. LMI Task 67–3, *Total Package Procurement Concept: Synthesis of Findings* (Washington, DC: LMI, June 1967), 1, 49–51, 58, 62–63, 66–67, 100–109.

78. "Summary Minutes, Meeting of the DIAC, 18 and 19 February 1966," att 1, box 990, OSD/HO, 6–7 (quotations).

79. "Pentagon Tests One-Stop Bidding," *Business Week*, 6 November 1965, 99; "Summary Minutes, Meeting of the DIAC," 5–7 (quotations).

80. Craig Powell, "Has the C–5A Procurement Established the Case for TPPC?" *Armed Forces Management* 12, no. 7 (April 1966): 73–74.

81. "Summary Minutes, Meeting of the DIAC, 10 and 11 June 1966," box 990, OSD/HO.

82. "TPP vs Innovation," tab 8 to memo, ExecSec, DIAC, to SecDef and DepSecDef, "DIAC Meeting, 10–11 February 1967," fldr 334–DIAC 1967, box 32, 72–A–2468, RG 330, WNRC.

83. LMI Task 67–3, *Total Package Procurement Concept*, 59–66.

84. Ibid.

85. Ibid.

86. "Summary Minutes, DIAC Meeting, 13–14 October 1967," box 990, OSD/HO; "Proceedings of the 1967 DoD-Wide Procurement Pricing Conference," box 1, 72–A–4524, RG 330, WNRC.

87. House, Cte on Govt Ops, *Government Procurement and Contracting*, 91 Cong, 1 sess, 1182, 1288, 1284; House, Cte on Armed Svcs, *Military Posture*, 91 Cong, 1 sess, pt 4, 3073 (quotation, "showed for the first time . . . "); Fitzgerald, *High Priests of Waste*, 212–226 (Fitzgerald quotation, 223).

88. House, Cte on Armed Svcs, *Military Posture*, 91 Cong, 1 sess, pt 4, 3078–3079; interview, Charles by Officer, 36–37; testimony of Aaron Racusin, deputy assistant secretary of the Air Force (procurement), in House, Cte on Govt Ops, *Government Procurement and Contracting*, 91 Cong, 1 sess, 1184.

89. Interview, Charles by Officer, 39–41.

90. Ibid., 91–92, 124–125; Karen W. Tyson, J. Richard Nelson, Neang I. Om, and Paul R. Palmer, *Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness* (Alexandria, VA: Institute for Defense Analyses, March 1989), F1–F15; and Karen W. Tyson et al., *The Effects of Management Initiatives on the Costs and Schedules of Defense Acquisition Programs*, vol. I: *Main Report* (Alexandria, VA: Institute for Defense Analyses, November 1992), X2–X5.

91. The last four sentences are based on email, Fox to Poole, 14 Jul 04.

92. For OSD efforts in the 1950s to improve the quality of the acquisition workforce, see Converse, *Rearming for the Cold War,* 429–438.

93. Ibid., 236–237, 467–468, 508 n22.

94. Paul W. Cherington, "Management in an Environment of Accelerated Science and Technology," lecture to Industrial College of the Armed Forces, Fort Lesley J. McNair, Washington, DC, 27 August 1963, 3, NDU Library.

95. For the Air Force's Atlas, Titan, and Thor programs and the Army's Jupiter, see Converse, *Rearming for the Cold War*, 490–505, 619–627. For Polaris, see chapter VIII in this volume and Converse, *Rearming for the Cold War*, 539–547.

96. Converse, *Rearming for the Cold War*, 467.

97. Report of the Board Convened by the Chief of Naval Operations to Study and Report upon the Adequacy of the Bureau System of Organization, 14 March 1956, III: 22–23, enc to ltr, Libby Board to Chief of Naval Operations, 14 Mar 56, sub: Report of the Board, fldr Libby Board, box 11, entry 176 (Miscellaneous Records Relating to Management and Organization, 1944–1960), RG 72 (Records of the Bureau of Aeronautics), Archives II.

98. Converse, *Rearming for the Cold War*, 570–571.

99. Raymond J. Snodgrass, *The Concept of Project Management* (Huntsville, AL: Historical Office, U.S. Army Materiel Command, June 1964, 89–96.

100. Converse, *Rearming for the Cold War*, 522–523.

101. Memo, Deputy DDR&E Rubel to Asst Secs of Army, Navy, and Air Force (R&D), "Management of Research and Engineering." In 1962, the Air Force, through its "375" series of regulations, substantially increased the authority and responsibility of its program managers. Among the added functions were: changing functional concepts, major program objectives, operational concepts and dates, and funding authorizations; rescheduling events or actions to promote better balance among program objectives; effecting trades between performance parameters; and establishing detailed objectives and performance criteria for all participating organizations. See Air Force Regulation 375–3 (System Program Director), revision of 12 Feb 62, fldr 7, box 37, Phillips Papers, LC.

102. Interview, Davis by Converse and Poole, 2 Jul 01, 40.

103. "Department of Defense Conference on Program Management, Final Report," 1963, 1–5, box "Management Studies, Administrative and Technological Histories, 1940–1967," 71–A–2207, RG 402 (Records of the Bureau of Naval Weapons), Archives II.

104. Simon Ramo, address, "The Program Manager: Substance or Symbol?" nd, fldr Program Manager, in ibid.

105. "DoD Conference on Program Management: Final Report," 6–7, 3.

106. Ibid., 7, 10–11.

107. Memo, DepSec Gilpatric to Secs of MilDeps et al., "Weapons Program Management," 19 Sep 63, covering letter to "DoD Conference on Program Management: Final Report."

108. DoD Directive 5010.14 (System/Project Management), 4 May 65.

109. Memo, SecDef to Sec Army et al., "Career Development of Military and Civilian Procurement Personnel," 3 May 65, unmarked fldr, box 7, Assistant Secretary of Defense for Manpower, Personnel, and Reserve Affairs: Civilian Personnel Policy, 1949–1967, entry 618, RG 330, Archives II; J. Ronald Fox, *Defense Acquisition Reform, 1960–2009: An Elusive Goal* (Washington, DC: U.S. Army Center of Military History, 2011), 199.

110. Memo, SecDef to Sec Army et al., "Career Development of Military and Civilian Procurement Personnel," 3 May 1965, unmarked fldr, box 7, Assistant Secretary of Defense for Manpower, Personnel, and Reserve Affairs: Civilian Personnel Policy, 1949–1967, entry 618, RG 330, Archives II.

111. Interview, Sarah W. Clements by Army Materiel Command historians, 21 Sep 87, AMC Historical Office, Alexandria, VA, 6, 8, 23, 9, 21–22. Between 1964 and 1975, Mrs. Clements was assistant chief in the Office of Project Management at Headquarters, AMC.

112. "Problem Areas in Air Force Weapons Systems Management," att to memrec by J. Ronald Fox, 3 May 65, 17, 18, 8–14, provided to author by Fox.

113. Ibid., 53, 7–8, 54.

114. Comptroller General, Report B–164682 to Congress, "Action Required To Improve DoD Career Program for Procurement Personnel," 13 Aug 70, 9, 1.

115. Ibid., 16, 19, 32, 31, 33.

116. Ibid., 26–27.

117. Ibid., 40–42.

118. Ibid., 2, 44, 46. It would be wrong, however, to assume that assignments in program management were career dead ends. Maj. Hans H. Driessnack, originally a fighter pilot, headed the Program Evaluation Division in the C–141A system program office. Shifting specialties quite successfully, he served in several comptroller assignments, rising to become comptroller of the Air Force, and culminating his career as the Air Force's assistant vice chief of staff. Navy Capt. Jeffrey C. Metzel, Jr., was program manager for Westinghouse's entry in the Mark 48 torpedo competition. Although Westinghouse lost to Clevite's version after extensive trials, Metzel's reputation survived and he advanced to rear admiral. After improving performances by the "3 Ts" (Talos, Terrier, and Tartar surface-to-air missiles), described in chapter IX, Rear Adm. Eli T. Reich served as deputy comptroller of the Navy. Earning a third star, Reich then became deputy assistant secretary of defense (production engineering and materiel acquisition). Maj. Gen. Welborn G. Dolvin served for three years as program manager of the Army's Main Battle Tank (MBT) project, a collaborative effort between the United States and West Germany. Leaving in 1966 while the MBT still had promise, Dolvin held important posts in Europe and Vietnam before retiring as a lieutenant general in 1975. As program manager of the Mauler missile system, Col. Bernard R. Luczak advised in 1965 that Mauler was technically feasible but would need much more time and money to reach production, a judgment that helped terminate the program. But Luczak went on to command the Army Ammunition Procurement and Supply Agency, supervising 27 government-owned, contractor-operated plants. He was promoted to brigadier general and designated program manager for the MBT in 1968. Retiring from the service one year later, Luczak remained in place as a civilian and oversaw the MBT's termination but served for three years after that as program manager of the follow-on XM–803.

119. Ramo, "The Program Manager: Substance or Symbol?" 7.

120. These two paragraphs draw heavily upon emails, J. Ronald Fox to Walter S. Poole, 17 Mar and 10 May 04, in which Fox described impressions he had formed while working in the office of the assistant secretary of the Air Force (financial management) during the mid-1960s.

121. DoD/NSIA, "Proceedings of Symposium on Major Defense Systems Acquisition," 11–12 Aug 71, 179, 102, 99, NDU Library. It must be remembered that the contractor, not the government, set the target price for a total package procurement contract.

122. The General Motors Corporation was regarded as a corporate model, but McNamara looked upon the GM example as unsound. "One of the things that always surprised me," he said many years later, "was how Charlie Wilson could have run General Motors since it was so screwed up. The reason was that Alfred Sloan and Donaldson Brown laid out a system of planning." A "moderately intelligent executive," McNamara believed, could survive at General Motors simply by following what they had established as a "modus vivendi." George M. Watson, Jr., and Herman S. Wolk, "'Whiz Kid': Robert S. McNamara's World War II Service," *Air Power History* 50, no. 4 (Winter 2003): 13. Charles E. Wilson was president of General Motors from

1941 to 1953 and secretary of defense from 1953 to 1957.

123. Richard M. Anderson, "Anguish in the Defense Industry," *Harvard Business Review* 47, no. 6 (November-December 1969): 163, 164, 169.

124. Hudson B. Drake, "Weapon System Management: Has the Potential Been Realized?" *Armed Forces Management* 13, no. 8 (May 1967): 66–67 (quotation, 67).

125. Robert F. Coulam, *Illusions of Choice* (Princeton: Princeton University Press, 1977), 378.

I. House, Cte on Armed Svcs, Report No. 67, *Special Subcommittee on Procurement Practices in the Department of Defense, Consideration of H.R. 12299*, 86 Cong, 2 sess, 6082–6085.

II. Office of the White House Press Secretary, press release, 15 January 1964, fldr Cost Reduction 1964, box 977, 11–14, OSD/HO; Department of Defense Cost Reduction Program Report, 7 July 1964, fldr Cost Reduction 1964, box 977, OSD/HO; press release, the White House, 10 July 1967, fldr: Air Force Organization, 1965–1968, box 593, OSD/HO; press release, the White House, 4 August 1967, fldr Air Force Organization, 1965–1968, box 593, OSD/HO; Statement of Thomas D. Morris before the Subcommittee on Economy in Government, 28 November 1967, fldr I&L 1964–1968, box 972, OSD/HO; press release, "Barry James Shillito Nominated to be Assistant Secretary of Defense (Installation and Logistics)," 22 January 1969, fldr I&L 1969–1976, box 615, OSD/HO; Nomination of Thomas D. Morris, Senate Committee on Finance, Nominations of Hale Champion, Thomas D. Morris, and Arabella Martinez: Hearings before the Committee on Finance, 95 Cong, 1 sess, 8–10 March 1977, 11–12; Thomas D. Morris oral interview, 6 April 1987, OSD/HO; Thomas D. Morris oral interview, January 1990, U.S. General Accounting Office History Program, v; and Historical Office, Office of the Secretary of Defense, *Department of Defense Key Officials, 1947-2004* (Washington, DC: OSD/HO, 2004), 56.

III. Press release, 7 May 63, fldr "Research, 1961–1968," box 864, OSD/HO; "Can Weapon System Management Be Taught in School?" *Armed Forces Management* 12, no. 8 (May 1966): 83–84; David D. Acker, *A History of the Defense Systems Management College* (Fort Belvoir, VA: Defense Systems Management College, 1986), 1–12; Wilson Summers, "Before DSMC, There Was DWSMC," *Program Manager* (January-February 2000): 60–61; Brig Gen Edward Hirsch, USA (Ret.), "Meeting the Challenge . . . Fulfilling the Promise: PMC to APMC—a 30-Year Odyssey," *Program Manager* (May-June 2001): 30; interview, James N. Davis by Elliott V. Converse III and Walter S. Poole, 29 Jun 01, 44–47. In 1967, the Industrial College of the Armed Forces started a course titled "Management in the Department of Defense" that was tailored for field-grade military officers as well as GS–13s, –14s, and –15s in the civil service. See "Industrial College Shoots for Middle Managers," *Armed Forces Management* 13, no. 6 (March 1967): 83–84.

CHAPTER IV

Innovation: Coping with "Unanticipated Unknowns"

Throughout the Cold War, a basic tenet of U.S. defense policy was that superior weapons technologies could offset an opponent's advantage in numbers of weapons and personnel. Maintaining a technological lead required continuous innovation. But acquisition officials struggled to devise policies and processes that would support timely, affordable, successful innovation. Many contractors claimed that cost and schedule overruns kept recurring because DoD acquisition policies were incompatible with the natural pattern of system development and production. That was the argument of a 1968 study sponsored by the Aerospace Industries Association. Hudson Drake, a participant who worked for North American Rockwell, argued that a contractor had to solve two kinds of technological unknowns. First were those of which he was aware and believed he could solve; their costs could be estimated with considerable precision. Second, and more important, were the "unanticipated unknowns," the costs of which could not be estimated. For the Air Force's C–5A transport, as an example, brakes made of beryllium had to be developed after those made of standard carbon or alloy steel proved to be inadequate. Since an error in one estimate tended to amplify itself as development and production proceeded, nothing could "crumble the pyramid so rapidly and thoroughly as the emergence of important unanticipated unknowns."[1] DoD officials, in short, wanted contractors to move into technologically advanced areas with a speed and precision that contractors deemed impossible to achieve.

Drake pinpointed the most critical juncture for "unanticipated unknowns" as that between contract definition and engineering development. According to DoD Directive 3200.9 (Initiation of Engineering and Operational Systems Development), issued in 1965 and described in chapter II, a contract for engineering development could not be signed until the basic technology had been established sufficiently. Drake's experience, however, convinced him that no existing procedure could ensure "such a complete technical baseline for any project of greater than trivial dimensions." Indeed, every project reviewed by the Aerospace Industries Association had needed substantial technical revisions during the engineering development phase. The root of the problem, then, lay in "the total uncertainty . . . which induces the government to press for definitive specifications at the same time that it induces the contractor to press for broad and flexible specifications."[2]

Under the assumption that development was more predictable and more easily improved through incentives than research, OSD set out to reduce uncertainty in the acquisition process by severing research from development.[3] But an intense competition for funds among the services and throughout the defense industry regularly produced overly optimistic cost, schedule, and performance estimates. Debates that were not and probably could not be resolved took place over the merits of concurrency versus prototyping and component growth, the achievements of private industry versus government laboratories, and whether innovation was a gradual, cumulative process or resulted from the cascading effect of major breakthroughs. But no reliable methodology emerged for measuring the advances that weapon systems in service had delivered, let alone what might come from those under development. Such values proved to be impossible to quantify or analyze in a logical, objective manner. In sum, a succession of unanticipated unknowns made negotiating realistic target prices almost impossible, which in turn defeated the purpose of many fixed-price incentive contracts.

CONCURRENCY

For many Americans, the launch of Sputnik on 4 October 1957 signaled a Soviet surge toward technological leadership. The United States already was dedicating about half of its scientists and engineers to supporting the full spectrum of weapons development. Yet the Soviets, it appeared, were fielding aircraft and missiles within four or five years compared to seven or eight for their U.S. counterparts.[4] What could be done to compress lead time, the period extending from the point when a decision was made to proceed with development until production items reached operating units? In time it became apparent that Soviet lead times often were shorter because their long-range bombers and missiles were qualitatively inferior to comparable U.S. weapons. But this fact was not clear in 1957.

The development of a weapon system could proceed sequentially or concurrently. If carried out sequentially, stages of the acquisition process were not compressed or allowed to overlap. Competing prototypes were built during the development phase and, if possible, tested against each other. Final designs and program schedules would remain open while developmental testing went ahead. Concurrency, on the other hand, strove to compress the process by starting preparations for or initiating production before development had been completed. Competition usually ended prior to full-scale development because supporting two contractors beyond that point would require setting up two production lines. Concurrency, therefore, involved a gamble. If a system needed no major modifications after the first test, much time would be saved. If significant changes proved to be necessary—a frequent occurrence—a good deal of time and money would be lost.[5]

To field weapon systems rapidly, concurrency had been widely practiced in World War II, even though cost overruns resulted. Its use represented a significant departure from the prewar approach, in which each stage of the acquisition process—research, development, testing of prototypes, and production—generally proceeded in series. Between World War II and the Korean War, the Air Force and Navy used both sequential and concurrent acquisition strategies. The Army, however, returned to the prewar sequential approach. During the Korean War, money for defense increased dramatically, enabling the services to initiate programs for a large variety of advanced systems. All of the services employed concurrency in many of these programs. Haste was thought to be necessary, due not so much to the requirements of the war in Korea as to the possibility of a global conflict with the Soviet Union, which the Truman administration had judged might occur as early as mid-1952. But the widespread use of concurrency during the war resulted in costly modifications of many weapon systems during production and into deployment, as well as schedule delays and even cancellation of some systems. Often, the net results were higher costs and no real improvement in the effort to field effective systems rapidly.[6]

In response, the services took steps to preserve concurrency's potential to shorten lead times for advanced systems while reducing its tendency toward cost overruns and schedule delays. A 1958 RAND study described these measures: first, develop subsystems that would be mated to each other at the earliest stage; second, tool up for quantity production concurrently with the development and testing of prototypes; and third, order large quantities of test vehicles from the outset of a program. But the reality, according to the RAND analysts, was that these procedures often created more problems than they solved by failing "to take sufficient account of the uncertainty that pervades research and development." Early integration required program managers to make predictions about schedule, cost, and performance before preliminary test data became available. Inevitably, modifying systems to comply with test results obtained after integration was difficult and costly. Additionally, narrow and excessively detailed specifications created subsystems so highly specialized that adapting them to other uses proved difficult. Yet concurrency called for highly integrated development programs in which, for example, the weight and dimensions of electronic equipment usually were spelled out to the last pound and fraction of an inch; power supply and cooling capacity were determined in advance and allocated among the various components; and missiles had to fit tightly within their bays or silos. Instead of emphasizing subsystem integration, critics of concurrency recommended aiming for better subsystem performance and reliability. Start with broadly written specifications, provide for sequential decisionmaking, let project offices make more technical decisions, pursue multiple approaches in a program's early stages, and test equipment as soon as possible.[7]

During the spring of 1959, the Defense Science Board (DSB), the senior civilian advisory group for the DDR&E, considered ways to reduce the time between the conception and prototyping of systems. The board's main suggestions paralleled those from RAND. For example, one idea was to pursue state-of-the-art research and component development before developing major systems, deferring detailed military characteristics until exploratory work and preliminary tests had established the validity of concepts and the feasibility of applying them. The board believed that management reforms then being adopted by the services would save time. But one member called attention to "the extraordinary immensity of a Defense program as against an industrial undertaking." During the past 10 years, he argued, the state-of-the-art in defense research and technology had advanced so rapidly that no comparable situations were available for guidance.[8]

To create an environment conducive to achieving research breakthroughs prior to the initiation of development projects, DoD opened a new source of funding for corporate research: Independent Research and Development (IR&D). An amendment to the Armed Services Procurement Regulation in 1959 allowed contractors to charge unsponsored basic and applied research to their overhead costs and spread a predetermined percentage of such independent research across their existing contracts. So began the IR&D program, whose 1962 costs came to $480 million, about $90 million of which was dedicated to basic research. Defense officials hoped that IR&D reviews would force contractors to do a better job of separating research costs from development programs.[9]

In addition to reducing lead time and improving the environment for conducting research, system reliability emerged early on as a central concern of the Defense Science Board. Nothing aroused public consternation more than well-publicized missile test failures. (Soviet failures, of course, occurred beyond the media's gaze.) In March 1959, Director of Defense Research and Engineering Herbert York selected Rudolph Furrer, an engineer and industrialist who had designed the bomb casing for the first thermonuclear device, to be his special assistant for reliability. Eighteen months later, Furrer warned the Defense Science Board that improvements would not come easily:

> Until a very few years ago . . . the successful bidder was expected to do his job without benefit of a reliability clause. . . . Perhaps in those days we functioned under an unwritten code which might well have been called the "pursuit of excellence." Now the inference or the code often seems to be, "give us enough money and we'll still take the job, because we need the work." . . . Responsible men representing top management told us they had been compelled to acquiesce in order to obtain the business.

Furrer also stressed the difficulty of pinning down exactly who held responsibility for the schedule, cost, and technical performance of any weapon system. It was not, in many cases, the prime contractor: "Strictly speaking, this may not be a research and engineering problem, but I am sure it has affected reliability and has also increased the costs."[10]

During the mid-1950s, concurrency was deemed to be necessary to catch up with the Soviets in the missile race. As practiced in the Air Force ICBM and Navy Polaris programs, however, concurrency involved more than overlapping development and production or compressing testing. Thus, in the Atlas and Titan ICBM programs, site construction, missile installation and checkout, flight testing, and crew training were all undertaken simultaneously and as rapidly as possible, within a very narrow schedule. The Air Force claimed that, barring a complete failure, this expanded concept of concurrency was much less expensive than the fly-before-buy approach. Since the indirect costs of major programs ran as high as the direct costs, the extra time needed to test prototypes in fly-before-buy would inevitably raise the price.[11]

In its haste to deploy operational ICBMs, however, the Air Force apparently had neglected quality control mechanisms. In January 1960, George B. Kistiakowsky, President Eisenhower's special assistant for science and technology, warned the National Security Council that "the managerial situation at the Martin Company [where Titan ICBMs were assembled] is very bad and the failures of the last eight months can all be traced to human factors: lack of staff training, low competence, lack of adequate instructions." The Air Force, he added, had put heavy pressure on the Martin Company to remedy those weaknesses. But problems persisted. In March 1960, one of Convair's Atlas missiles exploded, destroying its test facility; one of Martin's Titans did the same in December. In October 1960, one year after the Atlas D had been declared operational, "no deployed missile could be considered fully reliable; hence, its chance of being launched was zero." Reliability, defined as the likelihood of a missile reaching its target, stood around 50 percent for Atlas and 66 percent for Titan.[12]

Late in 1960, Air Force investigators attributed missile reliability problems to several factors, including inadequate testing, facilities, technical data, training, and configuration and quality controls. According to Air Force historian Bernard C. Nalty, for example, Atlas "contained some 40,000 identifiable parts, many of them components of delicate electronic subsystems. . . . Difficulty of maintenance, plus the caution necessary in fueling the missile before firing, prevented Atlas and Titan I from attaining the 15-minute reaction time required" by the Air Force's Strategic Air Command.[13]

The response, a one-year exercise called Golden Ram, exposed and corrected hundreds of shortcomings in the Atlas missile and its maintenance procedures. But General Thomas S. Power, commander-in-chief of the Strategic Air Command, warned that the Air Force could not "stand another Golden Ram." Instead, the Air Force employed techniques, identified in its 375 series acquisition management regulations, to coordinate and control changes, ensure the compatibility of designs with hardware, and establish costs and schedules. The 375 series regulations also divided the life cycle of weapon systems into three phases—conception, acquisition, and operations—and defined the responsibilities of a system program office and its directors. To deal with problems that had escaped detection during R&D, Air Force managers made "update" modifications a routine aspect of missile programs. Consequently, Minuteman, the solid-fuel, second-generation ICBM, registered notable improvements, including increased reliability. Improved procedures also made liquid-fuel missiles more reliable.[14]

With the exception of some ballistic missile programs, the Army's experience with concurrency was not positive. In 1957, at about the same time "pentomic" divisions were being organized for operations on tactical nuclear battlefields, the Atomic Energy Commission developed a lightweight warhead with a subkiloton yield that appeared suitable for frontline use. The Ordnance Corps determined that a jeep-mounted recoilless rifle offered the best means of delivery. The Army subsequently supported development of the Davy Crockett, a crew-transportable, tactical nuclear weapon system. The chief of ordnance assigned development responsibility to the commanding general of Ordnance Weapons Command. He in turn gave a special assistant, Col. Richard Restetter, unusual authority to act in his name. Early in 1958, the Army chief of staff awarded Davy Crockett the highest priority among the Ordnance Corps projects. Army leaders wanted the system to be ready for deployment by 31 March 1962, thereby proving again, after the success of the Jupiter IRBM program, that the Army could bring a weapon system into service within four years.[15]

Davy Crockett (*National Archives*)

Colonel Restetter and his project office coordinated work done at 14 Army installations, with Picatinny Arsenal in New Jersey bearing the main responsibility for research and engineering. The only technical breakthrough involved a spigot-tube launching device.[16] Portions of the program were telescoped, so that R&D personnel fed drawings of components to the production engineers as soon as they were completed. Also, engineering tests (conducted by developers to ensure the completeness and acceptability of the design) and user tests (conducted in a realistic operational environment with users present to determine the effectiveness and suitability of the overall system) were combined.[17] Thus, Davy Crockett's readiness deadline was met, but the weapon proved to be so dangerous and unreliable that it stayed in service only a few years. By 1966, Davy Crockett was replaced with a nuclear projectile for the 155mm howitzer that had a larger yield, greater range, and less vulnerability.[18] Even so, as described in chapter V, the Army's methods in developing the Shillelagh, Redeye, and Mauler missile systems remained closer to concurrency than to anything else, with overlaps causing schedule delays and cost increases.

ALTERNATIVES: PROTOTYPING OR COMPONENT GROWTH

Although concurrency remained the dominant approach to organizing major weapons projects for much of the 1960s, criticisms of it emerged early in the decade. In 1961, the Military Construction Subcommittee of the House of Representatives Committee on Appropriations blamed cost overruns on divided responsibilities, gross underestimation of the tasks involved, and inability to stabilize missile designs. The Air Force and its contractors, the committee suggested, used concurrency as an excuse to cover up their mistakes. OSD responded that "[t]ime is the key to national security and concurrency has saved a great deal of time."[19] But in mid-1962, DDR&E Harold Brown told congressmen that he considered concurrency justifiable "only in a very few vital programs."[20] Despite such reservations, OSD and the services, especially the Air Force, remained wedded to concurrency until late in the decade.

A RAND study, commissioned by the Air Force and published in February 1963, rated concurrency against prototyping by analyzing 12 aircraft development programs. The study defined a prototype as a vehicle or component used primarily to test a design concept and obtain the information necessary to make sound decisions about development. By the early 1950s, the Air Force had abandoned prototyping and efforts to enhance the capabilities of individual components almost completely. But RAND analysts judged the merits of concurrency to be much exaggerated. What crippled concurrency were not simply uncertainties about forecasting enemy capabilities and technological advances. Even if predictions about general kinds of capabilities proved to be correct and the more dramatic technological uncertainties could be controlled, experience showed that the detailed follow-on decisions could be erroneous. Of the Air Force's six most recent fighters, four ended up with engines other than those originally planned, three with different electronic systems, and five with substantially modified airframes. A review of 10 fighter and 7 bomber programs showed that the time needed to deliver the first squadron proved to be as long under concurrency as in any of the prototype programs.[21]

To explain why concurrency's apparent advantages failed to materialize, RAND analysts drew attention to the experience of the Air Force's F–102 interceptor. Convair had been authorized to build 42 test aircraft and tool up to produce 125 aircraft per month. When it became clear that the delta wing's aerodynamic drag was keeping the F–102 below supersonic speed, the first 10 planes were so far along in production that they had to be finished in the original configuration. Redesign forced Convair to discard 20,000 of its 30,000 tools, but the next version of the aircraft proved to be too heavy. A third retooling meant discarding $30 million worth of tools; even more was spent on airframes that had to be substantially reworked or handled as salvage. In sum, RAND analysts saw compelling reasons for seeking alternatives to concurrency. They recommended more widespread use of expedited prototyping, putting airframes and subsystems quickly into testing, particularly when seeking major technological advances.[22]

The Air Force declined to adopt this advice. In August 1963, when Secretary of the Air Force Eugene Zuckert testified at hearings about the F–111 fighter-bomber, Sen. John L. McClellan (D–AR) cited the RAND report to support his argument for competitive prototyping. Why not have a fly-off and let the best company win? Zuckert disagreed: "You will certainly not determine quickly, automatically, which is the better airplane because . . . you don't learn about a weapon system until you have used it. We found this out to our sorrow." Zuckert termed the RAND report "interesting" but not "conclusive by any means."[23] In fact, a DoD Draft Presidential Memorandum of December 1966 argued strongly against prototyping:

> We have learned from bitter experience that even when development problems have been solved, a system can run into trouble in production or when it is put into operation. All too often the development prototype cannot be produced in quantity without extensive re-engineering. . . . Sometimes these problems are not discovered until the new system actually enters the inventory and has to function in an operational environment. The Terrier, Talos, and Tartar ship-to-air missiles are a good example; after spending about $2 billion on development and production of these missiles, we had to spend another $350 million correcting the faults of those already installed and we still plan to spend another $550 million modernizing these systems.[24]

Neither concurrency nor prototyping, it appeared, could prevent expensive reengineering when a system reached production.

In September 1960, the DDR&E had proposed two ways of dealing with "uncertainties of unprecedented orders of magnitude": first, by weapon system growth; second, by component growth. Weapon system growth, characteristic of the Air Force's approach to development, stressed the early integration of specialized subsystems, theoretically saving time and avoiding extensive postdevelopment modifications. After studies showed that aircraft often did not carry the engines and avionics originally intended for them, RAND recommended advancing the capabilities of individual components apart from specific weapon systems, an approach known as component growth. This approach devoted resources and focused attention on incorporating advanced components into test models, emphasizing early tests of new ideas, and freeing component development from the constraints of compatibility with a particular weapon system.[25]

In the DDR&E's judgment, weapon system growth was not well suited to development efforts fraught with uncertainty. Conversely, component growth was time consuming but kept open a wide range of possibilities. Of course, a poor job of integration could offset any gains from good component performance.

The difficulty, the DDR&E stressed, lay in deciding which approach would be appropriate to the particular circumstances at hand and when to shift from component to weapon system growth.[26] Alain Enthoven, who became assistant secretary of defense (systems analysis) in 1965, had contributed to the DDR&E study. Testifying before the House Armed Services Committee in 1968, Enthoven described what he called the Defense Department's "new approach" to managing innovation. Applying weapon system growth, he related, often had meant that "unpredictable things happened—the engine development fell behind schedule, so a different engine was used. Sometimes they put an engine they had developed for a bomber into a fighter plane." Recently, Enthoven continued, "we develop advanced technology in key areas for its own sake"—engines, electronics, and fire control systems were examples. By fostering component growth, "when we need a new aircraft we will have the most advanced technology available, 'off the shelf,' so to speak. . . . That is why we have asked the Congress repeatedly for funds . . . to support exploratory development."[27]

The verdict on component growth appears mixed. Systems Analysis helped push a concept for a jet engine using high turbine inlet technology to improve efficiency; that idea turned into the engine chosen for the C–5A transport. Developing a fighter aircraft, by contrast, essentially involved designing an engine and then wrapping an airframe around it. Component growth was applied more widely by the late 1970s, when modules of electronics could be inserted into new and existing platforms.[28]

During 1967–1968, Richard A. Stubbing, a Budget Bureau official, analyzed how well the acquisition process had worked for the electronic systems used in 13 aircraft and missile programs. He found that two programs had been canceled, two had to be phased out quickly, and five had registered a reliability that came to less than 75 percent of the initial specifications. Only four programs showed reliabilities above 75 percent—"an uninspiring record that loses further luster when cost overruns and schedule delays also are evaluated." Stubbing evaluated the operational performance of electronic systems carried aboard 12 types of fighters, bombers, and air-to-air missiles from the standpoint of their mean time between failures (that is, the average number of continuous hours that a system would work before failing). Of the nine that he rated as high-risk programs, six fell far below expectations. Sidewinder, a heat-seeking air-to-air missile and a successful performer, had benefited from a "leisurely" nine-year development program as contractors explored parallel approaches to key components. The F–4 Phantom fighter-bomber, another success, was the only one of these programs chosen through a prototype competition. Although the Phantom carried new radar and a new computer, competitive prototyping had allowed enough time to fix problems before the production run began. Overall, recent trends ran toward highly complex crash development programs (three to four years during the 1960s versus five to seven years in the 1950s) with technical goals that were almost impossible to attain. Costs swelled rapidly from original estimates, schedules slid, and the reliability of operational equipment degraded rapidly. Competitive development therefore offered the best prospect of maximizing incentives while improving quality and cost. Stubbing suggested funding at least two contractors for at least two years, "culminating in an extensive demonstration of prototype equipment in an operational environment with special emphasis on the maintainability of the equipment by service personnel."[29]

In fact, by the end of the decade, Air Force Systems Command (AFSC), the Air Force's field command for acquisition, was turning toward prototyping. Speaking to the National Security Industrial Association in December 1968, General James Ferguson, AFSC commander, criticized paper competitions because they embodied "the state of the art at a point in time five to seven years prior to initial operational capability." But such an approach ruled out "ingenious, radical, perceptive advances." As a result, the Air Force was selecting a contractor and committing itself "to a whole development and production run—spares and all—before any tin is bent." Ferguson instead advocated "a contract definition in hardware"—that is, a prototype test model. Then, source selection could be based on "a hundred cubic feet of hardware rather than a hundred cubic feet of paperwork."[30] The Nixon administration would make frequent use of prototype competitions in the 1970s.

CASE STUDY: THE MARK II AVIONICS SYSTEM

A combination of technological and managerial problems frustrated efforts to produce the Mark II avionics system. The Mark II suffered major delays and large cost overruns and fell well short of its original performance requirements. Unanticipated unknowns were not wholly responsible. The government and the contractors made a number of avoidable mistakes.

Between 1945 and 1965, the techniques for hitting targets with unguided iron bombs underwent little improvement. Then the air campaign against North Vietnam, requiring a precise application of graduated pressure, put a premium on accurate delivery of conventional munitions. A quantum jump appeared feasible. The Mark I avionics system, consisting of an attack radar, a navigation-attack system, and a lead computing optical sight, was to be installed on Air Force F–111s. Air Force officers wanted reliable systems requiring a minimum amount of maintenance per flight hour but permitting high sortie rates from austere runways. Many civilians in the Office of the DDR&E had somewhat different priorities, seeing aircraft mainly as platforms for avionics systems. They viewed the Mark I as designed primarily for low-level delivery of tactical nuclear weapons at supersonic speeds, which no longer was the primary mission of tactical aircraft. The DDR&E, supported by the President's Science Advisory Committee as well as the Air Force Scientific Advisory Board, pressed for a much more sophisticated Mark II. The Air Force acceded, and Secretary McNamara approved development of a more advanced system.[31]

The Sperry Rand Corporation, the Hughes Aircraft Company, and North American Rockwell's Autonetics Division competed for the Mark II contract. Theoretically, the Mark II would be able to separate a target from ground clutter and maintain a fix on it, regardless of the aircraft's speed and altitude or whether the pilot could see it.[32] Autonetics was chosen and, on 1 July 1966, entered into Purchase Agreement 181 with the F–111's prime contractor, General Dynamics. A fixed-price incentive contract put the estimated target price at $183 million minus a "management reduction" of $38 million taken by General Dynamics. Autonetics could not negotiate changes to the statement of work, but General Dynamics could negotiate reductions in the target price.[33]

Deadlines were tight. Mark IIs had to be ready for installation in F–111As during 1968. Stripped-down Mark IIBs were planned for FB–111s, the strategic bomber variant. To meet delivery schedules for FB–111s, though, the first Mark IIBs would be needed six months ahead of the Mark IIs. Consequently, contract definition, development, and initial production had to be completed within 33 months for Mark IIs and within 28 months for the Mark IIBs. Merely three months were permitted for preparation of subcontractors' proposals and six weeks for their evaluation and source selection. For the F–111Ds, essentially F–111As carrying Mark IIs, flight tests would start a scant six months before production deliveries, so test results could not be used to improve the initial production units. The schedule drawn for FB–111s was even tighter, with the first test unit slated for completion four months after a production go-ahead.[34]

Autonetics promptly made substantial changes in many designs. By September 1966, a new set of performance specifications—called the "A–1 Specs"—had been drafted and some reductions in performance accepted. On 15 March 1967, Autonetics asked for $367 million, more than double the target price. When Secretary of the Air Force Harold Brown rejected that figure, Autonetics on 15 April proposed $297 million. Brig. Gen. J.L. Zoeckler, program manager for the F–111 in AFSC, told General Dynamics that $297 million was a "not to exceed" price about which negotiations could begin—provided that Autonetics could trace when and why the cost increase had occurred. Autonetics countered that traceability was impossible. Instead, it attributed the increase to 12 government-ordered contract changes, which had been issued before the A–1 Specs appeared.

At Deputy Secretary of Defense Vance's direction, the Air Force established its own technical trace team directed by Brigadier General Zoeckler. The team concluded that design changes had been made to meet performance specifications, not to implement contract change notices. Moreover, specifications had been revised at the request of Autonetics to relax those that it was unable to meet, not to accommodate changing Air Force requirements. Zoeckler's team identified, as the maximum amount of government responsibility, only $20.2 million.[35]

By January 1968, Autonetics anticipated a price increase of $600,000 per production unit. Worse, costs apparently would not decrease when the Mark II entered quantity production. In June 1966, cost estimates had been $425 million ($39 million for RDT&E and $386 million for production); by January 1968, the cost estimates had ballooned to $1.09 billion ($173 million for RDT&E and $917 million for production).

The Air Force did not want a major supplier to suffer a heavy loss, but saw no evidence to justify higher prices. The Air Force often had tolerated the practice of companies submitting underestimated bids. Consequently, many in the Air Force viewed Autonetics as the "innocent victim" of an overall system that was switching from verbal promises to written agreements. Others, however, felt that this contract had to be enforced to maintain the integrity of the source selection process.[36]

Analyzing the Mark II acquisition in May 1968, William W. George, who worked under OSD Comptroller Robert Anthony, reached a dismaying conclusion. All of the reforms of the 1960s had been employed: providing meaningful competition by strong contenders; specifying a fixed-price incentive contract with a tight ceiling and a cost-sharing pattern; using total package procurement (the only variation being exclusion of support and logistics equipment); conducting concept formulation and contract definition in accordance with DoD Directive 3200.9; allowing the contractor to specify technical characteristics, schedule milestones, and cost targets; using performance rather than design specifications; signing a definitized contract immediately after source selection; and minimizing the number of substantive changes to requirements.[37]

Why, then, were the Mark II results still unsatisfactory? Hurrying the final phase of contract definition and forcing a high degree of concurrency, which George labeled the biggest mistakes, did not by themselves explain such a severe cost overrun. In fact, the usual causes of overruns (sole-source contracting, undefined requirements, numerous changes, undefinitized contracts, lack of risk placed on the contractor, "gold-plating," and major unexpected problems) were conspicuously absent. Instead, George put forward two explanations. First, both Autonetics and the Air Force had been unrealistic about ultimate costs.[38] Aggressive competition led bidders to be unduly optimistic. Autonetics, he surmised, knew what it was getting into but resorted to the familiar tactic of "buying in." The Air Force, anxious to sell the Mark II to Congress, made no independent cost assessment at the time of source selection. Second, at source selection and for months thereafter, Autonetics believed it would not be held to written agreements and expected to use government-ordered contract changes as a way of "getting well." The Air Force, however, made no changes of any magnitude. It had rushed the final stages of contract definition but was encouraged to do so by what George called Autonetics's "unguarded optimism" that deficiencies could easily be set right. Cost-controlling incentives were "vastly overshadowed" by the organization's belief that meeting performance and schedule specifications would assure follow-on contracts. In March 1967, George concluded, Autonetics realized that it would have to do a major redesign of the

Mark II system and reacted by claiming that government-ordered changes had invalidated the original contract. This was exactly the strategy that Autonetics had employed successfully on its Minuteman guidance contract. Unfortunately, Autonetics failed to appreciate that OSD was shifting the acquisition process from oral promises to written agreements.[39]

Autonetics delivered the first Mark IIs to General Dynamics on 21 November 1967. Flight testing by an F–111A began on 31 March 1968. Still more "unanticipated unknowns" appeared. During the first full test of the system, in June, components started interfering with each other.[40] In mid-September 1968, Charles A. Fowler (deputy director, tactical warfare systems, DDR&E) warned John Foster, the DDR&E, and Secretary of the Air Force Brown that problems looked "formidable." Fowler also cited high-power traveling wave tubes and storage tubes as possible areas of major trouble. Already, cracking had occurred at the windows of traveling wave tubes. An alternative tube was being developed, Fowler told Foster and Brown, but "as you know, Murphy's Law applies to new tubes more than anything else."[41] Inability to solve this and other problems promptly meant that 141 production-model F–111As entered service with Mark Is, as did 94 F–111Es.[42]

Mark IIs were still programmed for 315 F–111Ds. By late 1969, however, the Mark II's snowballing cost forced a reduction in F–111D production from 315 to 96, meaning that component costs swelled as production slumped. The Air Force accepted one F–111D in June 1970, but none followed for the next 12 months because Mark IIs still were unavailable.[43] By June 1972, only 24 F–111Ds were available—two years beyond the time when a 72-plane wing should have been operational. Even then, F–111Ds were crippled by lack of spares. Moreover, according to historian Marcelle Knaack, the commonality that McNamara prized "had long disappeared. Technical problems, remedial cures, and expedients had left the F–111D with a complex, highly integrated, one-of-a-kind avionics system."[44]

The Mark II stands as an example of technological overreach that no acquisition reforms could remedy. A basic incompatibility existed between air-to-air systems, which needed extremely fast data-processing rates and variable waveform flexibility, and air-to-ground systems, which needed very large data storage and processing capabilities for high-resolution mapping. The Autonetics strategy of "buying in," accomplished with the complicity of its backers in OSD and the Air Force, only compounded the difficulties.[45]

RATING GOVERNMENT VERSUS PRIVATE CONTRIBUTIONS

Throughout this period, policymakers largely took for granted the superior creativity and productivity of the private sector. President Kennedy tasked

Budget Director David Bell with leading an interagency study (discussed in chapter III) of "the experience of the Government in using contracts with private institutions and enterprises to obtain research and development work needed for public purposes." Bell's report of April 1962 recommended continuing a heavy reliance on private contractors. The government, however, needed enough in-house competence so that contractors' technical advice would not become de facto technical decisionmaking. But the report identified "a serious trend toward eroding the competence of the Government's research and development establishments—in part owing to the keen competition for scarce talent which has come from Government contractors." That trend could be reversed by assigning significant and challenging work to government establishments, giving more authority to laboratory directors, easing the rigidities of civil service assignments, and raising salaries, particularly for the higher grades.[46]

The Bell Report did not articulate a rationale compelling enough to pour resources into government facilities. The Salary Reform Act of 1962 helped to ease pay disparities, but little change occurred on other fronts. "Organizational generalities in themselves solve few problems," the Defense Science Board recognized in March 1965. "The success of a research group depends principally upon the inspiration of its people and perhaps most of all on the leadership of a single inspiring individual."[47]

In November 1965, John Foster, who had succeeded Brown as DDR&E the previous month, called for a comprehensive plan to strengthen the government's in-house R&D facilities. Lacking the priority enjoyed by nuclear weapons laboratories, these R&D facilities, in Foster's view, were staffed by heavily entrenched bureaucracies and headed by military officers who lacked R&D expertise and focused most of their attention on the basic operations of their facilities.[48]

During the mid-1960s, the Army and Navy each established a civilian director of laboratories, while the Air Force created, at the assistant secretary level, a special assistant for laboratories. Even so, expectations outran results. The Navy director, for example, received no program responsibilities, was denied clear-cut control over laboratory funds, and lacked adequate staff assistance. The Defense Science Board appointed a task force to examine how laboratories run by the services could best support basic missions. Reviewing in-house contributions to the Army's Nike-X antiballistic missile, the Navy's Poseidon, and the Air Force's Minuteman, the task force uncovered a problem. Under incentive contracts, prime contractors hesitated to use government laboratories because they had little control over them. Also, Foster found it very difficult to remove civil servants of marginal ability, and Congress prevented the closure of an outmoded laboratory.[49]

Harold Brown (*OSD/HO*)

Harold Brown

Born in New York City on 19 September 1927, Brown earned three degrees at Columbia University, including a Ph.D. in physics at age 21. After a short period of teaching and postdoctoral research, he became a research scientist at the University of California Radiation Laboratory at Berkeley. In 1952, he joined the staff of the Lawrence Radiation Laboratory at Livermore, California, becoming its director in 1960.

In May 1961, Brown became the second director of defense research and engineering, succeeding Herbert York. As DDR&E, Brown advocated cancellation of both the Skybolt air-launched ballistic missile (December 1962) and the Dyna-Soar space glider (November 1963), systems he believed were inadequate, unnecessary, and too costly. Brown backed the TFX (Tactical Fighter Experimental), which became the F–111, for its cost effectiveness, anticipated capabilities, and the new technologies incorporated in its design, including variable-geometry (swing) wings. In early 1964, he initiated Project Hindsight, a study to identify the sources of innovation and to determine the extent to which DoD investments in science and technology contributed to the development of new weapon systems.

Appointed secretary of the Air Force in September 1965, Brown was heavily involved in the controversy surrounding the production and deployment of the F–111A. Along with John Foster, his successor as DDR&E, Brown recommended additional testing, which postponed the deployment of the F–111A to Southeast Asia by two months. Performance problems that appeared after the plane entered the theater in March 1968—three were lost within a month of its arrival—caused the Air Force to withdraw the F–111A from combat until avionic and engine modifications were completed. The land-based Minuteman II ICBM was also rushed through development, forcing Brown to commit additional funding to correct problems with the missile's computerized guidance and control components.

Brown resigned as secretary of the Air Force in February 1969, serving as president of the California Institute of Technology until 1977, when he became secretary of defense in the Carter administration, the first scientist to hold that post.[1]

Government facilities received a psychological boost from Project Hindsight, a DoD-wide effort initiated by the DDR&E in July 1965 to explore the sources of technological innovation. Hindsight provided a catalogue of innovative "events," which were defined as discrete contributions occurring between the conception of an idea and the initial demonstration of its validity. Between the early 1940s and the mid-1960s, the proportion of such events coming from in-house laboratories fell from about 60 percent to around 30 percent. During this span, though, "the national scientific and technological community essentially quadrupled in strength while the in-house laboratories were constrained to a growth of about a factor or two." As of 1966, Hindsight rated the productivity of government laboratories as being comparable to that of industry.[50]

In October 1966, a DSB task force reported that teams from industry and system program offices were managing most of the costly and sophisticated weapon systems, while government laboratories handled a significant percentage of the research and development for subsystems and components. At that time, DoD laboratories were responsible for spending about $4 billion, roughly 40 percent in-house and 60 percent by contract.[51] Some of the products developed by government engineers—fuzes, air-to-surface missiles, and munitions—led to working models that were delivered to industry for production. The Army and Navy performed substantial amounts of in-house development, the Air Force considerably less. Allowing laboratories to work on more important problems, the task force argued, could increase their relevance substantially. It further recommended combining laboratory resources into weapons centers that would concentrate on particular problems of conventional warfare. The Army and Navy already operated some mission-oriented laboratories, but the Air Force organized its facilities around technology areas. Although some weapons centers were created, bureaucratic resistance, underfunding, and lack of incentives hampered them. [52]

A Defense Science Board member who reviewed the services' R&D programs called the Navy program "hard to penetrate and assess," the Air Force's "best with respect to rationale and organization," and the Army's "distinctly lacking" in those qualities. In retrospect, Foster judged this appraisal to be accurate about the Navy's nonnuclear programs but not about Polaris and Poseidon, where cooperation with OSD was very good.[53]

Defense spending for RDT&E leveled off in 1965 and declined thereafter in some areas. By 1967, funding for government laboratories remained roughly constant while funding for industry declined about 26 percent.[54] Popular revulsion against the Vietnam War had a spillover effect. By mid-1967, the Defense Science Board observed "an increasing drift of the academic community away from the military."[55] The board's task force on basic research policy noted "the failure of the DoD research program to grow along with the rest of the country [and] the apparent failure of the DoD to attract young technical people to its research program in the same degree as before."[56] The latter difficulty would last as long as the war itself.


John S. Foster, Jr. (*OSD/HO*)

John S. Foster, Jr.

For over 60 years, John S. Foster was involved either directly or as an advisor in the U.S. Government defense science and technology effort. Born in New Haven, Connecticut, on 18 September 1922, he advised the 15th Air Force on radar and radar countermeasures in the Mediterranean theater of operations during World War II. In 1952, he earned a Ph.D. in physics from the University of California, Berkeley. That same year, he was employed as a division leader in experimental physics at the newly established Lawrence Radiation Laboratory at Livermore, California (later called the Lawrence Livermore National Laboratory), rising to succeed Harold Brown as the federally funded institution's director in 1961.

In 1965, Foster left Livermore to become the director of defense research and engineering (again following Brown). During his eight-year tenure as DDR&E, Foster continued his office's role in shaping U.S. plans and programs in strategic forces, missile defense, and satellite communications and warning. Additionally, in response to the Vietnam War, he oversaw the development of technologies to support that conflict, including night vision devices, laser-guided bombs, satellite communications, ceramic armor, and tactical sensors.

After leaving the DDR&E post in 1973, Foster spent more than 20 years with TRW, Inc., as a vice president in the company's Energy Systems Group, and as a member of the board of directors. During this period, he also continued his government service as a member of the President's Foreign Intelligence Advisory Board from 1973 to 1990, as both a member and chairman (1990–1993) of the Defense Science Board, and as an adviser to the administration of President George W. Bush on the U.S. nuclear stockpile.[II]

Looking back, Foster believed that selecting a good leader and providing him access to top officials made all the difference. Thus, the achievements of the Naval Ordnance Test Station at China Lake in California flowed from the leadership of physicist William B. McLean, its civilian technical director from 1954 to 1967. As Foster saw things, no other service laboratory matched its record of aggressive action.[57]

FORECAST AND HINDSIGHT

What were the major sources of innovation: sudden breakthroughs or cumulative advances? Project Forecast, initiated by Secretary of the Air Force Zuckert in March 1963, sought to determine the possible implications of recent and impending technological breakthroughs for the Air Force's mission, technological portfolio, and force structure between 1965 and 1975. General Bernard Schriever, commander of Air Force Systems Command, supervised a nine-month study by panels comprised of individuals drawn from the services, other government agencies, corporations, and universities. The panels evaluated possible innovations according to four criteria: direct usefulness, chance of success, likelihood of a major advance, and reasonable cost.[58]

In the final Forecast report, completed early in 1964, the materials panel identified five areas that promised high payoffs. First, high-strength composites from resins and boron filaments, which were 10 times stronger than steel and far less dense, could reduce platform weights by as much as 75 percent.[59] Second, dispersing oxide particles in the chemical structures of metals could raise their heat resistance as much as several hundred degrees. The other three areas involved materials for expandable structures, new families of polymers (in which small molecules combined to form larger ones with the same chemical composition), and high-strength titanium alloys. Higher operating temperatures and faster speeds on the tips of rotating machinery could lead to turbofan engines with radically reduced fuel consumption. Practically, the payoffs might be cargo planes able to carry four times the tonnage of the Air Force's C–141 transports, hypersonic airplanes flying four to eight times the speed of sound, and vertical takeoff and landing (VTOL) aircraft for strike reconnaissance and light transport. Overall, Forecast anticipated a "cascading" effect from collective gains that would create new generations of aircraft.[60]

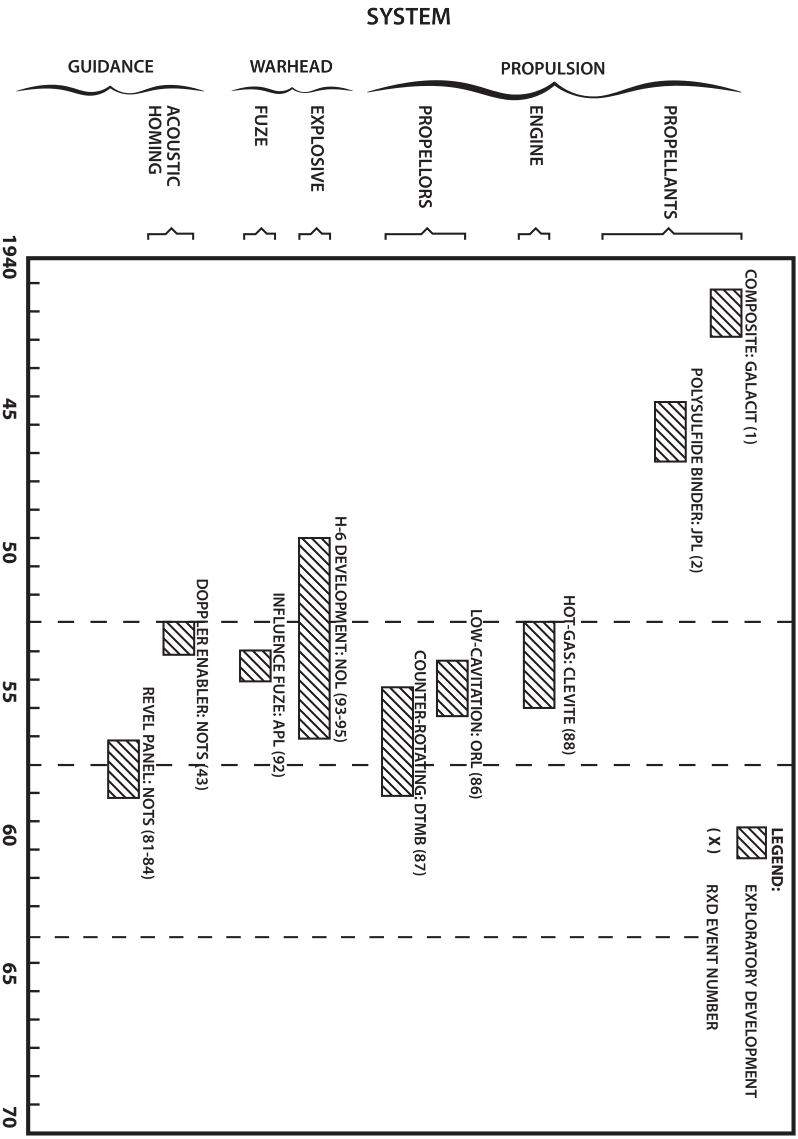
In July 1965, panel chairmen reviewed progress and gave General Schriever an optimistic assessment. The propulsion panel, for instance, reported that using boron fibers in a titanium matrix promised great improvements in engine thrust-to-weight ratios. Schriever subsequently opened a system program office for a medium-size VTOL cargo aircraft. He also felt so confident about fielding a supercargo plane that even before its engines had been fabricated or tested, he advanced the C–5A's initial operational capability from late 1971 to early 1969. Forecast's flight dynamics panel judged the C–5A to be "progressing quite well," although the level of technology being applied to its aerodynamics and structure lagged behind the propulsion concepts.[61]

Nevertheless, progress during the year following the panel chairmen's report was, in General Schriever's judgment, quite disappointing. In August 1966, the month of Schriever's retirement, a task force from Systems Command expressed concern that "with few exceptions we are fielding a force based on a technology of five or more years ago." Funding had decreased, due in part to demands of the Vietnam War; nearly all high-payoff programs had been scaled back "into lower-risk, lower-cost levels, with a rejection of any work involving more than a minimum extension beyond the state of the art." According to the task force, DoD Directive 3200.9 had imposed a "low risk" approach requiring that virtually all technology be proven before development could begin. That tended to "freeze" designs to whatever could be derived from the technology in hand when contract definition started. As a case in point, one of Forecast's strongest recommendations called for vigorously developing materials such as boron filaments. Yet applying 3200.9's procedures to the advanced materials research overseen by the newly established Advanced Filaments and Composites Division of the Air Force Materials Laboratory resulted in paring funds and stretching out deadlines. Funding for a supersonic combustion ramjet also had been cut to less than 20 percent of what the Air Force proposed, and work was redirected toward conceptual and design studies.[62]

In mid-1963, soon after the Air Force initiated Project Forecast, the Defense Science Board conceived a study to "identify features of the environment of exploratory research and early development that have led to innovation, productivity, and successful projects." The study's leaders were to select and examine a few examples of outstanding research advances to determine common features and patterns of successful management that could be adapted to other projects.[63] Early in 1964, the DDR&E's office signed a contract with the consulting firm of ADL to carry out the study. With guidance from the DSB and the staff of the DDR&E, the ADL team examined the history of six weapon systems: Mark 46 torpedo; XM 102 105mm howitzer; AGM–28 Hound Dog air-to-ground missile; Polaris SLBM; Minuteman ICBM; and Sergeant short-range, tactical surface-to-surface missile. The findings of the completed study were published in April 1965 and first summarized for the Defense Science Board on 13 May 1965.[64]

The ADL study analyzed scores of "events," which it defined as innovative acts that forced irreversible changes upon accepted knowledge. At the outset, many participants believed that weapon system development depended upon achieving the kinds of major breakthroughs described in Forecast. Instead, ADL analysts found only two events that constituted real breakthroughs: the invention of the transistor and the development of a high-temperature shock tube that led to advances in gas dynamics. In most cases, modest innovations interacted with and reinforced one another. As an example, the high search rate for the Mark 46 torpedo's guidance system was useful only because of the vehicle's high speed, which had been made possible by innovations in the fuel and motor. Those advances in turn affected requirements for the propeller, hydrodynamic noise reduction, and signal processing, all of which incorporated still other innovations (see figure 4–1).[65]

Figure 4-1: DISTRIBUTION OF MARK 46-0 TORPEDO RXD EVENTS BY TIME AND LOCATION



Source: Arthur D. Little, Inc., *Management Factors Affecting Research and Exploratory Development* (Cambridge, MA: Arthur D. Little, Inc., 1965).

According to ADL, a successful event typically occurred when three elements were present: an explicitly understood need, goal, or mission; a source of ideas (usually a pool of information, experience, and insight in the minds of those who could apply it); and available facilities, manpower, and funding. The "triggering" element generally occurred one or two years after the other two had joined, but "the distribution of delay time was very broad." Turning to management, a long-running tug-of-war had taken place regarding whether the government should be the servant of the contractors or vice versa. ADL judged that nearly all successes had been nourished by "adaptively organized" groups working in a "consensus-collaborative relationship" with sponsors:

> In summary, the Defense Department should abandon its claim to superior knowledge and its prerogatives for making or passing on all decisions when dealing with R&D people. The claim of superior knowledge is invalid, and good R&D people will not long tolerate the exercise of authority by outsiders whose knowledge they do not respect. . . . It is to the Defense Department's advantage to be seen as helpful cooperative servants to R&D personnel, rather than as firm-minded masters, no matter how just or fair.[66]

Chalmers W. Sherwin, the DDR&E deputy director (research and technology), informed the DSB Executive Committee at its 14 July 1965 meeting that he would shift the emphasis of the committee's effort from understanding the nature of innovation to studying how money invested in research and exploratory development could cut costs during later phases of the development process. Clearly, substantial benefits came from innovations that took place after the completion of contract definition. Such proof bolstered board members' belief that the contracting system must allow innovative work to be carried out during advanced development and beyond. Tension persisted between engineers who wanted unbridled funding and systems analysts who tried to impose financial controls on major weapon systems. Sherwin argued that tight constraints of the program package system were hampering good research and development work. Board members recognized that while the cost-effectiveness approach pursued by OSD Systems Analysis was necessary, its overly severe application might eliminate many creative proposals.[67]

Project Hindsight was the new phase of the effort to understand the nature of innovation and cost factors involved in R&D investments. Sherwin and Col. Raymond S. Isenson, USA, who then worked in the Office of the Assistant Director (Research), DDR&E, ran the project, which involved teams of DoD scientists and engineers working closely with principal contractors. An "interim" report appearing in June 1966 explored 15 systems and identified 556 events.[68]

Hindsight's most significant finding was that large changes in cost and performance flowed from "the synergistic effect of many innovations, most of them quite modest." A quantum jump in system capability typically required between 50 and 150 events. None of Hindsight's 13 teams could find "a dominant invention or discovery which by itself seemed to account for most of the performance/cost increase."[69] While the interval between a system and its predecessor averaged 13 years, only 10 percent of the events used in the system had occurred when its predecessor was designed. The C–141 transport, a particularly successful acquisition, provided a good example. Events affecting the C–141 began in 1949 with development of a titanium-aluminum-vanadium alloy used in the compressor blades of its turbofan engine. The C–141 engine's efficiency and reliability were substantially better than those of the C–130A, and its alloy blades reduced its weight and extended its life. The aircraft's operating cost per ton-mile was only 60 percent that of the turboprop C–130. Yet using steel blades in C–141 engines would have reduced cost per ton-mile by only about 1 percent. Another explanation, apparently, was needed to account for the overall increase in efficiency. The team ultimately identified more than 80 events that combined to explain the improved efficiency of the C–141.[70]

According to Sherwin and Isenson, Hindsight provided "a strong, factual demonstration that recent, mission-oriented science and technology are a good investment in the short term—the 10- to 20-year period." Nearly 80 percent of events had been funded by DoD, and some 90 percent had as their motivating target a government, predominantly military, need. While the organized body of scientific knowledge developed over the past 60 years, particularly in the physical sciences, was critical to weapons development, the impact of undirected scientific research on military technology since 1945 was surprisingly small. Among Hindsight's innovations or events, 9 percent qualified as science and 91 percent as technology.[71]

In January 1967, the Defense Science Board heard a critique of Hindsight by Andrew D. Suttle, a Texas A&M chemistry professor associated with the university's Cyclotron Institute. He judged the study to be "fairly accurate" in analyzing how the process worked from exploratory development forward but called it "wholly inadequate for drawing conclusions about the contributions of basic research." Other members agreed that its sampling methods contained conceptual flaws. All events had been assigned equal weight "somewhat questionably," and many events could have been either aggregated or subdivided with equal plausibility. Members generally agreed that there were "many important things to be gleaned from the 'Hindsight' study but that it is not the whole story."[72]

Forecast emphasized the likelihood that major breakthroughs, particularly from new composite materials, would create quantum jumps in capabilities. Hindsight, however, stressed the slower, synergistic effect from many modest innovations. The effort of building and operating a complete working system, Hindsight also found, would generate a burst of innovative activity. In fact, 37 percent of the events that occurred after engineering design had begun proved to be necessary to a system's ultimate performance.[73]

Conducted for different reasons, and with incomparable objectives and methods, Forecast and Hindsight were not considered to be competing studies during the 1960s. Yet they did offer dissimilar perspectives on the nature of technological advance. While criticism of Hindsight focused on whether the approach of the study and its research methods accurately captured how past innovations occurred, judgments on Forecast could consider whether its predictions on technology came to fruition. Some major advances did follow the pattern Forecast anticipated. With improvements in inertial guidance and missile accuracy, yields from nuclear warheads could be reduced. This provided the impetus for reshaping the Single Integrated Operational Plan during 1972–1974.[74] Yet several of Forecast's projected innovations did not occur as predicted or within the timeframe expected. Neither hypersonic nor VTOL aircraft had entered the inventory by 1975. The C–5A's high-bypass engine expanded thrust and surge capabilities,[75] but other troubles marred that project. Harold Brown later described attaining a circular error probable (CEP)[76] of zero—pinpoint accuracy—as "the most important goal set forth in Project Forecast."[77] Low CEPs were not achieved until the Global Positioning System, developed for quite a different reason, became fully operational in the 1990s.

In some cases, the outcome was harder to assess. John Foster, who participated in Forecast and oversaw the completion and release of Hindsight as the DDR&E, argued that the shift to composites constituted a revolution, pointing to the Air Force's B–2 stealth bomber as a system that could not have been built without broad advances in the use of composites.[78] Harold Brown noted that advances in composites came more slowly than desired, largely due to the time-consuming nature of research, development, and testing. He concluded that composites were significant, but "not as revolutionary . . . as the Forecast study had predicted."[79]

Brown, who initiated Hindsight, concluded that the process of innovation it described more accurately captured how technological changed unfolded than did the assumptions contained in Forecast. Expecting a cascade of innovation to follow a single, major conceptual breakthrough, Forecast did not acknowledge the many small innovations needed to bring new technologies to fruition. It also overlooked the role of both need and the development process in stimulating technological advance. In recognizing the importance of integrating existing technologies while at the same time generating new innovations for systems under development, Hindsight, Brown claimed, more accurately captured the complexities of weapons innovation.[80] The implication of Hindsight was that innovation could not be confined to singular acts of conceptual genius. Nor was it realistic to expect the development of new weapons to proceed in an orderly fashion given the high percentage of innovations and adjustments typically required after engineering design had begun.

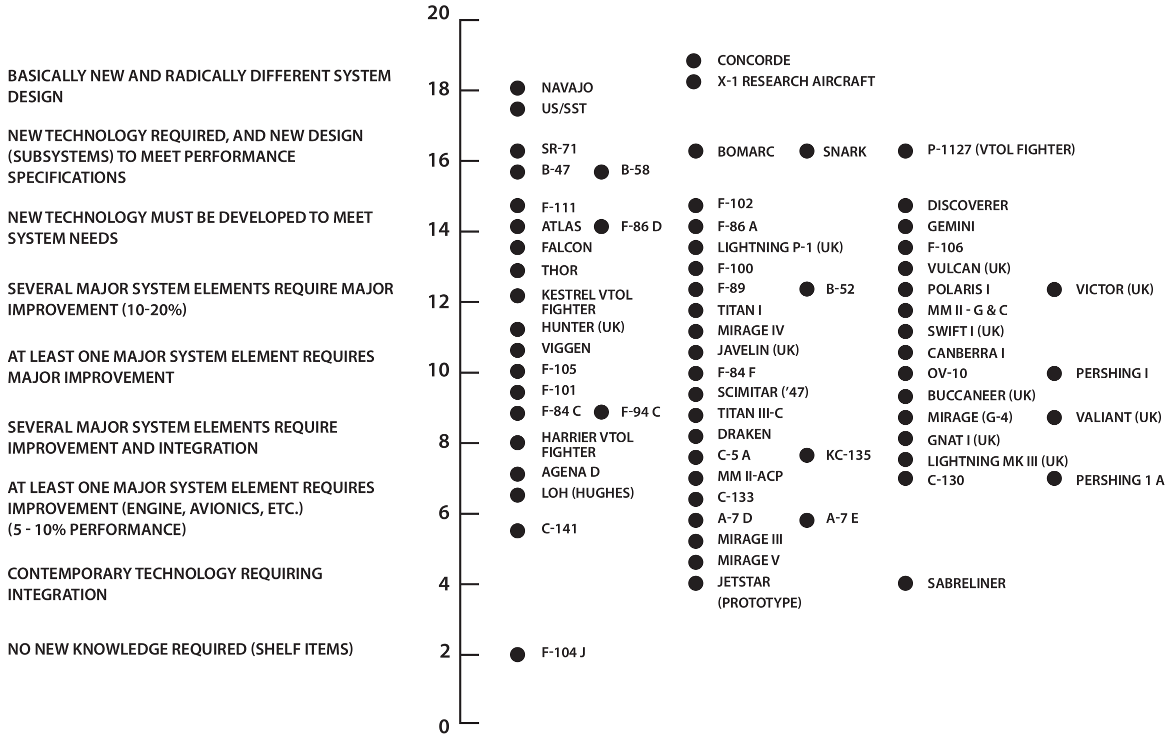
* * * * *

Air Force Systems Command fretted that the consequences of pursuing what it deemed "low-risk" programs favored by OSD would mean either fielding inferior equipment or inviting another Sputnik-like surprise.[81] Soon after McNamara left office, critics charged that his tenure had been "sterile" with respect to weapon system development. According to the President's Blue Ribbon Defense Panel (1969–1970), McNamara used contract definition to avoid investing in new weapons. The panel stated that although four strategic offensive systems were started, Minuteman II and Polaris A–3 amounted to advanced versions of earlier systems while the FB–111 and the short-range attack missile faced serious technical difficulties. Two tank programs had begun, but the Main Battle Tank–70 was more than five years behind schedule, and the other, the M60A1E2, was "simply a re-turreted version of the 1960 M60A1." The sole new torpedo, the Mark 48, faced significant technical difficulties and experienced a $3 billion cost overrun.[82]

From a longer perspective, though, the charge of stifling high-risk, high-payoff projects seems unjustified. For example, Forecast emphasized a program that would lower the CEP of ICBMs from 1.0 to 0.1 nautical miles. In response, the Air Force formulated a "Self-aligning Boost and Re-entry" (SABRE) guidance technique and deemed it ideally suited for maneuvering reentry vehicles. In 1964, OSD disapproved developing a hardened computer and flight testing the system. It allowed nothing but the testing of inertial guidance instruments and measurement units, thereby eliminating the possibility of retrofitting SABRE into Minuteman. Nonetheless, as General Schriever acknowledged years later, major improvements in missile accuracy did occur.[83]

What, in fact, constituted a "new" system? After reviewing 21 weapon systems spanning the 1950s through the 1960s,[84] RAND analysts concluded that outcomes deviated less from predictions during the 1960s because "lower technological advances and shorter programs were characteristic of that decade. . . . But for programs of comparable length and technical difficulty, differences in [the cost, schedule, and technical performance] of program outcomes are not statistically significant." Obviously, they reasoned, the main result of McNamara's reforms was to weed out some higher risk programs.[85]

Figure 4-2: TECHNOLOGICAL ADVANCE RATINGS



Source: Robert Perry et al., *System Acquisition Strategies*, report R–733–PR/ARPA (Santa Monica, CA: RAND, June 1971), 13.

RAND analysts also prepared a chart (see figure 4–2) rating the technological advances incorporated into weapon systems. But the chart actually revealed the difficulty—and perhaps the impossibility, absent an accepted methodology—of making such ratings. Why, for example, was Atlas placed higher on the scale than Polaris? Was the Minuteman guidance and control system given a mid-range rating because, from a performance standpoint, it proved to be successful? The technological obstacles, in fact, had been daunting. The chart rated the B–47 and the B–58 strategic bombers the same, yet Secretary of the Air Force Zuckert claimed that the B–58 presented a much greater development challenge. RAND's ratings placed the C–141 and the C–5A not far apart, a judgment that the C–141's smooth development compared to the C–5A's succession of problems renders questionable. Repeatedly during the 1960s, as documented throughout this book, a contractor or a service would rate a proposed weapon system as being within the state of the art, only to be proven wrong after experience with the system accumulated.[86]

RAND analysts found that, despite determined efforts, recent programs had incurred cost, schedule, and technical system performance difficulties "not greatly different from those of the 1950s."[87] They did not, however, draw the clear inference that the scale of technological advances must have been as great in the 1960s as it had been in the 1950s. If McNamara really had preferred low-risk programs, fixed-price incentive contracts would have been far more successful. Instead, "unanticipated unknowns" compelled constant changes that often made fixed-price targets unattainable and incentives irrelevant.

Endnotes

1. Hudson B. Drake, "Major DoD Procurements at War with Reality," *Harvard Business Review* 48, no. 1 (January-February 1970): 119, 126 (quotation, 124–125).

2. Ibid., 135, 138.

3. Harbridge House, *DoD Incentive Contracting Guide*, 3, NDU Library.

4. Livingston, "Decision Making in Weapons Development," 127, 129.

5. Michael E. Brown, *Flying Blind* (Ithaca, NY: Cornell University Press, 1992), 17–18.

6. Converse, *Rearming for the Cold War,* 177–186, 232–233, 239–241, 359–368, 404, 556–558, 651–652.

7. B.H. Klein, W.H. Meckling, and E.G. Mesthene, *Military Research and Development Policies*, report R–333 (Santa Monica, CA: RAND, 4 Dec 58), 3, 8 (quotation), 9, 10, 13–19.

8. ODDR&E, Summary Agenda, 12th Meeting of the DSB, 13 May 59; Minutes, 12th Meeting of the DSB, 13 May 59, 8 Jun 59, 7, both in box 835, OSD/HO.

9. Glen R. Asner, "The Cold War and American Industrial Research," Ph.D. diss., Carnegie Mellon University, 2006, 273, 275–276. In October 1966, Secretary McNamara directed that bid and proposal (B&P) costs be managed separately from IR&D costs. During 1966, DoD paid $227 million for IR&D and $204 million for B&P. Over the long term, it was hoped, added controls would arrest the trend of steep increases. Memo, Asst SecDef (I&L) Ignatius to Dep DDR&E Larsen, "Independent R&D Costs and Bid and Proposal Costs," 3 Jul 67; memo, Asst Sec Ignatius to Sec McNamara, "Independent R&D Costs and Bid and Proposal

Costs," 22 Jul 67, both in fldr 160–Contracts, box 9, 70–A–3493, RG 330, WNRC.

10. Minutes, 17th Meeting of the DSB, 29–30 Sep 60, 1 Nov 60, tab C, 8–9, box 835, OSD/HO.

11. Converse, *Rearming for the Cold War*, 472–473, 478, 502–503, 519 fn190.

12. *FRUS 1958–1960*, vol. 3, 360–361 (Kistiakowsky quotation, 361); Jacob Neufeld, *Ballistic Missiles in the United States Air Force, 1945–1960* (Washington, DC: Office of Air Force History, 1990), 216 ("no deployed" quotation); Johnson, *Culture of Innovation*, 92.

13. Bernard C. Nalty, *USAF Ballistic Missile Programs 1962–1964* (Washington, DC: USAF Historical Division Liaison Office, April 1966), 33 (quotation); and "Gen. Phillips' Notes, SPO School, Jan '63," and "Notes from 6 May '63 Presentation to SPO Class," both in fldr 6, box 37, Phillips Papers, LC.

14. Neufeld, *Ballistic Missiles in the United States Air Force*, 217; Johnson, *Culture of Innovation*, 198–199, 203–206, 96–97, 101; Air Force Regulations 375–1, 375–2, 375–3, and 375–4, revisions of 12 Feb 62, fldr 7, box 37, Phillips Papers, LC. Minuteman did in fact show cost growth, as chapter VIII explains. Whether staying within a new, higher ceiling constituted "coming in at cost" is debatable.

15. Historical Branch, Rock Island Arsenal, *Project Management of the Davy Crockett Weapon System, 1958–1962* (Rock Island, IL: Headquarters, U.S. Army Weapons Command, October 1964), 3–12.

16. Ibid., 34. A spigot cylinder was loaded into the muzzle of the weapon while an atomic round was held at the muzzle by stud attachments at the foremost end of the cylinder. The spigot served as a piston once the weapon was fired.

17. Ibid., 16–17, 49. On the Army testing system, see Sammy J. Cannon et al., *Army Test and Evaluation Revisited: An Appraisal of the Present System* (Carlisle Barracks, PA: U.S. Army War College, 10 Jun 74).

18. *Department of Defense Annual Report for FY 1967*, 157.

19. Neufeld, *Ballistic Missiles in the United States Air Force*, 201, 219–220.

20. House, Cte on Govt Ops, *System Development and Management*, 87 Cong, 1 sess, pt 2, 465–466.

21. B.H. Klein, T.K. Glennan, Jr., and G.H. Shubert, *The Role of Prototypes in Development*, RAND Memo RM–3467–PR, Feb 63, in Senate, Cte on Govt Ops, Hearings, *TFX Contract Investigation*, 88 Cong, 1 sess, 1105–1115.

22. Ibid. The F–102's troubles are described in Knaack, *Post–World War II Bombers*, 162–167.

23. Senate, *TFX Contract Investigation*, pt 8, 2229–2230.

24. *FRUS 1964–1968*, vol. 10, 496.

25. ODDR&E, "Some Problems in Military R and D," 21 Sep 60, 1, 14–15, 7–10, 17, box 834, OSD/HO.

26. Ibid.

27. House, Cte on Armed Svcs, *Hearings on Military Posture*, 90 Cong, 2 sess, 8880–8881.

28. The C–5A example comes from email, Enthoven to Poole, 5 Aug 04. The fighter and module examples come from the Harold Brown interview, 4–5. Because the program's annual budget was a lump sum, aircraft engines developed under the guise of component improvement were shielded from congressional staff scrutiny and inquiry at open hearings. Robert W. Drewes, *The Air Force and the Great Engine War* (Washington, DC: NDU Press, 1987), 92–93.

29. Richard A. Stubbing, "Improving the Acquisition Process for High Risk Electronic Systems," in *Congressional Record*, vol. 115, pt 3, 91 Cong, 1 sess, 3171–3176 (quotation, 3176).

30. Edward C. Mishler, *The A–X Specialized Close Air Support Aircraft: Origins and Concept Phase, 1961–1970* (Andrews AFB, MD: Office of History, Headquarters, Air Force Systems Command, 1977), 73 (quotations).

31. Knaack, *Post–World War II Bombers*, 238, fn 32; memo, John McLucas to Eugene Fubini, "ILAAS–Mark II Coordination," 10 Apr 64, black binder, box 2, 78–0003, RG 330,

WNRC; Coulam, *Illusions of Choice*, 127–129.

32. A Mark II contained seven major components: Autonetics's Inertial Navigation Set and Attack Radar; IBM's computer; converter and panels; the Norden Company's Integrated Display Set; Doppler radar; Horizontal Situation Display; and Stores Management Set. Knaack, *Post–World War II Bombers*, 253 fn 89. Astronautics Corporation of America would develop the Horizontal Situation Display, about the size of a small radar screen, showing the pilot the aircraft's position at every second. Under a tiny aircraft silhouette, a map would move in any direction as the silhouette continued to show the aircraft's actual location and heading. The IBM computer, recording the aircraft's location, speed, and altitude, would move the map. The Doppler processing system, contained in the Autonetics radar, would create a completely new capability to strike moving targets automatically. It did so by eliminating all fixed targets from the display, leaving only those in motion and tracking them wherever they went. Claude Witze, "The F–111's Mark II Avionics System," *Air Force/Space Digest* 52, no. 8 (August 1969): 63–65; "Mark II Avionics: Briefing to PSAC," 16 Oct 68, black binder, box 2, 78–0003, RG 330, WNRC.

33. Ibid. Purchase Agreement 181 established a baseline for performance rather than design specifications for individual end items. Later, Autonetics would claim that the contract definition phase did not establish a baseline for design. Autonetics had agreed, however, to develop and produce the Mark II according to its own baseline for performance, incorporating whatever changes the periodic deficiency reports showed to be necessary

34. William W. George, OASD Comptroller, report, "An Analysis of the Mark II Program," 17 May 68, 3–5, black binder, box 2, 78–0003, RG 330, WNRC. George's report is distinguished by its analytical objectivity.

35. Ibid., 5–10; ltr, SecAF Brown to SecDef McNamara, "Mark II Avionics Program," 4 May 67, black binder, box 2, 78–0003, RG 330, WNRC.

36. George, "Analysis of the Mark II Program," 17–23. As examples, the cost of attack radars rose from $24.1 million in June 1966 to $91.6 million in March 1967 because of airframe limitations and redesigns to meet performance specifications. The cost of inertial navigation sets went from $21.8 million to $51.6 million because platforms had to be redesigned.

37. Ibid.

38. Chapter VIII relates how, in 1958, Autonetics grossly underestimated the cost of a guidance system for Minuteman I. The Air Force's estimate was better but was still too low.

39. George, "Analysis of the Mark II Program," 27–33.

40. Knaack, *Post–World War II Bombers*, 245 fn 61.

41. Memo, Charles A. Fowler to Sec Brown and Dr. Foster, "Mk II," 19 Sep 68, black binder, box 2, 78–0003, RG 330, WNRC.

42. Knaack, *Post–World War II Bombers*, 233, 240.

43. The Integrated Display Set, comprising the primary flight-control instrumentation, included five units, each replaceable: a vertical situation display, a multi-sensor display, a signal transfer unit, and two head-up display units. Knaack, *Post–World War II Bombers*, 255 fn 97.

44. Ibid., 252–253, 255 fn 98 (quotation), 256. The last and most successful model, the F–111F, carried a Mark II without Doppler radar.

45. Michael Wilson, ed., *Jane's Avionics: 1982–1983* (London: Jane's Information Group, 1982), 28.

46. "Report to the President on Government Contracting for Research and Development, April 30, 1962 (Bell Report)," printed in House, Cte on Science and Astronautics, *Utilization of Federal Laboratories*, 90 Cong, 2 sess, 339–367 (quotations, 339, 341). Secretary McNamara was among the agency heads who concurred with these findings.

47. Booz, Allen & Hamilton, Inc., *Review of Navy R&D Management, 1946–1973*, vol. I (Washington, DC: Department of the Navy, 1976), 145–150; Minutes, Exec Cte, DSB, 10 Mar 65, box 837, OSD/HO. Earlier, the board rejected the Bell Report's idea of creating a "Government Institute" overseeing research and development.

48. House, *Utilization of Federal Laboratories*, 407–409, 425–426; Booz, Allen & Hamilton, *Review of Navy R&D Management*, 150–151; Minutes, Exec Cte, DSB, 16 Feb and 17 Mar 66, Box 837, OSD/HO; E.M. Glass, "DoD Laboratories in the Future," Management Analysis Memorandum 67–3, Office for Laboratory Management, ODDR&E, Washington, DC; W.S. Poole, notes on conversation (face-to-face meeting) with Dr. John S. Foster, Jr., 3 Oct 07.

49. Booz, Allen & Hamilton, *Review of Navy R&D Management*, 150–151; Minutes, Exec Cte, DSB, 16 Feb and 17 Mar 66, Box 837, OSD/HO; E.M. Glass, "DoD Laboratories in the Future," Management Analysis Memorandum 67–3, Office for Laboratory Management, ODDR&E, Washington, DC.

50. Minutes, 36th Meeting of the DSB, 15 Sep 66, 2–3, box 836, OSD/HO; ODDR&E, "First Interim Report on Project Hindsight (Summary), 30 Jun 66 (Rev. 13 Oct 66)," 6 (quotation), box 864, OSD/HO.

51. *History of Air Force Systems Command, 1 July 1966–30 June 1967*, vol. I, 132, microfilm roll 2852, AFHSO. A study by the Defense Science Board in November 1966 recommended that the ASPR give better guidance regarding the types of contracts to select for the several categories of R&D. Among other things, guidance should stress the importance of determining in advance whether technical objectives were measurable, and ascertaining the degree of inherent risk, as reflected by the technical uncertainties. House Cte on Govt Ops, *Government Procurement and Contracting*, 91 Cong, 1 sess, pt 4, 1131. No changes resulted. Asner, "Cold War and American Industrial Research," 331–336.

52. Arthur D. Little, Inc., *Management Factors Affecting Research and Exploratory Development* (Cambridge, MA: Arthur D. Little, Inc., 1965), I–9; Report by the DSB Task Force, "DoD In-House Laboratories," 31 Oct 66, printed in House, *Utilization of Federal Laboratories*, 410–411, 413, 422–423; Booz, Allen & Hamilton, *Review of Navy R&D Management*, 156–162.

53. Minutes, Exec Cte, DSB, 14 Jun 66, 7, box 837, OSD/HO; Poole, notes on conversation with Foster, 3 Oct 07.

54. Draft for Comment Memo for the President, "Recommended FY 69–73 R and D Program," 22 Sep 67, 6–1, 6–2, 6–7, box 330, OSD/HO.

55. Minutes, 38th Meeting of the DSB, 11 May 67, 7, box 836, OSD/HO.

56. Minutes, Exec Cte, DSB, 13 Sep 67, 2, box 837, OSD/HO.

57. Poole, notes on conversation with Foster, 3 Oct 07. McLean's signal achievement was the Sidewinder air-to-air missile, which performed markedly better than the Falcon and Sparrow missiles developed by industry. For the Sidewinder and McLean's role, see Ron Westrum, *Sidewinder: Creative Missile Development at China Lake* (Annapolis, MD: Naval Institute Press, 1999).

58. Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944–1986* (Washington, DC: AFHSO, 1988), 96–102, 107–111; "USAF Project Forecast, Materials Report," January 1964, viii, microfilm roll 35269, AFHSO; R.F. Futrell, *Ideas, Concepts, Doctrine* (Maxwell AFB, AL: Air University Press, 1989), 230.

59. The Advanced Research Projects Agency had been funding universities' exploration of composite materials.

60. Gorn, *Harnessing the Genie*, 96–102, 107–111; Brig. Gen. Charles Terhune, USAF, "Organization and Mission Planning Group Report," 13 Apr 63, microfilm roll 35271, and "USAF Project Forecast, Materials Report," viii, both AFHSO; Futrell, *Ideas, Concepts, Doctrine*, 230.

61. Gorn, *Harnessing the Genie*, 112; "Project Forecast Technology Panel Review," 15–16 Jul 65; "Review of Propulsion Panel, Project Forecast," 16 Jul 65; "Rpt to Gen. Schriever on Activity Related to Project Forecast, Flight Dynamics Panel," 16 Jul 65 (quotation), the last three on microfilm roll 35271, AFHSO.

62. AFSC Task Force rpt, "Technological Program Trends," Aug 66, microfilm roll

35272, AFHSO (quotations); Gorn, *Harnessing the Genie*, 114.

63. Minutes, Exec Cte, DSB, 4 Sep 63, 2 (quotation) and tab A, box 837, OSD/HO.

64. Little, Inc., *Management Factors*, I–1, I–7, II–5–7, 11–19. The summary is given in tab A to Minutes, 32nd Meeting, DSB, 13 May 65, box 836, OSD/HO.

65. Ibid.

66. Minutes, Exec Cte, DSB, 4 Sep 63, box 837, OSD/HO; Little, Inc., *Management Factors*, I–1, I–7, II–5–7, II–18 to II–19 (quotations).

67. Minutes, Exec Cte, DSB, 14 Jul 65, 1–2, and 8 Sep 65, 3–4, both in box 837, OSD/HO.

68. Ibid.; ODDR&E, "First Interim Report on Project Hindsight (Summary)." Among the systems added to the original six studied by ADL were the Bullpup air-to-surface missile, Minuteman II ICBM, short-range Lance tactical ballistic missile, Mark 56 and 57 sea mines, and C–141 transport aircraft.

69. Chalmers W. Sherwin and Raymond S. Isenson, "Project Hindsight," *Science* 156, no. 3782 (23 June 1967): 1574–1575 (quotations). At the Defense Science Board meeting on 11 May 1966, Sherwin claimed that "almost nothing of what would properly be called basic new science has entered into usable military technology in the last twenty years, with solid state, electronic and information theory as notable exceptions." Minutes, Exec Cte, DSB, 11 May 66, 4, box 837, OSD/HO.

70. ODDR&E, "First Interim Report on Project Hindsight (Summary)," 2, 4, 5, 11, 13.

71. Sherwin and Isenson, "Project Hindsight," 1575–1577 (quotation, 1576). The final report appeared in October 1969. Public accounts of the report, on which the above paragraphs draw heavily, are Chalmers W. Sherwin, "How Do Weapon Systems Get Born?—Project Hindsight Seeks Answers," *Air Force Monthly* (June 1966): 115–118, and Sherwin and Raymond S. Isenson, "Project Hindsight," *Science* 156, no. 3782 (23 June 1967): 1571–1577.

72. Minutes, 37th Meeting, DSB, 12 Jan 67, 9–10, box 836, OSD/HO. Project Traces, a study commissioned by the National Science Foundation that explored the development of commercial technologies and generalized research tools, also challenged Hindsight. Project Traces found that an average of 70 percent of all research events leading to innovations occurred in the context of undirected research. Asner, "The Cold War and American Industrial Research," 317.

73. ODDR&E, "First Interim Report on Project Hindsight (Summary)," 11.

74. Interview, Brown by Moody and Poole, 28 Jan 04, 5–6; Poole, notes on conversation with Foster, 3 Oct 07, CMH.

75. Gorn, *Harnessing the Genie*, 115.

76. The CEP denotes the length of the radius inscribing a circle within which one-half of the weapons targeted for the center of the circle will likely impact.

77. Interview, Brown by Moody and Poole, 28 Jan 04, 5–6.

78. During 1967, an F–111 flight-tested components that used weight-saving boron fibers. By then, the Air Force Materials Laboratory was providing more than 20 aerospace firms with boron fibers free of charge in return for coordinated research programs and complete exchange of data among the participants. George S. Hunter, "Composite Materials Turning Point Seen," *Aviation Week and Space Technology* 87, no. 11 (30 October 1967): 47–49.

79. Interview, Brown by Moody and Poole, 28 Jan 04, 5–6.

80. Ibid.

81. AFSC Task Force, "Technological Program Trends," 23.

82. Blue Ribbon Defense Panel, Staff Report B–1, Annex B, "Weapon System Development during the Sixties," 12 Mar 70.

83. AFSC Task Force, "Technological Program Trends," 9–10; Gorn, *Harnessing the Genie*, 115–116.

84. The study covered cost, schedule, and performance for the following: Army Pershing I (medium [450-mile]-range) and Pershing II (intermediate [1,100-mile]-range) ballistic

missiles, and OH–6A helicopter; OV–10A observation and close support aircraft (developed in a tri-service Navy/Marine Corps/Air Force program); Navy DIFAR (Directional Frequency and Analysis Recording) sonobuoy; and Air Force F–111, C–141, C–5A, Titan III C ICBM, Minuteman II Airborne Command Post, and Minuteman II Guidance and Control. Coverage of other systems was limited to one or two of those three factors.

85. Robert Perry et al., *System Acquisition Strategies*, report R–733–PR/ARPA (Santa Monica, CA: RAND, June 1971), 14.

86. MacKenzie, *Inventing Accuracy*, 206–213.

87. Perry et al., *System Acquisition Strategies*, 40.

I. Harold Brown biography, available at <http://history.defense.gov/brown.shtml>; Harold Brown, oral interview, 20 Apr 90; Glen R. Asner, "The Linear Model, the U.S. Department of Defense, and the Golden Age of Industrial Research," in *The Science-Industry Nexus: History Policy, Implications*, ed. Karl Grandin, Nina Wormbs, and Sven Widmalm (Sagamore Beach, MA: Science History Publications, 2004), 3,15–16; Kaplan, Landa, and Drea, *The McNamara Ascendancy*, 9–10, 379, 481; and Drea, *McNamara, Clifford, and the Burdens of Vietnam*, 9–10, 520–522.

II. Press release, "Project Hindsight Report Issued by Director of Defense Research and Engineering," 7 Dec 66, and *Project Hindsight: Final Report*, October 1969 (Washington, DC: Office of the Director of Defense Research and Engineering, 1969); both in fldr "Project Hindsight, 1964–1966," box 864, OSD/HO; address by Dr. John S. Foster, Jr., to the 29th Annual Meeting of the Aviation Space Writers' Association, 18 May 67, and address by Dr. Foster to the Iron Gate Chapter, Air Force Association, 19 Sep 68, both in fldr "DoD Research 1961–1968," box 864, OSD/HO; John S. Foster, Jr., oral history interview, 19 Feb 03, OSD/HO; Appendix D, "A Brief History of the Office of the Director of Defense Research and Engineering," and Appendix F, "Reflections from a Former Director of Defense Research and Engineering," in *Defense Science Board Task Force on the Roles and Authorities of the Director of Defense Research and Engineering* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, 2005), 30; Kaplan, Landa, and Drea, *The McNamara Ascendancy*, 352; Drea, *McNamara, Clifford, and the Burdens of Vietnam*, 7, 358, 371–372; "John Foster, Jr.," biography on American Institute of Physics Web site, available at <www.aip.org/history/acap/biographies/bio.jsp?fosterj> (accessed 25 Jul 12); and "John S. Foster, Jr.," biography on California Council on Science and Technology Web site, available at <www.ccst.us/ccstinfo/fellows/bios/foster.php> (accessed 26 Jul 12).

CHAPTER V

The Army Re-equips Itself

In 1961, the Army's role in national strategy expanded. Shifting from massive retaliation to flexible response required, at one end of the spectrum, contributing sufficient conventional forces to allow a nonnuclear defense of Western Europe and, at the other, creating enough counterinsurgency capability to help defeat communist "liberation" movements in Third World countries. The number of combat-ready divisions rose from 11 to 16 during 1961. Starting in 1965, the worsening situation in South Vietnam brought a large influx of new units, raising the Army's active strength to 19 divisions and more than 1.5 million soldiers by 1968 from the post–Korean War low of just over 850,000 in 1961.[1]

The Kennedy administration inherited pentomic divisions, which were tailored for tactical nuclear battlefields and built around five battlegroups of 1,350 soldiers each. To meet the requirements of flexible response, the Army eliminated the pentomic divisions and brought back its traditional combat battalions, about 10 per division. The old regimental commands were replaced by three brigade headquarters per division, each capable of controlling a variable number of battalions. Known as Reorganization Objective Army Division (ROAD), the new division structure retained pentomic flexibility but made the battalion the tactical and training building block of the field army.[2]

Concurrently, equipment allocations for the Army rose to $2.5 billion for FY 1963—twice the average for FYs 1956–1960—and reached $3.3 billion in FY 1964. Although a ROAD infantry division had only 2 percent more personnel than an augmented pentomic division, the increase in combat power was ultimately "profound" as new weapon systems entered the inventory. During the 1960s, combat units were almost completely re-equipped, more often as the result of compelling events than of deliberate design. Nevertheless, the end results were impressive.[3]

THE ARMY MATERIEL COMMAND

In developing weapon systems during the decade and a half after World War II, the Army's main organizational issue was whether to bolster R&D by separating it from production and supply. Arguing for separation, civilian scientists inside and outside the Army, as well as some uniformed officers, achieved major victories in 1955. In that year, the secretary of the Army created the position of director of research and development in his office, making it organizationally equivalent to the four existing assistant secretary posts (the statutory limit). He also approved establishment of the Office of the Chief of Research and Development on the Army staff, headed by a three-star officer and independent of and equal to the three existing deputy chiefs of staff. On the Army staff, however, the transformation was incomplete. The deputy chief of staff for logistics (DCSLOG) continued to oversee the seven technical services (Chemical, Engineers, Medical, Ordnance, Quartermaster, Signal, and Transportation) that did most of the actual R&D work. Moreover, the chief of R&D had little or no say about placing personnel in responsible positions within those services. In sum, as of 1959, the Army's approach to weapons development consisted of a "loose-jointed arrangement" among the technical services, several elements at Army headquarters, and the Continental Army Command, which had its own Materiel Development Section. Inevitably, coordination and concurrences consumed enormous amounts of time.[4]

Starting in 1960, the chief of research and development gained control from the DCSLOG over the technical services' R&D budgets and personnel, although each service chief could reprogram other funds allocated to him. The DCSLOG remained the principal channel of command between the Army staff and the technical services, but with diminished authority.[5]

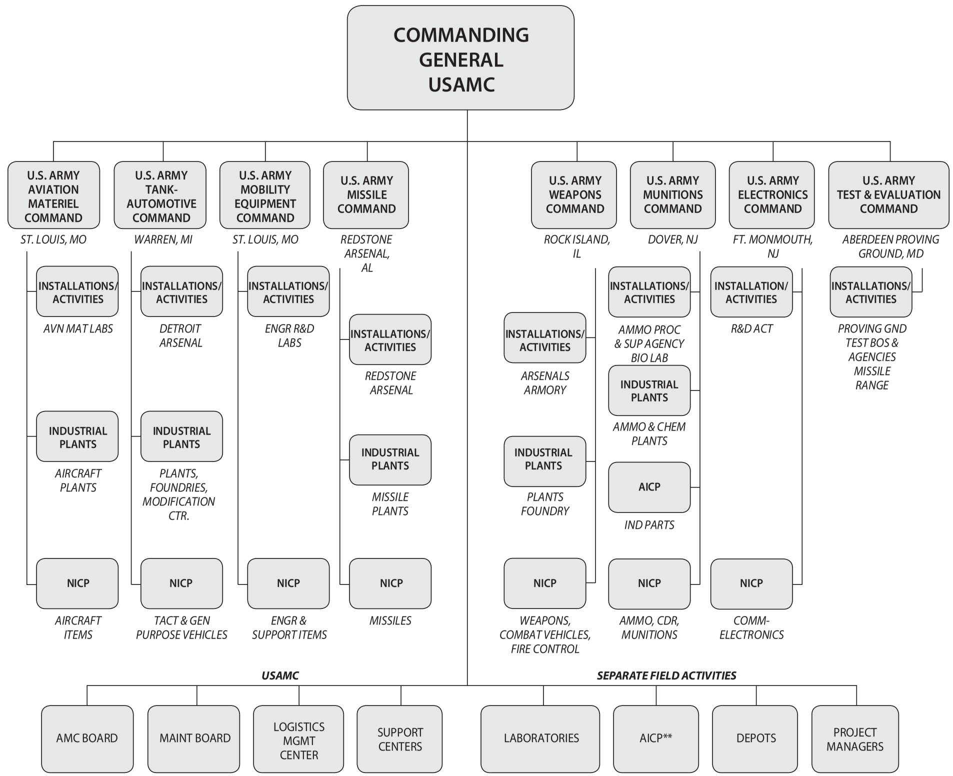
Fulfilling the expanded requirements of flexible response required speed and ingenuity in Army acquisition. Army Regulation 11–25 (Reduction of Lead Time), issued in September 1961, set a goal of cutting the time from project initiation to production rollout to four years or less.[6] But the Army's cumbersome acquisition structure worked against this objective. Although the DCSLOG bore responsibility for melding the technical services into an integrated logistical system, they remained nearly self-sufficient entities, leaving the Army with something akin to seven separate supply systems. Moreover, the technical services were focused on developing and providing particular commodities at a time when complete weapon systems increasingly cut across the jurisdictions of two or more of them. With respect to Army aircraft, for example, the Transportation Corps was responsible for airframes, the Signal Corps for electronic gear, and the Ordnance Corps for armament. Project 80, a study of the Army's functions, organization, and procedures commissioned by Secretary McNamara early in 1961, was expected to address the role of the technical services.[7]

The Army responded to Project 80 through a committee led by its deputy comptroller, Leonard W. Hoelscher. The chief of staff, General George H. Decker, saw this as a chance to promote change. In October 1961, the Hoelscher committee recommended organizing the technical services around functions to be performed rather than commodities to be provided. It further proposed creating a Systems and Materiel Command (eventually designated the Army Materiel Command), believing the organizational separation of R&D from production to be unwise and impractical. Not surprisingly, several chiefs of the technical services objected to almost any reorganization. Lt. Gen. John H. Hinrichs, chief of ordnance, was particularly outspoken, but the Ordnance Corps's poor performance with several recent projects eroded his credibility in McNamara's eyes. So when the secretary of the Army deferred reorganization pending further study, McNamara took it upon himself to move matters forward.[8]

On 10 January 1962, McNamara abolished the statutory positions of the technical service chiefs, subject to congressional approval; absent formal objections in Congress, the order became effective on 17 February. Dissatisfied with vague Army plans to activate a new logistics command gradually by March 1963, he insisted on a faster timetable. Consequently, the Army Materiel Command (AMC) became fully operational on 1 August 1962. Lt. Gen. Frank S. Besson, Jr., who as chief of transportation had strongly endorsed the Hoelscher committee's recommendations, was appointed commanding general. Promoted to four-star rank in May 1964, Besson would remain at the post until March 1969.[9]

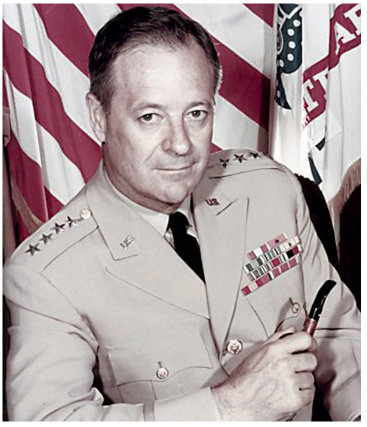
Located near the Pentagon, AMC provided command supervision over materiel from development through production to supply and for the duration of its life in the inventory. As commanding general, Besson's principal responsibilities were to acquire new weapons for the service; to create and operate a single, integrated Army supply system; and to assure through test and evaluation that equipment performed effectively before entering the inventory. AMC headquarters was organized functionally with five major staff divisions: research and development, procurement and production, materiel readiness, personnel and training, and installations and services. Initially, AMC controlled five subordinate commodity commands (Electronics, Missile, Mobility, Munitions, and Weapons) and two functional commands (Supply and Maintenance, and Test and Evaluation) (see figure 5–1). During his tenure, General Besson implemented two major organizational changes. In 1966–1967, the Supply and Maintenance Command was merged with AMC headquarters, and the Mobility Command was dissolved and divided into three major subordinate commands: Aviation, Mobility Equipment, and Tank-Automotive.[10]

Figure 5-1: UNITED STATES ARMY MATERIEL COMMAND



* NATIONAL INVENTORY CONTROL POINTS
** ARMY INVENTORY CONTROL POINTS

Source: Stuart J. Evans, Harold J. Margulis, and Harry B. Yoshpe, *Procurement* (Washington, DC: Industrial College of the Armed Forces, 1968), 40.



General Frank S. Besson, Jr. (*OSD/HO*)

General Frank S. Besson, Jr. (1910–1985)

Frank Besson, Jr., was born in Detroit, Michigan, on 30 May 1910. He graduated from West Point in 1932 and earned a master's degree from MIT in 1935. Assigned to the Engineer Board at Fort Belvoir, Virginia, in 1940, First Lieutenant Besson developed new equipment to support combat operations. During World War II, he rose rapidly in rank. By 1944, he was a brigadier general and director of the Third Military Railway Service in Iran. Near the end of the war, he became the Army's deputy chief transportation officer in the Western Pacific. Following service in a series of logistics posts after the war, Besson was named the Army's chief of transportation in 1958.

In an effort to make the Army more efficient, early in 1961 Secretary of Defense McNamara ordered a study of the service's functions, organization, and procedures, termed Project 80. Among other initiatives, the resulting report recommended the creation of a centralized logistics command to replace the Army's technical services. Lieutenant General Besson, who favored the centralization of Army acquisition functions, was selected to be commanding general of the new Army Materiel Command, which became operational on 1 August 1962. As AMC commander, Besson controlled a budget that exceeded $14 billion annually, an inventory valued at $23.5 billion, some 250 installations and activities, and 186,000 personnel, about 22,000 of them uniformed military.

Headquartered near the Pentagon, AMC supervised research and development, procurement and production, storage and distribution, and maintenance and disposal. To carry out these activities, the command was organized initially into five commodity and two functional subordinate commands. With respect to the acquisition of major weapon systems, General Besson greatly expanded the use of the project management organizational form.

In 1964, Besson became the first Army officer to become a four-star general as the head of a logistical organization during peacetime. He retired from the service in 1970 and was nominated by President Nixon to be one of the founding directors of the National Rail Passenger Corporation, which operated Amtrak.[1]

While AMC headquarters and the headquarters of its subordinate commands were organized along traditional horizontal and functional lines, AMC also employed the vertical project-management structure for its major weapon systems that was used in both industry and the other services, especially in the Air Force. In this organizational arrangement, a single individual (the project manager) was responsible for a system's development, production, and deployment. In 1961, Secretary McNamara had directed the Army to employ the project manager form. When AMC became operational in August 1962, 13 systems—including the M–14 rifle, the M60 tank, the Shillelagh and Mauler missiles, and the Mohawk surveillance aircraft—were under project managers. General Besson greatly expanded their use. By October 1962, 30 project managers had been appointed; 12 reported directly to Besson, and each of the others could bypass their immediate superiors to put their problems directly before him. By 1965, there were 41 project managers, 17 reporting directly to Besson; in 1968, the total exceeded 60.[11]

What did creating AMC accomplish? Improving efficiency through centralization was a public justification. An unstated reason was to break up the technical services that some likened to medieval fiefdoms. Whether AMC achieved either aim remains debatable. In the 1970s, some high officials viewed AMC as essentially the Ordnance Corps writ large. One of Besson's successors believed that the breakup destroyed the technical, albeit parochial, training given by each corps. Conversely, during the Vietnam War, AMC could take credit for the generally ample flow of materiel to fighting forces. [12]

Two other organizational changes affected the Army's acquisition process. The first was the creation in 1962 of a separate Combat Developments Command (CDC) that took over some responsibilities borne by the Continental Army Command. Here, too, recommendations by the Hoelscher committee helped spur change. The CDC formulated tactical doctrine and determined the necessary types of forces and materiel. In formulating requirements, the CDC prepared either a "Qualitative Materiel Requirement" that stayed within state-of-the-art technology or a "Qualitative Development Objective" that advanced it. If the Army staff approved, the requirement or objective would be appraised by a committee consisting of the deputy chiefs of staff for operations and logistics and the chief of R&D. The committee identified funds and approved initiating development, at which point responsibility passed to AMC.[13] The second organizational change created, in 1963, an assistant chief of staff for force development (ACSFOR) with responsibility for Army aviation; chemical, biological, and radiological operations; nuclear and air defense; and tactical mobility.[14]

As will be illustrated later in the chapter, creating ACSFOR and CDC and replacing the technical services with Army Materiel Command helped to systematize and accelerate acquisition. Nonetheless, setting requirements and developing weapon systems remained in many respects a "loose-jointed arrangement." Examination of the acquisition of Army weapons ranging from rifles to tanks and helicopters provides insight into the operation of these extensive organizational changes.

CHOOSING A RIFLE: M–14 VERSUS AR–15

Determining the attributes for a new rifle, the Army's iconic weapon since its founding, sparked a clash between innovation and tradition. The publication of S.L.A. Marshall's *Men Against Fire* in 1947[15] challenged the Army's historic emphasis on long-range, single-shot marksmanship. Marshall argued that automatic weapons fire had proven to be most effective in U.S. Army infantry actions in World War II. During the 1950s, trials run by the Operations Research Office (ORO), a civilian research center managed by Johns Hopkins University under an Army contract, reinforced Marshall's conclusion, highlighting the effectiveness of area fire from multishot bursts at 150 meters or less. Rapidly building up suppressive fire was seen as the best way for small units to gain battlefield superiority. Trials showed that simple aimed shots failed to deliver more lethal hits than sprayed bursts. These findings suggested that the Army's insistence on having full-power, long-range small arms rested on flawed assumptions. Likewise, the value of a rifle that performed better when firing semiautomatic than fully automatic was open to question.[16] Introduction in 1951 of the Soviet AK–47 assault rifle, which enabled infantrymen to deliver a large volume of fire rapidly at close range, provided an additional justification for giving American soldiers a comparable capability.[17]

Yet technological conservatism and development difficulties slowed the Army's efforts to acquire a reliable automatic weapon. In May 1957, the secretary of the Army announced that the M–14 rifle developed by the service's Springfield Armory in Massachusetts would replace M–1s, carbines, and Browning automatic rifles currently in use. His decision represented a victory for doctrinal, fiscal, and technological conservatism, as well as efficiency, since M–14s could be fabricated using M–1 production tooling. Critics called the M–14 merely an improved M–1 that took almost no account of ORO's findings. Advocates countered that the M–14 was much more reliable, had a 20-round magazine versus the M–1's 8-round clip, and used NATO's lighter, standard 7.62mm cartridge. The M–14, unlike the M–1, could deliver fully automatic as well as semiautomatic fire if equipped with the appropriate selector switch. But that version of the weapon would be issued to only two men per squad, forestalling waste and shortages of ammunition.[18]

Initial problems with producing M–14s reached almost scandalous proportions. Engineers at the Springfield Armory failed to prepare final production drawings before mass manufacturing began. Such work, termed an "industrial engineering package," would have provided the specifications needed to create the inspection procedures and fabricate the gauges needed to guarantee quality products and ensure that components were completely interchangeable. Fault for the delays rested with the Weapons Command of the Ordnance Corps, which did not authorize such a package until March 1958, allowing Springfield engineers only 6 months rather than the normal 12 desired to assemble data. One month later, in April 1958, Ordnance gave the Springfield Armory a work order to establish a pilot production line and deliver 15,669 M–14s in two years. The schedule allowed Springfield no time to stockpile critical materials; moreover, a four-month strike by steelworkers in 1959 left the armory without the necessary special steels. As a result, only 4,245 rifles were completed by April 1960.[19]

Meantime, the Army solicited fixed-price bids for 70,000 more M–14 rifles from commercial firms. One contract would be awarded to the low bidder, the other to a small business in a depressed area; each required the production of 35,000 M–14s. The first award went to Winchester-Western Division of the Olin Mathieson Chemical Corporation, which planned to automate production of some complex components. The Harrington and Richardson (H&R) Arms Company of Worcester, Massachusetts, won the second contract. H&R proposed to economize by rebuilding M–1 production equipment—a poor decision because the M–14 proved to be just different enough that using older equipment created production headaches. In October 1960, H&R received a fixed-price contract for an additional 70,000 M–14s, raising its total to 105,000.[20]

H&R began using multiple shifts to turn out 10,000 rifles per month. Increased production, however, met with increased rejections by Ordnance inspectors. In December 1960, several M–14 bolts and receivers (housing the rifle's other operating parts) disintegrated while they were being test fired.

Ordnance traced the cause to H&R's use of improper steel. The steel bars used to make rifle receivers had special square cross sections with rounded corners, readily recognizable by sight and touch. Although H&R had ordered its receiver stock in standard round bars, a mix-up occurred between the warehouse and the production line. Unable to identify their stock, H&R workers used the wrong bars for some receivers. In January 1961, Weapons Command suspended all commercial production for one month while tougher quality assurance controls were put in place. Meantime, the Army retested every M–14 produced by Winchester and H&R and found that 1,784 were defective. Metallurgical analysis showed that the heat treatment process applied to high-stress areas required new specifications and much tighter controls.[21]

In April 1960, Winchester won a fixed-price contract for 81,500 more M–14s, raising its total to 116,500. Besides the delays caused by changing the heat treatment, another problem identified by Winchester was that the specified steel was particularly hard to machine at the speed required for high output. More importantly, Winchester's effort to automate production of the M–14's complex receiver suffered delays. Instead of the conventional milling machines used to make M–1s, where one worker often performed one task, Winchester planned to use two multistation, transfer-type machines specially designed for the work. But this government-owned, contractor-run equipment did not start operating until April 1961, much later than Winchester had anticipated. Industry was not performing any better than the Springfield Armory.[22]

M–14 rifle manufactured at Springfield Armory in 1962 sits on pile of spent bullet casings (*Springfield Armory National Historic Site*)

Here, as in so many areas, Secretary McNamara acted forcefully. A speech by Sen. Margaret Chase Smith (R–ME) provided the catalyst. Worried about possible layoffs by Saco-Lowell Shops, a Maine subcontractor for H&R, she called for an investigation of the M–14 program.[23] Why, she asked, did the Army need more time to produce a rifle than the Air Force needed to develop and deploy the B–52 bomber? After reading her speech in the *Wall Street Journal*, McNamara created an Army-OSD investigating team to inspect production facilities. He also insisted on the prompt selection of a program manager for the M–14. The choice fell on Brig. Gen. Elmer J. ("Hoot") Gibson, then commanding the Army's Rock Island Arsenal in Illinois. Deputy Assistant Secretary of Defense for Weapons Acquisition and Industrial Readiness James Davis warned Gibson that he would either earn a second star or retire early.[24]

Testifying before a Senate subcommittee on 28 July 1961, just as East-West tensions over Berlin were escalating, Secretary McNamara called the record on M–14 production disgraceful, since manufacturing a rifle should be simpler than building a satellite or a missile system.[25] The Boston District Ordnance Office bore responsibility for the financial aspects of procuring M–14s. Looking for ways to speed production, Brigadier General Gibson and OSD officials concluded that the Boston office was more a hindrance than a help. Springfield Armory knew how to heat-treat steel selectors and achieve the needed hardness, but Boston invoked provisions in the fixed-price contract to prevent such information from being passed on to the manufacturers. Allowing contractors access to government technical information, Gibson expedited output enough that within six months, supplemental funds were needed to pay for overproduction. He won his second star.[26]

Brigadier General Gibson and the investigating team also recommended adding a third commercial source to manufacture another 100,000 rifles. Since fixed pricing had elicited unrealistically low bids, the Army decided to prohibit price renegotiation in the future but provide a $2.50 bonus for every rifle produced ahead of schedule (up to $250,000) and a similar penalty for every late delivery.[27] Hoping to win another depressed-area contract, H&R created the West Virginia Ordnance Company to assemble components made in Massachusetts. But despite pressure from Congress and the White House,[28] the Army stoutly opposed H&R on grounds of poor performance. In October 1961, the award went instead to the newly organized Ordnance Works of Thompson Ramo Wooldridge (TRW). Nevertheless, both H&R and Winchester garnered follow-on contracts.[29]

Mainly a missile and space firm, TRW planned to capitalize on its metalworking specialties and designed a plant specifically for M–14 production using the latest equipment to make the most complex components. For example, while H&R's assembly line had a large number of individual machine tools, TRW used a one-person transfer machine that performed 30 operations, replacing 15 single-point machines. Similarly, its one-person broaching machine made 15 cuts in the magazine slot of the M–14's receiver. TRW made its first delivery in October 1962, more than a month ahead of schedule; by mid-1963, its production rate reached more than 24,000 per month. TRW did not expect to make any money on this first contract, hoping that profits would come from the lower unit costs of later contracts. In October 1962, TRW won a follow-on contract for 219,691 M–14s. But that was all. Four months later, Secretary McNamara decided against any further purchases of the weapon. When output ended in 1964, deliveries totaled 1,380,346 M–14s, with Springfield having produced 167,100; Winchester, 356,501; H&R, 537,582; and TRW, 319,163.[30]

After long and often heated arguments, the M–14 gave way to a radically different model. The M–16 rifle traced its origins to the 7.62mm AR–10, created by Eugene Stoner, senior designer for ArmaLite, a division of the Fairchild Engine and Airplane Corporation. Presented to the public in 1956, the AR–10 incorporated such innovations as a steel-sheathed barrel made of aluminum alloy, fiber-filled plastic stocks, and hand guards. The stock's straight-line geometry gave better control over bursts of automatic fire, allowing weight reductions that otherwise would have lessened controllability. Work by the Army's Ballistic Research Laboratories indicated that a small-caliber, high-velocity cartridge could score the same lethality as a 7.62mm round, while reducing the weight and volume of ammunition, minimizing recoil, and improving accuracy. Project SALVO, a multiagency project run at Fort Benning, Georgia, confirmed these findings. Continental Army Command then intervened to sponsor development of a small-caliber rifle.[31]

Since the Army required an AR–10 round to penetrate a steel helmet at 500 yards, Stoner redesigned a .222 caliber Remington round, making it slightly longer and filling it with more powder. This .223 caliber round (later 5.56mm) would be fired from what had been redesignated the AR–15. Stoner later described the AR–15 as especially effective when fired at a high cyclic rate, designed to meet the combat realities revealed by Project SALVO.[32] At 6.7 pounds, the AR–15 was a true lightweight rifle.[33]

After working less than 9 months on his AR–15, Stoner submitted 10 prototypes to the Infantry Board (one of several Army boards that tested and evaluated weapons and other equipment). In September 1958, with minor changes, the board recommended replacing the M–1 with this rifle. During tests at Aberdeen Proving Ground, Maryland, however, water retained in the AR–15's bore raised gas pressure to the point that a barrel exploded. The potential defect raised the question of whether AR–15s could work in Asian monsoons. While

Ordnance officers made much of the problem, testers found that simply tilting the AR–15's muzzle downward and slightly opening the bolt would allow air into the chamber and let the water spill out. The rifle also performed poorly in Arctic tests, but upon arriving at Fort Greely, Alaska, Stoner found that front sights on some AR–15s had been loosened while other weapons had been fitted with homemade parts. An Army board assessed the AR–15 favorably but the chief of staff, General Maxwell Taylor, decided that abandoning NATO's 7.62mm cartridge would be too high a price to pay. In February 1959, Taylor ordered all production and procurement concentrated on the M–14, seeming to settle the matter.[34]

In December 1959, Fairchild sold its AR–15 manufacturing rights to the Colt Firearms Company for $325,000 plus a royalty-sharing guarantee with Stoner and the firm of Cooper-MacDonald. In June 1960, Colt asked the Army to retest the rifle. Dr. Frederick H. Carten, Ordnance's chief of small arms R&D, refused. From the outset, Ordnance looked askance at a weapon that Continental Army Command sought to force on it. Colt's president believed he was fighting against the NIH factor—"Not Invented Here."[35]

M-16A1 automatic rifle manufactured by Colt in 1967 (*National Museum of American History*)

Colt turned to the Air Force, which needed to replace the M–2 carbines carried by sentries guarding air bases. General Curtis LeMay, vice chief of staff in 1960, attended a Fourth of July picnic at the farm of ArmaLite's president. Testing the AR–15 against watermelon targets, he was impressed by its lightness, apparent lethality, and gentle recoil. In mid-1961, LeMay sought money for 80,000 AR–15s, primarily for Air Force security personnel. OSD authorized 8,500, which Congress funded in 1962.[36]

The Vietnam War revived the AR–15's fortunes. Under the aegis of the Advanced Research Projects Agency, South Vietnamese soldiers received 1,000 AR–15s in mid-1962. Combat results were rated little less than spectacular, as the rifle's high-energy, easily tumbled bullets turned flesh or extremity wounds into fatalities. The M–16 appeared well suited to short-range jungle engagements; South Vietnamese soldiers, often smaller in stature than Americans, preferred the AR–15 to the heavier M–1.[37]

The focus now shifted to OSD. Deputy Assistant Secretary Davis discussed the M–14's performance with Robert Phelps, assistant director of ARPA, who had led a Marine Corps platoon in Korea. The two men watched a TV news clip that showed a Congolese soldier firing a rifle fully automatic, with an arc of empty shells spewing out of the chamber—and the rifle held steady. Could an M–14 do that? Phelps went to the Marine Corps base at Quantico, Virginia, where he fired every type of rifle. Returning to the Pentagon, Phelps told Davis there was not a Marine big enough to stand erect with the new M–14 at his shoulder, fire fully automatic from 100 yards at a six-square-foot target, and put more than the first bullet in it.[38]

Assistant Secretary of Defense (Comptroller) Charles Hitch, who was experienced with firearms, test-fired the AR–15 and was impressed. He convened a study group that included Lt. Col. Richard R. Hallock, who came back from Vietnam dedicated to replacing the M–14 with something better. The comptroller's report, sent to Secretary McNamara on 27 September 1962, labeled the AR–15 up to five times as effective as the M–14, offering significant improvements in reliability, durability, ruggedness, performance under adverse conditions, and ease of maintenance. In fact, it rated the M–14 somewhat inferior to the old M–1 and decidedly inferior to the Soviet AK–47.[39]

Secretary McNamara directed the Army to assess the relative effectiveness of the AK–47, the AR–15, and the M–14. Combat Developments Command conducted tactical evaluations and troop testing with the rifle, while Army Materiel Command carried out technical tests. The testing and evaluation was done Army-wide, Pacific Command excepted. The finding, submitted on 9 January 1963, rated only the M–14 acceptable for general use. The CDC commanding general recommended equipping all air assault, airborne, and Special Forces units with AR–15s after deficiencies in reliability and night-firing capabilities had been corrected. But General Besson, the AMC commander, was sold on the AR–15. If problems with firing in the rain and in cold dense air were eliminated, he preferred the AR–15 over the M–14 for worldwide use.[40]

Civilian officials had reason to question the objectivity of the Army's test and evaluation process. The small-arms experts from Army Materiel Command were former Ordnance personnel partial to the M–14.[41] Consequently, the AR–15 was tested against essentially traditional rifle criteria in a way that virtually guaranteed failure.[42] Deputy Assistant Secretary Davis related how Hitch's people produced a stream of reports about what appeared to be dishonest testing. In the Aberdeen tests, it was later found that Ordnance officials had searched for the most accurate, consistent .30 caliber rounds, even sending a plane to Louisiana to secure them. Enough rumors circulated for Secretary of the Army Cyrus Vance to order an investigation by the service's inspector general. The results documented a substantial bias in the M–14's favor. Senior civilians in OSD, who strongly favored the AR–15, took these findings as confirming their suspicions about Army resistance to change.[43]

The previous year, around Thanksgiving 1962, a group of general officers began to review the rifle issue at the direction of Army Chief of Staff General Earle Wheeler. Field grade officers (colonels, lieutenant colonels, and majors) charged with arranging briefings and technical papers soon learned that the "facts bearing on the problem" were highly contentious. Most of the younger officers believed that long-range hitting power mattered less than a rifle's size and weight and a soldier's ability to use the weapon effectively within battle range. Nevertheless, when Wheeler convened the group in January 1963, most generals stressed the criticality of killing at long range. One officer, brandishing an M–14 and making jabbing motions, announced that he much preferred going into combat carrying a hefty weapon rather than some plastic gimmick. Another held aloft an AR–15 and loudly declared, "You can tell it's swell, it's by Mattel!"—the slogan of a well-known maker of plastic toys. However, Maj. Gen. Creighton W. Abrams, Jr. (a future commander of U.S. forces in Vietnam and chief of staff), stated that he had never seen a German killed by rifle fire from beyond 50 yards during World War II. Tactically, Abrams said, what mattered was pushing infantrymen forward where the volume of their fire would prevail. Therefore, he favored the AR–15. The deputy chief of staff for operations, Lt. Gen. Harold K. Johnson, held the same view. Provisionally, General Wheeler and Secretary Vance decided to buy AR–15s for airborne, air assault, and Special Forces units but keep M–14s with their standard NATO caliber in Europe.[44] At that time, jungle fighting by U.S. ground troops did not appear likely.

Secretary McNamara wanted to procure one model for all the services. In April 1963, he established a Technical Coordinating Committee that included Air Force, Marine Corps, and OSD members. Army Lt. Col. Harold W. Yount, who had just become project manager for the AR–15, headed the committee.[45] Soon, OSD analysts became dismayed when the committee began considering over 130 modifications, provoking months of controversy. Two problems proved to be particularly difficult. First, test firings in a cold chamber showed that rounds became severely unstable when temperatures approached -65° Fahrenheit. The Air Force tester recommended giving a bullet more spin by tightening the barrel twist to one turn in 12 inches rather than 14 inches. But imparting more spin could lessen the bullet's lethality. Why not relax the accuracy or temperature requirements instead? OSD considered -65° an unrealistic standard, but the Army was obdurate. The second, sharper debate involved Army insistence on adding a forward bolt assist that would allow the bolt to be shut manually if, because of dirt or other fouling, it failed to close by itself. Stoner argued, and Air Force tests appeared to confirm, that simply ejecting the round, checking the chamber, and inserting a new cartridge would suffice. None of several manual closing devices seemed satisfactory. General Wheeler, however, decided that infantrymen needed something familiar on such an innovative weapon.[46]

By this time, Secretary McNamara had lost patience. In June 1963, he admonished Vance that lead times for the rifle and its ammunition were unnecessarily long and that most of the modifications being sought were either not needed or already accomplished. Convinced by Wheeler, however, Vance replied that adding a bolt-closure device was "absolutely essential." In the end, McNamara agreed to add the device and tighten the barrel twist.[47] The original AR–15 was now designated the M–16. On 4 November 1963, Colt was awarded a contract for 85,000 XM–16E1s—with bolt-closure devices—for the Army and Marine Corps and 19,000 M–16s for the Air Force. Still, the Technical Coordinating Committee classified the new rifle as the XM–16E1, a limited-production item that many Army officers saw as a special-purpose weapon for a unique war in Southeast Asia.[48]

In November 1964, the Marine Corps complained to Vance, now Deputy Secretary of Defense, that the Army was procrastinating over the M–16. General Johnson, now chief of staff, reacted by ordering the Combat Developments Command to reevaluate its small arms programs yet again. There followed engineering and service tests, field experimentation and troop tests, computer simulations and projections, and cost data studies. The Army staff, drawing heavily on simulation results, argued for preserving the M–14 production base, bypassing the M–16, and developing a "Special Purpose Individual Weapon" (SPIW), with deliveries starting in 1971. But the Force Planning and Analysis Office, a relatively new Army systems analysis group with military and civilian codirectors, made an evaluation that relied much more on operational testing. The office recommended dropping the M–14, relegating the SPIW program to long-range research, and focusing procurement on M–16 rifles and new M–60 machine guns.[49]

U.S. Army Test and Evaluation System

In 1960, the Army's test and evaluation system had not undergone major change since its establishment in the years between the two world wars. The developing agency (a technical service) conducted "engineering" tests to determine if the new equipment met scientific and technical standards. "User" tests followed: first, "service" tests carried out by "test boards" representing various types of equipment or operating environment (e.g., Armor Test Board, Arctic Test Board) under the Continental Army Command, and, if further testing was required, "troop" tests conducted in field units. Engineering and service tests normally took place sequentially, except when telescoping was authorized to some extent during World War II and more generally during the Korean War, and for guided missiles, which had unique testing requirements.

Significant changes to the test and evaluation system took place in the early 1960s. To reduce lead time, in 1961–1962 Army regulations provided for joint or concurrent engineering and service tests. As a result of the Army reorganization of 1962, the new Combat Developments Command would conduct concept testing and field experiments with new equipment; a Test and Evaluation Command, one of the subordinate commands of the newly established Army Materiel Command, assumed responsibility for engineering and service tests; and, while Continental Army Command would still conduct troop tests, they would be supervised by AMC's Test and Evaluation Command.[II]

What counted more than stateside tests were reports from Vietnam, where soldiers praised the new weapon's firepower and lethality. In December 1966, despite reports of jamming and malfunctions, General Johnson and Secretary of the Army Stanley R. Resor recommended acquiring only XM–16E1s and, ultimately, replacing all M–14s with them (see chapter XI).[50] Two months later, the XM–16E1 was redesignated M–16A1 and classified "Standard A," signifying that it was fully engineered and ready for issue. Between November 1963 and June 1968, the Army let contracts for delivery of 2,259,658 rifles. The final step came on 13 March 1970, when the secretary of defense announced that all NATO-assigned forces would be equipped with M–16/M–16A1s.[51]

To summarize, Springfield's M–14 was a product improvement while Stoner's AR–15 was a private-sector innovation that better reflected the Army's evolving tactical doctrine and ultimately its combat needs. Within the Army, Ordnance and Combat Developments Command disparaged the AR–15; General Besson and, crucially, General Johnson were its advocates. Adoption of the M–16 was a factor in McNamara's decision to shut down the Springfield Armory, which closed in 1968.

SHILLELAGHS, SHERIDANS, AND M60S

Throughout the 1950s, the Army's tank force left much to be desired. The M48 medium tank, mainstay of U.S. armor in the mid-1950s, was an upgrade of the Korean War–vintage M47, which in turn was an improved version of the M26 fielded near the end of World War II. In 1957, to match Soviet armor, Army Chief of Staff General Taylor approved development of a new main battle tank and a reconnaissance/assault vehicle that could be air-dropped. The Army also convened an ad hoc group on Armament for Future Tanks or Similar Combat Vehicles (ARCOVE) drawn from field-grade officers as well as civilian scientists and engineers. In January 1958, ARCOVE concluded that the Soviets enjoyed not only a tremendous superiority in numbers of tanks but also a qualitative advantage. Accordingly, ARCOVE assigned paramount importance to developing a weapon with 80 percent or more probability of "killing" its target with the first round. In ARCOVE's judgment, missiles using line-of-sight guidance offered by far the greatest potential for coping with the 30,000 Soviet-designed T54s that American soldiers might confront on European battlefields.[52]

Although the Army intended to continue producing M48s, the Bureau of the Budget in May 1958 deleted funds for procuring them. Putting the M47's power train into a new M48 hull had caused mechanical problems that required extensive rebuilding and shortened the M48's operational range. Rather than contest the bureau's veto, senior Army officers recommended another upgrade: install a more powerful compressor-ignition engine on the M48 and replace its 90mm gun with a 105mm gun,[53] thus creating the M60 main battle tank.

Three firms bid to produce the new tank. The Chrysler Corporation won an advanced production contract in September 1958 and completed four pilot models between July and October 1959. Outfitting M60s with M48A2 turrets speeded development. U.S. Army Europe received its first M60s in December 1960. Chrysler turned out 360 tanks at its Newark, Delaware, plant, then switched production to the Detroit Arsenal Tank Plant (owned by the Army but operated by Chrysler) for a total output of 2,205 by the autumn of 1962. An M60A1 with the same chassis but a "needle-nose" turret for better ballistic protection followed, with a rate of output kept near the minimum necessary to maintain the production base. Both models were equipped with the 105mm gun for their main armament. Conceived as another interim vehicle, the M60 thus began a production and modification run that would last for two decades.[54]

Meanwhile, in January 1958, development of a tank-fired missile had begun. That month, Redstone Arsenal in Alabama awarded feasibility contracts to four firms. Launched from a 152mm tube only half as long and heavy as the 105mm gun, the missile had to knock out the heaviest armored vehicles as far away as 2,000 meters. The winning firm, the Aeronutronic Division of the Ford Motor Company, proposed a system with a rocket-boosted guided missile that traveled along a line-of-sight trajectory from the gunner to the target. An infrared tracker would automatically follow the missile while a fire control system computed and signaled course corrections. How to keep the signal strong enough to overcome background noise while course corrections were being transmitted emerged as a critical problem. Nonetheless, Aeronutronic's president was confident that a system could be fielded in 54 months for about $34 million. Once developed, 50,000 missiles could be produced in three years for $573 apiece, together with turrets, launchers, and fire control equipment at $58,930 per unit. In June and November 1959, the Army Rocket and Guided Missile Agency (ARGMA) awarded a cost-plus-fixed-fee contract to Aeronutronic.[55]

The Shillelagh, as it came to be named, was burdened by complex arrangements for program management. In April 1959, the chief of ordnance assigned overall responsibility to his Ordnance Tank-Automotive Command (OTAC), which delegated contract supervision to its subordinate ARGMA. Development work was divided among three Ordnance installations: Watervliet Arsenal in New York focused on the 152mm gun tube, Frankford Arsenal in Philadelphia worked on the fire control unit, and ARGMA at Redstone Arsenal handled the missile and guidance subsystem. Within this framework, ARGMA supervised the R&D phase of missile subsystems; then Frankford took responsibility for adapting guidance components to the final vehicle and formulating field service roles for the fire control components. The task of ensuring compatibility between the missile and its vehicular-mounted equipment lay with OTAC. Without a single project manager, though, the entire process was difficult to manage effectively. By autumn 1960, Aeronutronic complained that it was receiving technical instructions not only from two sources in ARGMA but also from OTAC and the Office of the Chief of Ordnance.[56]

The technical problem of transmitting infrared signals to the missile's command links proved to be greater than expected. Background noise and exhaust plumes smothered the signals even under near-ideal conditions. In mid-1960, a civilian in DDR&E warned that the Shillelagh development effort appeared to be creating more problems than it was solving. A year later, the only part of the system that functioned adequately was the warhead.[57]

Soldier holds Shillelagh missile beside Sheridan launch vehicle (*AMCOM History Office*)

ARGMA considered the contractor obligated to demonstrate the feasibility of Shillelagh's subsystems before spending substantial time and money on a near-final design. Yet Aeronutronic's contract authorized it to pursue concurrency, working out a producible design while still conducting research and tests. By 1961, Aeronutronic found a way to make background noise manageable, but the correction required redesigning two-thirds of the tracker's electronic assembly. As a result, although Aeronutronic had been paid almost $24 million by May 1961, most of these funds were devoted to correcting flaws in the original design.[58]

Meanwhile, concept studies for an armored reconnaissance/airborne assault vehicle, intended to be Shillelagh's basic carrier, had begun in 1959. Twelve bidders submitted proposals. After review by Ordnance and Continental Army Command, two firms were chosen to prepare competitive mockups. In May 1960, the Cadillac Division of the General Motors Corporation won a development contract for what was designated the M551 Sheridan.[59]

Adoption of the strategy of flexible response highlighted the importance of this effort. Prodded by OSD, Aeronutronic and OTAC claimed in May 1961 that Shillelagh could reach full production by March 1964 by increasing R&D funding, accelerating the award of preproduction contracts, and substituting M60s for Sheridan combat vehicles. Three pilot M60s with needle-nose turrets and other improvements were completed between May and July 1961, and the Detroit Arsenal Tank Plant constructed a mockup for retrofitting Shillelaghs into the tanks. ARGMA drafted two plans for bringing Shillelagh into service by 1964 but argued that starting manufacture prematurely simply pushed problems from R&D to the early production phase, when solutions would prove to be much more difficult and expensive. After a further review, McNamara on 30 September 1961 decided to mount Shillelaghs on Sheridans but not M60s.[60]

M551 Sheridan (*AMCOM History Office*)

M60A2 (*AMCOM History Office*)

At McNamara's order, the Army awarded Aeronutronic a 60-day letter contract for accelerated development work on Shillelagh. However, only 1 of the 11 test firings succeeded completely. Harold Brown, director of defense research and engineering, advised McNamara on 9 December that accelerated development would severely overlap with production, unacceptably jeopardizing the chance of achieving adequate reliability. The secretary of the Army and the chief of staff agreed with Brown; development halted until research and testing had solved critical problems. After these had been corrected, Aeronutronic still had to improve the infrared command link and reliability.[61]

Success came in a June 1962 test, when at maximum range a missile hit a target that was barely visible through blowing dust. More successes followed, as new propellants appeared clean enough to ensure the transmission of adequate tracking and command signals under most battlefield conditions. At the time, Brown informed McNamara that "by cutting Shillelagh back to a high-priority research program we forced the Army and the contractor to solve some of their fundamental problems . . . [and] will probably get a better product sooner for less money."[62] Again, however, optimism proved to be unfounded.

A major change occurred in November 1962 when the Army dropped plans to employ Shillelagh as a "heavy antitank assault weapon" for infantry units. That mission went to the less sophisticated tube-launched, optically tracked, wire-guided (TOW) missile; Shillelagh was limited to employment as a "combat vehicle weapon system." Using either TOW or Shillelagh for both roles would have meant accepting less than optimum performance in one of the systems. Confident of Shillelagh's ultimate success, the Army in September 1963 gave Aeronutronic a new contract extending research, development, and test and evaluation through December 1965.[63]

Meantime, in June 1962, the Army took delivery of the first pilot model Sheridan. A dispute followed over who should supervise development of the entire system: the missile's proponents or those responsible for the combat vehicle. At first, in August, Sheridan/Shillelagh became one of 30 project-managed systems reporting to the Army Materiel Command,[64] with its subordinate Missile Command assuming sole responsibility for Shillelagh's subsystems. Ten months later, however, AMC transferred the Sheridan/Shillelagh project office to another subordinate organization, Weapons Command at Rock Island, Illinois, which insisted that the project manager exercise full line authority for the planning, direction, and control of all associated tasks and resources. The commanding general of Missile Command at Redstone Arsenal objected, complaining his authority had been badly undermined. Efforts to clarify responsibilities only created more friction. On his own authority, for example, the project manager scrapped plans to assemble Shillelaghs at a government-owned, contractor-operated facility at Redstone, choosing instead the Iowa Army Ammunition Plant. Missile Command again protested to AMC that its personnel were used simply as a labor pool for technical management. General Besson responded by establishing, in September 1964, a Shillelagh project manager at Missile Command and a Sheridan project manager at Weapons Command.[65]

Sheridan M551 firing missile (*AMCOM History Office*)

By that time, both systems were approaching initial production. On 12 April 1965, Cadillac won the first increment of a four-year contract to produce Sheridan vehicles.[66] Shillelagh's first two buys, in October 1964 and December 1965, went to Aeronutronic through sole-source procurement. The first production contract was small; the second, much larger, also extended the Shillelagh's range from 2,000 to 3,000 meters. Missile Command next proposed, and the Army approved, awarding all Shillelagh contracts through open competition. In March 1966, the Martin Marietta Corporation at Orlando, Florida, won a small contract that was expanded substantially during 1967–1968. In July 1968, however, Aeronutronic beat out Martin for a big multiyear contract with a fly-before-buy provision that Missile Command employed for the first time. From each production lot of 1,650 missiles, 18 were to be randomly chosen and divided into 4 groups; 3 groups of 5 missiles each were to be tested and 1 group of 3 held for contingencies. If there were only one or two failures in each sample, the lot could be accepted; three or four failures required the testing of a second sample. Six failures from each sample were permitted, but seven or more compelled the contractor to analyze failures and rework plans. Aeronutronic met the acceptance criteria in all 22 lots.[67]

Another problem delayed the fielding of the Sheridans. A long-running effort to create combustible cartridge cases for conventional rounds had progressed enough that, in 1959, Picatinny Arsenal in New Jersey undertook development of a 152mm round for the Sheridan. In December 1964, the Army approved the manufacture of 64,000 such rounds, expecting Sheridans to be fielded by mid-1966. But Picatinny struggled with designing a usable cartridge. The case, which was supposed to be consumed along with the propellant it contained, failed to combust fully so that much of the residue—some of it smoking, some actually burning—remained in the gun barrel. Yet in March 1966, the Army Munitions Command declared itself highly confident that improvements were making the cartridge acceptable.[68]

Several tests were disappointing. Humidity distorted the cartridge case, making rounds hard to chamber, and smoldering residue persisted. Several projectiles detonated inside their gun barrels. The Army responded with an open-breech scavenger that directed jets of air into the gun tube after the breech had been reopened. However, tests showed that solution to be ineffective. Nonetheless, since its incorporation had been approved prior to the tests, Sheridans with ineffective scavengers rolled off the production lines until October. Finally, a closed-breech scavenger that blew residue out of the barrel before the breech opened proved to be successful and was cleared for production in July 1968. In November, Army Materiel Command finally approved the Sheridan system as suitable for issue. Sixty-four Sheridans without Shillelaghs went to Vietnam in January 1969, equipping two armored cavalry squadrons. Deployments to Europe and South Korea followed in April and August, respectively.[69]

Earlier, following a study by the Combat Developments Command, Secretary McNamara in 1964 reversed his decision of 1961 and approved installing Shillelaghs on M60A1 tanks. The M60/Shillelagh combination was thought to represent a state-of-the-art design that would create no problems in production. Tanks already on hand were to be retrofitted and designated M60A1E1s; tanks subsequently produced with Shillelagh firing barrels as part of their original equipment would be designated M60A1E2s. This adaptation, conceived as an economy measure, integrated proven components into a new turret mounted on an M60A1 chassis.[70]

Rating the need for an improved interim tank as urgent, the Army targeted availability of Shillelagh-equipped M60s for November 1967. Weapons Command initiated production engineering for M60A1E1s only six months after R&D had begun and awarded Chrysler a contract for long lead-time items in January 1966. Chrysler, already producing turrets[71] and retrofitting M60A1E1s, won a contract in May to deliver 300 M60A1E2s.

Once again, a rush into production went awry as tests failed. Turret stabilization was the major problem, with a design fault causing the gun to move erratically. The Army canceled installation of new turrets on M60A1E1s but continued turret production and, in September 1968, contracted for another 243 improved M60A1E2s.[72]

The accomplishments of a decade of effort were limited. By January 1969, all units in Europe, most active force units in the continental United States that were earmarked for assignment to Allied Command Europe, and part of the training base had been equipped with M60s. Between June 1966 and November 1970, 1,662 Sheridans were produced. Overall, the Sheridan program cost more than $1.3 billion (including Shillelagh systems, conventional ammunition, and support items), 23 percent above an initial planning figure that covered 2,426 vehicles plus missiles and ammunition. As to the M60/Shillelaghs, congressional investigators claimed that early in 1969 there were 300 unusable tanks, which cost $200 million, and 243 unusable turrets and components, costing $70 million, in storage at the Detroit Arsenal Tank Plant. Although the Army corrected those faults and acquired 540 Shillelagh-equipped M60A2s (as the M60A1E2 was redesignated), problems with the main gun's recoil system delayed their arrival in Europe until 1975. Even then, ongoing maintenance and reliability problems made the M60A2 unpopular with soldiers, who nicknamed it the "Starship."[73] By that point, the service life of the Sheridan was nearly over. In 1978, the Army began retiring all M551 Sheridans except a battalion with the 82nd Airborne Division and a unit at the National Training Center.[74]

Certainly, the Shillelagh/Sheridan project could have been handled better. Thanks to the novelty of program management, lines of authority and responsibility were not fully straightened out until September 1964. Clearly, however, the main barrier was not managerial but technological. The Army made a mistake by shifting to missiles and stopping work on a 120mm smoothbore gun designed to fire fin-stabilized rounds. Shillelagh was too large a leap and never lived up to its promise. The real breakthrough came later with armor-piercing, fin-stabilizing, discarding-sabot projectiles suited to calibers smaller than 152 millimeters. In 1958, a British 105mm gun, tested at the Aberdeen Proving Ground during the M60 competition, had shown exceptional penetration performance. The Soviet T62 tank, introduced in 1961, carried a 115mm smoothbore; the T64, entering service soon after, had a larger 125mm piece. Prototypes of West Germany's Leopard II, tested between 1966 and 1969, carried 105mm and 120mm smoothbores. Technologically, despite the dollars poured into missile development, U.S. tank gunnery lost ground to its Soviet, British, and West German counterparts.[75]

FAILURE OF THE MBT70 PROJECT

After ARCOVE, the Army experimented with several concepts for an entirely new main battle tank, none of which reached the pilot stage. On 14 July 1961, Secretary McNamara proposed a joint development program to his West German counterpart. McNamara envisioned a tank that would cost less than the M60, maneuver adroitly, operate at higher speed, and enter the operational inventory in three years. The Germans, having their own Leopard tank already in prototype, at first agreed only to collaborate in developing components. McNamara persisted, convinced that pooling ideas and sharing costs would result in a better end product at less expense.[76]

In 1962, American and West German experts agreed on a general set of tank characteristics. After a NATO working group accepted these, McNamara and West German Defense Minister Kai-Uwe von Hassell signed a letter of agreement on 1 August 1963. Using terms that were unusually broad for one of the Army's Qualitative Materiel Requirements, their letter stated that the Main Battle Tank 70 (MBT70) should have better firepower, mobility, and protection than the M60A1; be able to operate on a nuclear battlefield; and carry either a tube-fired missile or a missile and gun combination. Development costs up to $100 million would be shared equally; the first prototype was to be ready for testing in January 1967, with a complete technical package ready for procurement by September 1969.[77]

Washington and Bonn promptly established a Program Management Board, consisting of U.S. Army Maj. Gen. Welborn G. Dolvin and Dr. Fritz Engelmann of West Germany.[78] Under the board, with equal representation from both countries, was a Joint Engineering Agency (JEA) staffed by civil service and military personnel and, below that, a Joint Design Team (JDT) recruited from industry. The German Development Corporation, a consortium that included Daimler-Benz AG, Porsche AG, and Rheinmetall AG, furnished personnel for the JDT. Major General Dolvin considered creating a similar corporation and the consulting firm of Booz Allen so recommended, but in the end he elected to compete a support contract won by General Motors.[79]

When the JEA and JDT assembled at Augsburg, West Germany, in September 1964, many differences emerged. In Dolvin's telling, the program almost broke up once or twice over words. For example, the word *coordination* was *directive* in German. Also, the metric system, Dolvin found, lacked a set of standards comparable to that used by the U.S. Society of Automotive Engineers in rating strength of materials.[80] Additionally, although Dolvin and Engelmann agreed on a basic requirement for the MBT70 in March 1965, American and German R&D practices were radically different. Consortia in German industry dealt with their government almost as a peer and did not allow government representatives free access to their facilities. German engineers, unlike their U.S. counterparts, had the right to be compensated according to the commercial value of their inventions. German firms bore most R&D costs, with the inventors and their firms then receiving royalties from the government. In contrast, American inventors and their employers retained no patents when the U.S. Government paid for all R&D work.[81]

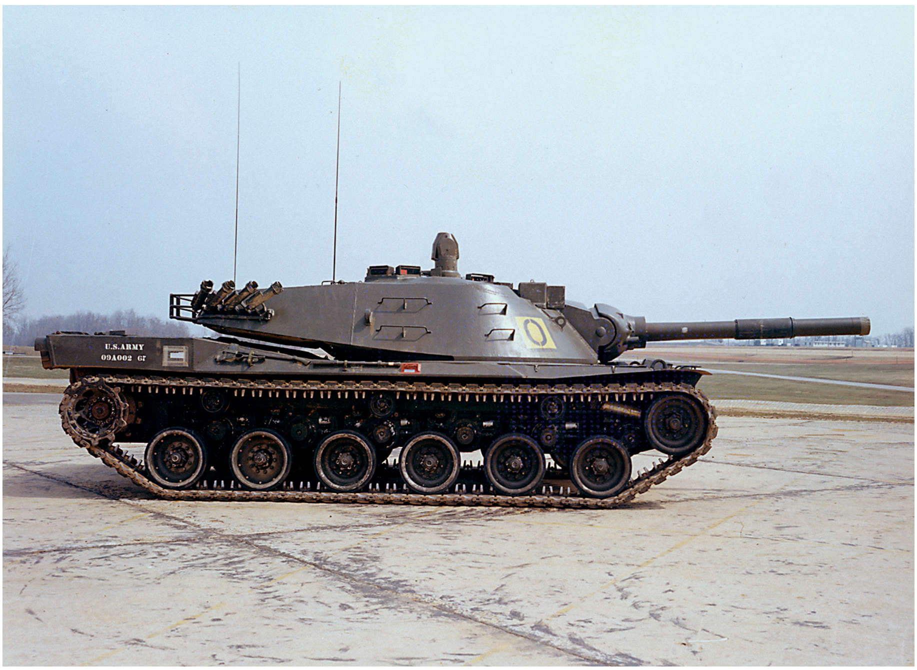
Doctrinal and operational divergences were just as great. Having only the M60 on hand, McNamara and the U.S. Army badly wanted a new main battle tank by 1970. But the Germans, who had begun turning out Leopards in September 1965, preferred to postpone MBT70 production until the Leopard's run had ended. In addition, the U.S. Army required a tank for worldwide use; the Germans, by contrast, focused on Central Europe. Americans wanted a Shillelagh and gun combination, believing that engaging the enemy at 2,000 or 3,000 meters minimized the need for mobility and allowed extra armor plate. German doctrine called for closer combat, in which a high degree of cross-country mobility mattered more than protection.[82]

Assignments to develop components were made according to which country enjoyed technical preeminence in a particular area; only the hull and turret layouts were designed jointly. Americans favored a 60-ton tank, but Germans insisted that a tank be light enough to cross the 50-ton bridges found on many of their secondary roads. Weight also affected what Dolvin later called the most important and most troublesome difference: over radiation protection. Anticipating exposure to small, high-radiation or "neutron" bombs, Germans insisted on thick, heavy shielding for the tank. Americans believed that thin armor could stop most forms of nuclear radiation, while thick armor could do little to stop fast neutrons.[83]

The Americans wanted to make more room for ammunition storage by reducing the armor inside the tank, which in turn required replacing the fourth crewman with an automatic loader. Cutting the crew to three and placing them all in the turret would make an antiradiation capsule feasible. Joint Chiefs Chairman General Wheeler worked out a compromise with his West German counterpart that added less radiation protection than the West Germans desired but still raised the MBT70 above its original weight limit. Arguably, in fact, the tank's final requirements were more complex than either country would have pursued if left to itself. An analyst later observed that no major NATO tank had ever housed an automatic loader, a three-person crew, or a radiological capsule.[84]

The engineering and design teams, both of which relocated to Detroit in July 1966, authorized firms in each country to build six prototypes.[85] But as these neared completion, analysts in OSD voiced doubts about the whole project. In July 1967, Assistant Secretary of Defense Enthoven advised McNamara that the MBT70 was not competitive. M60s and Sheridans with Shillelaghs, he claimed, would equal the MBT70 in firepower. The MBT70's weight had risen more than 40 percent above the original goal of 35 tons, which meant that its engine had to produce twice the horsepower of the M60 engine within about the same volume. Complexity also created problems; about 8,500 spare parts were unique to the MBT, compared to about 4,200 for the M60. An MBT would cost nearly $900,000, Enthoven calculated, an M60 only $290,000. Moving toward more expensive vehicles with greater capability might not make sense at a time when more effective antitank weapons were about to become available to infantrymen. According to Enthoven, the MBT70 contained everything that technology could achieve, without discrimination, cost-analysis feedback, or clear objectives. Matching an MBT against an improved M60, he rated the MBT far too expensive for its few unique attributes. Enthoven recommended finishing only a few pilot models, completing the development of some components, and dropping the idea of production.[86]

McNamara adopted Enthoven's views. Late in September 1967, just as the first German and American prototypes were being displayed publicly, McNamara told West German Defense Minister Helmut Schmidt that "we certainly . . . should complete the development and testing phase . . . to prove that we could do a development project together." Significantly, though, McNamara advised Schmidt that he was "quite relaxed about whether the Germans actually produced the tanks or not."[87]



Prototype of the U.S. version of the MBT70 (TACOM Life Cycle Management Command)

Even McNamara's development goal proved unattainable. Difficulties occurred with the automatic loader, the gun-turret drive, and the engine, all of which were advanced design components developed specifically for the MBT.

Neutron shielding was eliminated to save weight, even though one reason for putting the driver in the turret was the ease with which the entire crew could be shielded. Duplications began displacing tradeoffs as the preferred solution. German and American prototypes carried a long-barreled version of the 152mm gun used in Sheridans and M60A2s. When problems with the Shillelagh persisted, Germans turned to developing their own 105mm and 120mm smoothbore guns with newly designed rounds.[88]

For the MBT70's engine, having multiple developers only added to the difficulties. Chosen in 1965 as the prime candidate, Continental Aviation and Engineering Company's air-cooled engine was supposed to deliver 1,475 horsepower. But the engine's unproven "variable compression ratio" principle employed extremely high compression per cubic inch of displacement. Daimler-Benz developed a heavier but more conventional water-cooled engine as the backup. In 1967, the Army amended its contract with Continental, originally a best-effort, cost-reimbursement contract, to include NATO's 400-hour engine qualification test, already a part of the German contract with Daimler-Benz. In this process, the Germans held that major failures should end the NATO test, while the Americans argued that engineering judgment should determine whether a failure could be corrected and the test continued. Continental's engine failed the NATO test, but General Motors did not favor switching to Daimler-Benz because of the likely effect on overall tank design. For their part, the Germans balked at shouldering some of the steadily increasing cost of engine development. Although the U.S. Army put modified Continental engines into its pilot models, it finally opted for Avco Lycoming's much smaller and lighter gas turbine engine.[89]

Estimates of the MBT70's development costs kept escalating: from $80 million to $100 million in August 1963, with the two countries paying equal shares; $138 million by August 1965, with the United States paying $85 million and West Germany $53 million; and finally $300 million by March 1968. Technical troubles caused a good deal of the increase. But Brig. Gen. Bernard C. Luczak, who became the U.S. program manager in July 1968, also faulted the cost-plus contract. General Motors, he believed, handled projects well but did not spare the expense:

> If you get 10 percent of everything you spend . . . what motivation do you have for keeping costs down? . . . And in my judgment, giving incentive fees in this kind of program was almost ridiculous. Any time you didn't give them 100 percent of the fee, you were on the defensive to prove why they shouldn't get the full incentive fee. It should have been the other way around.

In April 1969, the West Germans ended joint funding and started work on an improved Leopard II. Formal dissolution of the collaborative project occurred in January 1970.[90]

Some Americans suspected that the Germans had joined the project mainly to gain access to U.S. technology and apply it to their Leopard II. As an example, Luczak related that the contract authorized the West Germans to use the U.S. turbine engine technology without being bound by the developer's proprietary information. Conversely, Rheinmetall assigned low priority to the automatic loader because the Leopard II would not have one. Rheinmetall made such slow progress that the work was shifted to General Motors, which produced a loader quickly and cheaply.[91]

In retrospect, Major General Dolvin cited three factors that smothered MBT70. First, the United States and West Germany operated on different time frames, with the U.S. Army wanting a new tank as soon as possible. Second, the U.S. armor community's support for radical changes gradually diminished. Third, and most important, the MBT70 had no conceivable role in the Vietnam War. In hindsight, Brigadier General Luczak speculated that *any* international program would have little chance of success "unless the two developers were going to fight the same kind of war in the same kind of environment against the same type of enemy—and both had the resources to hold up their end of the bargain, had the same enthusiasm, and the same commitment to results. Then, maybe."[92]

Collapse of the MBT70 project meant that the U.S. Army did not field a new main battle tank until 1980. Until that time, product improvements of the M60 had to suffice.[93]

TOW: A SUCCESS STORY

A heavy antitank/assault weapon research program received top priority in 1958, after the chief of R&D on the Army staff specified a requirement for a weapon that would be effective as far as 2,000 meters and could operate from the ground, a vehicle, or a helicopter. The Ballistic Research Laboratories at Aberdeen Proving Ground recommended developing what was described as a tube-launched, automatically optically tracked, wire-guided missile. Redstone Arsenal had been working on infrared guidance that would track a missile and transmit corrective commands automatically. The gunner need only align the crosshairs of his optical sight on the target and then squeeze the trigger. Rather than rely on radio transmissions to make in-course corrections, communication would occur through the thin wires that unraveled as the missile traveled to its target.[94]

In October 1961, when Shillelagh development faltered, McNamara and the assistant secretary of the Army (R&D) enthusiastically endorsed a study of TOW's feasibility. With a major Army reorganization looming, the chief of ordnance called on the Ordnance Corps to establish schedule, cost, and performance records for the system. Hughes Aircraft, Martin Marietta, and McDonnell Aircraft received six-month contracts to fabricate prototypes. A parallel in-house effort was supposed to supply a yardstick for evaluation and enable Ordnance personnel to carry out informed technical supervision. Hughes and Martin Marietta each delivered four test missiles. Ordnance's in-house effort, though, never progressed far enough to be considered a competing system.[95]

Hughes won the development contract in August 1962. Missile Command delegated authority for program management to its Antitank/Aircraft Weapons Commodity Office. DDR&E Harold Brown recommended dropping either TOW or Shillelagh. However, the Army's Ballistic Research Laboratories concluded that TOW could work best in an infantry role and Shillelagh in a combat vehicle role. TOW went forward on that basis.[96]

TOW missile fired from jeep (*AMCOM History Office*)

Hughes started development work in January 1963, projecting an initial operational capability for February 1965. Then, relying on an evaluation by Missile Command, General Besson raised TOW's maximum range from 2,000 to 3,000 meters. He stipulated that this increase should not delay development, significantly change design, or degrade performance at 2,000 meters. Unfortunately, increasing the range forced a major redesign of the signal transmission system as well as modifications to the motor and guidance subsystems. The number of electronic parts on the missile jumped from 136 to 591 and on the launcher from 1,100 to 1,900. Solving these problems added 21 months to TOW's development schedule. A 1964 decision to add a night sight further increased time and cost. On 1 October 1964, near the end of the experimental model program, General Besson activated a TOW project manager's office at Headquarters, Missile Command.[97]

TOW's great advantage over predecessors lay in its ease of operation. Inexperienced and experienced operators performed about the same. To mount TOWs on unarmed vehicles, Hughes sacrificed some capability in return for a simple kit that required minimal vehicle modifications. Airborne firing was more difficult; a major problem lay in stabilizing the line of sight from the aerial platform to the ground target. First installed on utility transport helicopters, an improved TOW was later used effectively by Cobra helicopter gunships.[98]

In July 1965, at AMC's urging, the Army proposed moving toward limited production by mid-1966. OSD disapproved, noting that 23 out of 49 firings had failed. Because TOW's design concept ruled out testing after the start of production, and because the cost of initial production units was so high, OSD wanted clear proof of the system's reliability before authorizing mass production.[99]

A plan to start series production in August 1967 broke down when, that same month, reliability problems and a failure in the missile container forced a suspension of testing. Missile Command technicians spent about six weeks at the Hughes plant working to improve reliability. Tests resumed in November and showed steady improvements. In one exercise, Marine Corps gunners scored direct hits on 9 of 10 fixed and 8 of 10 moving targets.[100]

In April 1968, the Army's assistant chief of staff for force development approved limited production for TOW. In November, Hughes received a two-year, cost-plus-incentive-fee contract for $168 million. For the first year, the contract specified production of 5,350 missiles and 250 launchers under fly-before-buy criteria, meaning inspectors at Redstone Arsenal would select random samples each week for test firing. A missile lot would not be accepted until Hughes provided samples that met these standards.[101]

By this time, TOW had fallen 38 months behind schedule and development costs had nearly doubled, from $51 million projected in 1963 to $96 million obligated during fiscal years 1962–1968. TOW's statistics were not markedly better than Shillelagh's slippage of 42 months and its escalation of development costs from $58 million to $151 million.[102] Yet ultimately, TOW was a success[103] and Shillelagh was not. What accounted for the difference? Basically, TOW simplified the operator's task and was easily adapted to armored personnel carriers, cross-country vehicles, and helicopters. Its simpler wire guidance system bypassed many difficulties endemic to Shillelagh's radio-based system. Unlike TOW, Shillelagh added complexities at every point while providing little advantage over tank-mounted cannon.

FORWARD AIR DEFENSE: HITS AND MISSES

By the late 1950s, air defenses operating against aircraft flying at high and medium altitudes were becoming quite effective. Against low-level air attack, though, frontline troops had only automatic weapons that were nearly useless because of their short range and inability to engage high-speed targets. In 1955, the Convair Division of General Dynamics started using its own funds to explore the feasibility of a very lightweight missile that could be fired by a foot soldier. Since no military characteristics for such a weapon existed, Convair formulated design objectives and fabricated a full-scale model of the missile, nicknamed "Redeye" because of its infrared homing device. The missile's receiver would pick up heat radiation from a target, launch directly toward it, and home in on the source.[104]

In 1957, Convair, Sperry Gyroscope (a subsidiary of the Sperry Corporation), and North American Aviation submitted unsolicited proposals for surface-to-air missiles to Redstone Arsenal. Evaluators at Redstone favored Convair but opposed any commitment to develop Redeye until a more thorough investigation of some obvious shortcomings was done. For instance, could the infrared seeker's head discriminate the target's radiation from background radiation like a hot spot on the horizon?

The Marine Corps, however, forced the issue. Having made a favorable evaluation of Redeye of its own and with $1 million in R&D funds to use or lose, the Corps urged immediate development. Convair already had considerable experience in developing Navy missiles. The Navy-owned plant that it operated in Pomona, California, was running at 50 percent capacity. Accordingly, in the spring of 1958, the assistant secretary of the Army (logistics) awarded an R&D contract to Convair, using Army and Marine Corps funds.[105]

Shoulder-launched Redeye missile (*AMCOM History Office*)

Test firings and radiation measurements began in 1958. The Naval Ordnance Test Station (NOTS) at China Lake, California, beginning in 1958, carried out all test firings and radiation measurements. NOTS had developed the Sidewinder air-to-air missile, and its staff was familiar with infrared mechanisms. NOTS also had excellent test facilities and was located only 100 miles from Pomona. General Dynamics selected Philco as subcontractor because it had produced the Sidewinder's infrared seeker, a modification of which was planned for Redeye. But funding cuts forced delays, cost estimates nearly doubled, and technical difficulties persisted—particularly involving the effects of electronic noise in Redeye's seeker. Nonetheless, Army Ordnance Missile Command decided that feasibility had been demonstrated. The chief of ordnance agreed, and the Army staff concurred. In August 1960, adhering to the time phasing laid out by Convair in 1956, Redeye advanced to limited production.[106]

The calculated risk of moving into production before completing reliability tests did not pay off. Basically, Redeye could not go fast enough, could not maneuver soon enough, and could not discriminate well enough. In May 1961, after five design changes, Continental Army Command and the Marine Corps accepted an imperfect Redeye as an interim system. Even that proved to be premature.[107] Late in 1961, increased funding allowed the pursuit of parallel solutions. Still, background noise remained a problem.

In October 1962, an ad hoc group from the Office of the Director of Defense Research and Engineering judged Redeye not ready for production. Simultaneously, a Redeye Commodity Office was established, consisting of a few technicians who reported to the deputy commanding general of Army Ordnance Missile Command. Redeye was reoriented yet again to stay within the state of the art. After flight tests went well, the missile advanced to the production stage early in 1964.[108]

Late in 1965, with engineering design completed, General Dynamics signed a fixed-price incentive contract to deliver 10,972 missiles between October 1966 and October 1967. Still, the Redeye project manager, located at Missile Command headquarters since 1964, had his hands full with engineering design changes that limited production. Finally, with problems resolved, deliveries in September 1968 reached a steady rate of 1,000 per month.[109]

Between fiscal years 1964 and 1973, $268 million was spent for 31,268 Redeye systems—20,755 for the Army, 7,637 for the Marine Corps, and 9 for the Air Force, with another 2,867 sold to West Germany, Sweden, Denmark, and Australia. The figure for research, development, and test and evaluation, originally estimated at $24 million, turned out to be $82 million, while engineering development lengthened from 30 months to nearly 7 years.[110]

How good was Redeye? As the first weapon of its kind, problems had to be expected. The missile suffered from a comparatively short range, vulnerability to simple countermeasures, and modest speed. Redeye was restricted to pursuit-only engagements, as it could be fired only *after* an aircraft had delivered its ordnance. Moreover, the missile probably could not have caught a high-speed aircraft.[111]

Concurrently, the Army had been working on a vehicle-mounted missile system, named Mauler, to protect forward areas against aircraft, rockets, and missiles. As early as 1957, Continental Army Command established a requirement for an all-weather, guided missile effective at 5,000 meters to be available by FY 1963.[112] In June 1958, ARGMA awarded six-month design study contracts to four firms. Evaluators drawn from universities as well as ARGMA selected Convair to develop the system. Not all were optimistic. Dr. John P. Clauser, head of the Aeronautics Department at Johns Hopkins University, doubted whether to proceed: "Against weapons possessing a sophistication comparable to the Mauler system itself, I believe it will not prove effective. Small [air-to-ground] homing rockets of lesser complexity than those of Mauler will be able to put Mauler out of action. . . . This vulnerability is not just happenstance or a case of poor design which is easily corrected." Nonetheless, in April 1959, Secretary of the Army Wilber M. Brucker formally inaugurated the Mauler project: a self-contained system with radar, Identification Friend or Foe equipment, a computer, and a launcher rack carrying 12 missiles, all mounted on a single tracked vehicle.[113]

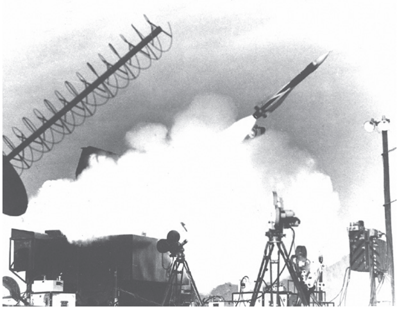
In October 1961, a small Mauler project office was established at Headquarters, Army Ordnance Missile Command. In 1962, the office was placed in AMC, reporting to the deputy commanding general, Air Defense Systems. Briefly joined with Redeye, it later split off and expanded to exercise more centralized control.[114]

Lean funding, lack of specific direction, and shortcomings of preliminary studies soon pushed Mauler's proposed operational date to 1966. In September 1962, General Besson tried to rescue Mauler by putting it under the scrutiny of Program Evaluation and Review Techniques. In September 1962, he designated Mauler as the Army's pilot project for PERT. Apparently, personnel at Convair's Pomona plant worried that findings from PERT would put them in a bad light. In May 1963, Missile Command admonished General Dynamics for its lack of tangible evidence of support and cooperation.[115]

In February 1963, Lt. Gen. Dwight E. Beach, chief of R&D on the Army staff, came away from a visit to Pomona worried that Mauler was starting down the same road as Redeye, with disastrous prospects. Subsequently, an ad hoc board gave Mauler only a guarded endorsement. In June 1963 and again in October, despite intensive checkouts and rehearsals, tests of Mauler's guidance system failed decisively. The date for the missile to become operational had to be delayed again. Lieutenant General

Beach told DDR&E officials that December 1963 should become a "kill-or-cure" deadline.[116]

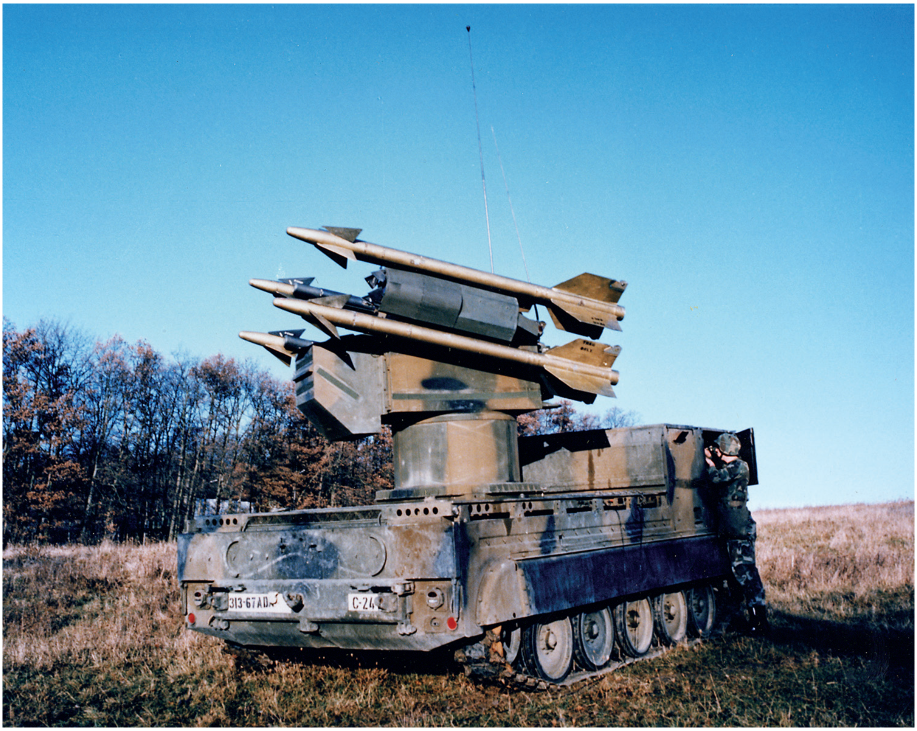
The deadline passed, and Mauler still lived. In February 1964, the Combat Developments Command ordered its Air Defense Agency to rate Mauler against alternatives expected to come available during 1970–1975. The agency concluded that SAM–D (later renamed Patriot), a more capable long-range weapon planned for deployment beyond the division operating area, would become the keystone of field army air defense within six to eight years. In the interim, the agency believed that Hawk would be more effective than Mauler.[117] At this point, Mauler had become so expensive that it could be justified only with a service life of 8 to 10 years. The agency therefore recommended terminating Mauler and developing SAM–D. Late in 1964, Secretary McNamara cut Mauler's FY 1966 funding from $46 to $10 million; the program limped on.[118]


Launch of vehicle-mounted Mauler missile (*AMCOM History Office*)

In May 1965, a board of high-ranking Army officers created by the secretary of the Army to evaluate Mauler's future dealt the missile a death blow. Colonel Luczak, the program manager, advised that the system had proved to be technically feasible, noting that 6 of 11 test flights between November 1964 and May 1965 had been successful. He emphasized, however, that the Mauler design still had a long way to go in both time and money before it would be ready for production. The Army Materiel Command rated Mauler superior to Hawk (fielded in 1960) and wanted to go ahead with it. But the board disagreed and so advised Army leadership. In July, Secretary McNamara at last halted Mauler's development; formal termination followed on 18 November.[119]

In June 1963, when Mauler began to falter, the assistant secretary of the Army (R&D) called for a backup system. Study contracts went to Philco, producer of the Navy's Sidewinder air-to-air missile, and to Hughes, producer of the Air Force's air-to-air Falcon missile. In January 1964, after competitive tests, Missile Command concluded that the Sidewinder had potential as a surface-to-air weapon, under the name Chaparral. About the same time, a study done by the Office of the Assistant Chief of Staff for Force Development highlighted the urgency of deploying forward air defenses to Europe by 1968.[120]

In November 1964, Secretary McNamara approved a plan to put six Chaparral battalions in Europe during 1968. Development would be based on a "bolt-together" concept, creating the Chaparral's launching unit from proven components: an M113 tracked vehicle and an M45 quadruple .50-caliber gun mount, with launchers replacing machine guns. Each would have four Sidewinder missiles ready to fire. Vulcan, a six-barrel, electrically fired 20mm gun, was selected as Chaparral's companion in these composite battalions.[121]



Chaparral missile system (*AMCOM History Office*)

In March 1965, the Aeronutronic Division of Philco-Ford won a fixed-price incentive contract for ground support equipment for Chaparral. Since Sidewinder and Chaparral shared about 95 percent of their components, the Navy developed Chaparral in-house without using a prime contractor. The Army acquired Chaparral's missile components from the Naval Air Systems Command through interdepartmental arrangements. Red River Army Depot then assembled the components into "full-up" rounds. In this area, the Army was completely dependent on the Navy for advice and decisions about technical matters.[122]

Chaparral experienced costly revisions. First, the bolt-together approach failed. M548 cargo carriers, rated best in the M113 family of armored vehicles, needed extensive modifications. Because mounts and rails proved to be incompatible with the missiles, the prototype completed in August 1965 bore scant resemblance to the original proposal. Second, after Mauler's termination, the Army decided that Chaparrals were needed worldwide. Accordingly, in December 1965, McNamara approved expanding the 6 battalions to 21. Because worldwide environmental requirements now had to be met, many completed designs were withheld from hardware fabrication pending reevaluation. Numerous electronic circuits had to be redesigned to provide the networks necessary to function in Arctic cold or tropic heat. The full cost of research, development, and test and evaluation came to $62.5 million, 257 percent above the original estimate of $17.5 million for this mostly off-the-shelf item.[123]

Hawk missiles on launcher (*AMCOM History Office*)

Although the Army's chief of R&D approved Chaparral for limited production in November 1965, its many problems caused a 15-month slippage. Also, deliveries from subcontractors lagged because they were saturated with higher priority orders for Vietnam. The first Chaparral/Vulcan batteries did not reach Germany until November 1969. Even then, the system had to deploy without an early warning and target identification capability. A forward area alerting radar, conceived as another modified off-the-shelf item, became mired in difficulties and was not fielded until 1974. What the Army acquired in 1969 was mainly a tail-chaser, like the Redeye. Chaparrals, therefore, were concentrated along the most likely approach avenues of enemy aircraft. Shorter ranged Vulcan guns usually protected command posts, bunkers, and supply dumps.[124]

In the 1960s, the Army improved its defenses against low-level air attack by applying missile technologies. Although the Mauler program was terminated, Hawk, Redeye, and Chaparral reached field units. Even so, technical difficulties, funding cuts, costs well beyond original estimates, and schedule delays were common. Moreover, none of the systems possessed the capabilities the Army needed to protect its field forces adequately. The wait for a more capable forward air defense system would be long; the Patriot missile would not be deployed until 1984.

SERGEANT: THE PERILS OF CO-CONTRACTING

The Army needed a successor to its liquid-fuel Corporal, a tactical guided missile with a 75-nautical-mile (NM) range that was rushed into development during the Korean War and became the first operational U.S. ballistic missile. Tentatively, in 1954, the Army set a requirement for a solid-fuel missile able to deliver a nuclear or conventional payload weighing 1,500 pounds up to 175 NM with a CEP of approximately 90 to 140 meters. The Jet Propulsion Laboratory (JPL), an Army-funded activity operated by the California Institute of Technology, drew upon its experience with Corporal in outlining a plan for its successor, the Sergeant. JPL successfully urged a major departure: avoid past practice in which the contractor selected to develop the system had no capability for producing it. Instead, a production contractor would be associated with JPL right from the start of hardware testing. By closely collaborating with JPL, the production contractor would acquire a thorough knowledge of the system's design. The scope of procurement would expand as development progressed so that, in theory, the final engineering model would need little change for full production.[125]

The Sperry Gyroscope Company, chosen by an ad hoc committee in 1956 to be co-contractor with JPL, began building a plant for producing Sergeant missiles at Salt Lake City, Utah. But the Sperry-JPL relationship soon soured. A shortage of funds, forcing a reduction of test hardware, resulted in some JPL designs based on insufficient test data. Sperry found it more practical to redesign a component completely rather than refine JPL's basic design. Another bone of contention was Sperry's selection, over JPL's protest, of the American Machine and Foundry Company to manufacture Sergeant launchers. JPL rated American Machine and Foundry's first launchers unacceptable for operational and environmental tests because parts were not properly mated and gaps were filled with weld material. When the Army Ordnance Missile Command supported Sperry's choice, JPL declared itself relieved of the accountability for schedule, quality, and compatibility of that portion of the Sergeant system.[126]

In December 1958, JPL became part of the newly created NASA. In May 1960, when Sperry was about to take charge of the Sergeant project, the company strongly opposed keeping JPL engineers working full time. To do so, it claimed, would put Sperry in the position of having basic program responsibility while de facto accountability stayed with JPL. The Army Rocket and Guided Missile Agency agreed with Sperry.[127]

JPL's participation in Sergeant ended on 1 July 1960, leaving some R&D problems unsolved. Since Sperry's interest lay in production, however, the R&D effort was downgraded. The transfer of ARGMA's responsibilities to the Army Ballistic Missile Agency (ABMA) on 1 August 1960 created more problems. There were enough test failures for industrial engineers at ABMA to scrap the prototype, placing it back in R&D. A resulting rash of engineering changes imposed further complications and delays.[128]

During March 1961, flight tests exposed failings serious enough to force a short suspension of firings. The accuracy requirement, or CEP, was relaxed to 300 meters. In 1958, Sergeant's availability had been accelerated by 14 months. During 1960, thanks to the falling out between JPL and Sperry, a 10-month slippage took place. When the deadline of August 1961 arrived, the Army decided that the only way to deploy the missile, even by mid-1962, was to accept shortcomings that would be fixed later. Secretary McNamara chose, in November 1961, to put Sergeant on what amounted to probationary status by cutting the program from 12 to 6 battalions.[129] Two battalions were activated in June 1962 at Fort Sill, Oklahoma.

Sergeant surface-to-surface missile on launcher (*U.S. Army Aviation and Missile Life Cycle Management Command*)

By mid-1963, the missile appeared vulnerable to interception, leading to the addition of ground-launched decoys and airborne jammers. By September 1964, seven battalions had been deployed: four in Germany and one each in Italy, Korea, and Japan. The next year, work began on miniaturized, solid-state electronics aimed at raising preflight reliability above 90 percent. By 1967, demonstrated preflight reliability stood at 70 percent and demonstrated inflight reliability at 77 percent; by 1968, those numbers were at 72 and 76 percent, respectively. It reached full production only in 1968. Despite the difficulties, Sergeant constituted a significant advance over Corporal:

> [Sergeant] was only half as large and bulky and required less than one-third as much ground support equipment [than Corporal]. Its highly reliable solid propellant rocket motor could be readied for firing in minutes, whereas the Corporal's high-compression propulsion system required hours to prepare for firing and invited plumbing failures, fires, and explosions. Another advantage was in the guidance technique, the Sergeant using an all-inertial on-board guidance system that made it immune to all known enemy electronic countermeasures. . . . Sergeant was the first missile to be fielded with anything like the degree of automation designed into it for checkout, firing, troubleshooting, and maintenance.[130]

The verdict on co-contracting is less favorable. Experiencing development problems during production was hardly unique to Sergeant. But the lack of JPL development support into production made the transition slower and more difficult than the Army had expected.

THE HELICOPTER COMES OF AGE

"Cavalry, and I Don't Mean Horses!" was the title of Maj. Gen. James M. Gavin's seminal 1954 article. Completely heliborne units, he emphasized, could carry out tactical missions rather than mere transportation tasks.[131] Maj. Gen. Hamilton H. Howze, who became the chief apostle of this doctrine, spoke in 1957 about creating large, completely airmobile units that he dubbed "sky cavalry." Early in 1960, an Army Requirements Review Board chaired by Lt. Gen. Gordon B. Rogers assessed ways of meeting the need for light observation aircraft and improving surveillance and tactical transport capabilities. It recommended making the Bell Aircraft Corporation's general utility helicopter, the Vertol Aircraft Corporation's double-rotor cargo helicopter, and a new light observation helicopter the foundation of Army air mobility.[132]

Lt. Gen. Hamilton H. Howze (*Personality Photograph Collection, U.S. Army Military History Institute*)

In June 1955, Bell won a contract to develop a general utility helicopter. The company's earlier piston-engine helicopter had worked well in Korea, and Bell began flying a model with a gas turbine engine.[133] At the time, Avco Lycoming (the engine division of the Avco Manufacturing Corporation)—with Army backing—was developing a T53 turbine engine. Bell engineers, working with Lycoming, tailored the T53 to Bell's specifications. The first flight of the UH–1, mating Bell's frame with Lycoming's engine, took place in October 1956. By August 1958, Bell had delivered six UH–1 Hueys for testing. A contract for 100 UH–1As followed in March 1959. The Hueys next went to the 82nd and 101st Airborne Divisions for field testing during the first half of 1960. During FY 1961, output rose from 10 to 30 machines per month. Bell quickly brought out additional versions with incremental improvements. The company delivered its first UH–1B, with an engine rated at 1,000 horsepower compared to 700 in the UH–1A, in March 1961. The UH–1D featured a 1,100-horsepower engine and a cabin large enough for 12 fully equipped soldiers. It first flew in August 1961, with deliveries starting in 1963.[134]

The Army also needed to replace its piston-powered cargo helicopters. In 1959, Vertol won a contract to develop a larger version of its twin-turbine Chinook. The fuselage of the CH–47 Chinook was made long enough to carry either 40 fully equipped soldiers or all the components of a Pershing missile. The Army ordered 5

CH–47s for testing, 5 more in 1960, and another 42 during 1961. During 1963–1964, the production line was turning out five per month.[135]

The acquisition of a light observation helicopter (LOH), designated the OH–6A Cayuse, broke new ground in several ways. Under procedures then in effect, the Army developed and procured aircraft using facilities and personnel of the Navy or Air Force. In March 1960, after the Army had rejected three models, the Army's chief of transportation asked the Bureau of Naval Weapons to let contracts for an LOH competition. The Transportation Corps provided the desired characteristics, which the bureau passed along to industry.[136]

UH–1A Iroquois ("Huey") (*U.S. Army Center of Military History*)

During January 1961, 12 companies submitted 19 designs to meet the Army's need for a small, highly maneuverable helicopter for reconnaissance. For industry, the stakes were high because manufacturers felt sure that a modified version would find a large civilian market. A joint Army-Navy evaluation group recommended developing designs by Bell and Hiller Helicopters. The Army's deputy chief of staff for operations suggested also pursuing a Hughes design that went beyond proven engineering capabilities but offered the opportunity for a technological breakthrough. The Army's LOH Design Selection Board, chaired by Lieutenant General Rogers, recommended procuring the Hughes design as well.[137]

CH–47 Chinook (*U.S. Army Center of Military History*)

Under past practice, the Navy would have carried LOH procurement to completion. However, DoD directive 3200.9 (Initiation of Engineering and Operational Systems Development), which took effect on 1 July 1965, allowed the Army to procure directly from manufacturers, who were free to make design and engineering decisions. As long as manufacturers' designs met the Federal Aviation Administration's requirements, the Army would not introduce any changes.[138]

In November 1961, Bell, Hiller, and Hughes each received a $6 million fixed-price contract to build five prototypes. Each firm found itself forced to spend an extra $2 million or more. In September 1964, after testing, Army evaluators ruled out Bell's entry as weighing too much. The survivors, Hiller and Hughes, were pursuing distinctly different design approaches. The Army had indicated that it did not want to increase the LOH's performance by later modifications. Nonetheless, Hiller offered a machine that could be improved without major changes to the airframe. Hughes chose to sacrifice growth potential and offered a model that was smaller, considerably faster, and lighter than Hiller's by some 400 pounds.[139]

The LOH Design Selection Board decided that since Hughes and Hiller were equal from a cost-effectiveness standpoint, the firm that submitted a lower price would win a three-year contract for 714 helicopters plus an option for 357 more at the same unit price. Sealed bids opened on 21 May 1965 showed that Hiller's was $22.250 million, while Hughes's was $14.968 million; both bids excluded engines and avionics. Somehow, beforehand, Hiller's cost data had been improperly disclosed to Hughes. Judging that the leak had neither helped Hughes nor harmed Hiller, the Army awarded the contract to Hughes. Although Hiller officials calculated that materials alone would cost $35,000 per aircraft, they had quoted a unit price of $29,415. Hughes's bid worked out to $19,860. Spokesmen for Hughes insisted that its price after the initial order would be based on cost plus a reasonable profit and confidently predicted selling more than 8,000 LOHs to the services, foreign governments, and civilians.[140]

As things turned out, this was a rare case in which buying-in benefited the Army much more than Hughes. Late in 1965, the Army decided to buy 121 of the Hughes-designed OH–6A Cayuses over and above those specified in the three-year contract. Negotiations broke down, however, when Hughes refused to budge from an all-inclusive price of $49,800 per helicopter, and the Army would not go beyond $45,000. In April 1966, the Army elected to fill its LOH requirement by keeping in Vietnam 121 UH–1Bs that were scheduled to return to the United States for rebuilding. Nonetheless, in 1968, with OH–6A production running at more than 70 per month, the Army bought 300 more OH–6As at an all-inclusive price of $53,000 per unit.[141] But that was the last purchase. Commercial and foreign military sales never came near expectations, and Bell won the contract for the successor OH–58 Kiowa.[142]

OH–6A Cayuse (*U.S. Army Center of Military History*)

How should Hueys, Chinooks, and Cayuses be employed? Starting in the mid-1950s, the Army experimented with small units of "sky cavalry" and studied the feasibility of an "Armair" brigade, a completely airmobile combined-arms unit capable of sustained operations. McNamara, however, believed that the evolution of doctrine was not keeping pace with advances in hardware. Accordingly, on 19 April 1962, he ordered the Army to break with traditional viewpoints and take a bold new look. In response, Lieutenant General Howze presided over a board that tested and evaluated concepts of air mobility. In August 1962, the Howze board recommended creating air assault divisions comprising 459 aircraft (including 154 Hueys and 48 Chinooks) compared with 100 in a standard division. Firepower would come from 105mm howitzers and Little John rockets transported by Chinooks, augmented by 36 Hueys armed with 2.75-inch rockets.[143]

During 1963–1964, the Army formed the 11th Air Assault Division to test concepts and tactics. Maneuvers showed that units could conduct quick-reaction, flexible operations at a high tempo, but they also revealed poor ground mobility and vulnerability to armored attack. The 1st Cavalry Division (Airmobile), activated on 1 July 1965 with a complement of 434 helicopters, seemed ideally suited for a low-intensity counterinsurgency war and promptly deployed to South Vietnam. Huey production rose to 450 in 1963, 700 in 1964, and 759 in 1965. Bell privately noted that its UH–1 was almost certain to be regarded everywhere as a success.[144]

The first armed helicopter company—UH–1Bs outfitted with machine guns and 2.75-inch rockets—had gone to South Vietnam in October 1962. Senior Army officers pushed for a specially designed weapons support helicopter built with available, proven components. On 27 March 1963, Secretary of the Army Cyrus Vance disapproved but emphasized that he did so only to spur development of a weapon system that would come closer to being the best possible. He wanted a cutting-edge system.[145]

The Army initiated development of an Advanced Aerial Fire Support System, the AH–56A Cheyenne helicopter. Since Cheyenne could not be fielded before 1970, Vance, now the deputy secretary of defense, suggested meeting immediate requirements by upgrading a helicopter already in service. Accordingly, in March 1964, Secretary of the Army Stephen Ailes ruled that UH–1Bs as currently configured would suffice.[146]

To start Cheyenne, the Army funded an exploratory development program aimed at providing data on "compound" helicopter configurations. Of 38 prospective bidders approached in August 1964, 12 responded. On 12 March 1965, Lockheed and the Sikorsky Aircraft Corporation won awards to carry out contract definition. Following the procedures in DoD Directive 3200.9, both firms submitted cost and engineering development proposals. An AH–56A Source Selection Evaluation Board deleted some items (passive radar defense, laser range finder, terrain avoidance radar) as being unattainable by 1970. On 3 November 1965, Lockheed was awarded an engineering development contract.[147]

Already, however, armed UH–1Bs had failed the test of combat. "Until Vietnam," a DoD official acknowledged, "we were sure we had found the most effective application of the helicopter and we were wrong."[148] A troop-carrying UH–1B cruised at 100 to 130 knots, but externally mounted machine guns and rocket pods cut its speed to 85 knots. On 18 July 1965, General William C. Westmoreland, commander of U.S. forces in South Vietnam, urgently asked for an armed helicopter fast enough to escort helicopter formations, scout ahead, and silence enemy ground fire.[149]

The Army's assistant chief of staff for force development and the chief of R&D instructed AMC to canvass industry for an off-the-shelf helicopter that would fly faster and deliver significantly more firepower than the armed UH–1B. General Besson created a group to evaluate Bell's AH–1G, Kaman's UH–2, Piasecki's 16H–1B, Sikorsky's S–61, and Vertol's CH–47, rating each in terms of improvement over the UH–1B, with the most importance assigned to firepower and a firm's production capability. Sikorsky's S–61 scored highest, so AMC recommended acquiring it. The S–61 also placed first in "productivity," defined as the product of firepower and range divided by unit cost.[150]

AH–1G Huey Cobra (*U.S. Army Center of Military History*)

An assessment by the deputy chief of staff for logistics, prepared at the request of the assistant chief of staff for force development, came out differently. DCSLOG evaluated only Bell's AH–1G, Kaman's UH–2, and Sikorsky's S–61. The AH–1G helicopter gunship, a derivative of the UH–1H and the latest in the Huey series, combined the Huey's engine, transmission, and tail structure with a new fuselage and armament; over 90 percent of the parts were interchangeable. The main difference was the AH–1G's radically narrower fuselage, a mere 38 inches wide. Kaman's UH–2 was in the Navy's inventory but not the Army's; introducing it would require stocking more than 300 line items. Similarly, Sikorsky's S–61 was only in the Air Force and Navy inventories; adding it to the Army's would require stocking 390 line items. Comparing cost estimates, man hours of maintenance per hours of flight, and time between overhauls of components, the AH–1G appeared substantially better than its competitors. Based on the Huey's record, the derivative AH–1G would be able to fly 70 hours per month, slightly more than double the rates of UH–2s and S–61s. Consequently, DCSLOG named Bell's AH–1G as the best choice.[151]

Faced with conflicting views, the chief of staff ordered flight tests of each helicopter. On 7 September 1965, Bell put the AH–1G through its first flight. By early December, after the three competitors had been tested, the chief of staff selected the AH–1G. Secretary McNamara disapproved. Among other reasons, he cited the lack of a performance guarantee, the absence of firepower tests to validate Bell's claims, inadequate flight testing, and the very short time between prototype and production delivery. The Army countered that Bell would provide a performance guarantee and that quantitative tests had established the UH–1H's ability to meet requirements in Southeast Asia. Lead time would be short because Bell had started fabricating a UH–1H prototype more than a year before.[152]

On 2 January 1966, General Westmoreland reaffirmed his urgent need for a helicopter gunship. Two months later, Deputy Secretary of Defense Vance approved procuring the AH–1G. On 13 April 1966, Bell contracted to deliver 110 between May and December 1967 and 210 more by June 1968.[153] An AH–1G Cobra was supposed to reach 130 knots and carry an automatic grenade launcher, 2.75-inch rockets, and a six-barreled 7.62mm machine gun.

Meanwhile, the AH–56A Cheyenne followed the development process laid out in DoD Directive 3200.9, with a lapse of 32 months between the statement of requirements and the selection of Lockheed in November 1965. For the AH–1G Cobra, only 9 months had elapsed between a statement of requirements and a production contract.[154] The time difference was typical of the gap between adapting off-the-shelf and pursuing a range of advances. Moreover, the AH–56A was competing against the Air Force's A–X close support aircraft (the A–10 Thunderbolt). The Army stopped Cheyenne production in May 1969 after a fatal crash. Under total package procurement, however, the development contract remained in place with $17 million allocated for FYs 1970 and 1971. In 1972, when Cheyenne's unit cost had risen from the original projection of $500,000 to more than $4 million, the program was canceled.[155]

* * * * *

Army Regulation 11–25 had set a goal of reducing the time between initiation and production to four years. Only the Davy Crockett, which otherwise must be labeled a failure, and Bell's Cobra helicopter gunship, derived in large part from Bell's Huey, met that target. Excepting the Jupiter IRBM program in the 1950s and the Pershing MRBM program in the late 1950s–early 1960s, concurrency did not work well for the Army.[156] In the 1960s, most notably with the Shillelagh, Redeye, and Sergeant missiles, efforts to overlap development with production created more problems than they solved.

Nonetheless, between 1959 and 1968, the Army re-equipped itself almost completely. A new weapon system reached the troops in most years. During 1959, the first M–14 rifles and M–60 machine guns arrived; deliveries of UH–1A helicopters started in June. In 1960, the Food Machinery and Chemical Corporation began turning out M113 armored personnel carriers; a diesel-powered M113A1 followed in 1964. Over the next 20 years, more than 70,000 M113s would be built for the U.S. Army and sold to foreign governments.[157] During 1960, also, the first M60 tanks entered the inventory. The first deliveries of the CH–47 cargo helicopter and the improved UH–1B began in 1961. Two years later came the UH–1D, the M72 light antitank weapon, the novel but much-praised M79 grenade launcher carried by infantrymen, and the M109 155mm self-propelled howitzer. Breaking with past practice where standard artillery tubes had been placed on modified tank hulls, the M109 stripped away external recoil mechanisms and breech assemblies, mounting the tube on a specially developed carriage. To correct shortcomings exposed in the Korean War, where the enemy encircled units and used the reverse sides of steep mountain slopes, the M109 had a 360-degree traverse, 75-degree elevation, and an enclosed crew shelter. Production of M–16 rifles began in 1964. The OH–6A Cayuse light observation helicopter appeared in 1966, the AH–1G Cobra the next year. In 1968, the M551 Sheridan combat vehicle was approved for issue, and the Sergeant and Redeye missiles moved from limited to full production. All told, the Army fielded a range of weapon systems unmatched by other services.[158]

Nonetheless, many OSD civilians rated the Army's acquisition performance as weak. Their main complaint was the lack of systematization, giving the impression of a helter-skelter approach that left project conception to chance and relied on improvisation to solve development problems. Indeed, every weapon system traced to a different originator or sponsor. The M–16 started with Eugene Stoner and ArmaLite, Shillelagh and Sheridan with the ARCOVE study, the Main Battle Tank 70 with Secretary McNamara, TOW with the chief of R&D, Redeye with Convair, Mauler with the Continental Army Command, Chaparral with the assistant secretary of the Army (R&D), Sergeant with the Jet Propulsion Laboratory, and Cobra with Bell and General Westmoreland. Likewise, every weapon system followed its own unique course of development, some being assigned program managers early and some late. When delays or difficulties arose, the device most frequently employed was appointment of an ad hoc board or committee. When committees split, as in the M–14 versus AR–15 debate, the chief of staff and the secretary of the Army opted for a compromise that did not last long. The difficulty in mating Shillelaghs with M60s and Sheridans, aggravated by changes in project management and performance goals, pointed to a continuing weakness in conceptualizing and integrating weapon systems.

Civilians held other reservations about the Army's performance. While there were clear failures, like M–14 production and MBT70 development, the Army could not boast of any spectacular successes, like Minuteman and Polaris. The M–16, although it eventually earned general praise, was beset with controversies throughout the 1960s. McNamara saw the Army as often hidebound, having to be pushed into such innovations as the M–16 and air mobility. Yet hindsight makes these judgments seem unduly harsh. The Army by 1965 was far better equipped than it had been for any previous war. In Vietnam, however, major achievements in acquisition—fielding an array of helicopters and producing new families of small arms—would be overshadowed by the shortcomings of policy and strategy.

Endnotes

1. Table 4, "Department of Defense Manpower, FY 1940–2005," in *Key Officials, 1947–2004*.

2. John B. Wilson, *Maneuver and Firepower* (Washington, DC: U.S. Army Center of Military History, 1998), 297–303. Conversions from pentomic to ROAD took place between 1962 and 1964.

3. Ibid., 293–298, 303–308, 337 ("profound," 308). The figures for equipment allocations come from draft memo, SecDef to Pres Kennedy, "Recommended FY 1964–1968 General

Purpose Forces," nd [late Nov 62], 37–38, binder "FY 1964 DPMs," box 116, Glass Papers, RG 330, OSD/HO.

4. James E. Hewes, Jr., *From Root to McNamara* (Washington, DC: U.S. Army Center of Military History, 1975), 242, 253, 258, 262, 261 (quotations, 262).

5. Ibid., 256–257, 332.

6. AR 11–25 (Reduction of Lead Time) is described in Converse, *Rearming for the Cold War,* 618–619.

7. Hewes, *From Root to McNamara*, 316.

8. Ibid., 316–318, 324, 331–335, 338–341, 350–351; interview, Gen. George H. Decker by Lt. Col. Dan Ralls, sec four, 51, 8 December 1972, U.S. Army War College Collection, copy at CMH. During the Army's review of the Hoelscher committee's recommendations and the planning for the establishment of the new logistics command, the Systems and Materiel Command was first redesignated the Materiel and Development and Logistics Command and then upon activation was renamed the Army Materiel Command. See *Arsenal for the Brave: A History of the United States Army Materiel Command, 1962–1968* (Alexandria, VA: U.S. Army Materiel Command [AMC] Historical Office, 30 September 1969), 9, 14.

9. Hewes, *From Root to McNamara*, 350, 354–355, 358–359, 363–364.

10. *Arsenal for the Brave*, 15, 18; *A Brief History of AMC and Biographies of the Commanding Generals* (Alexandria, VA: U.S. Army Materiel Command Historical Office, December 2000), 1.

11. Lt. Gen. Frank S. Besson, Jr., remarks at AUSA convention, 10 Oct 62, fldr Army Organization, 1962, box 585, OSD/HO; Lt. Gen. Frank S. Besson, Jr., "Project Management within the Army Materiel Command," in *Science, Technology, and Management*, ed. Fremont E. Kast and James E. Rosenzweig (New York: McGraw-Hill Book Company, 1963), 91–98; Lt. Gen. Frank S. Besson, Jr., "Acquisition of Weapon Systems," lecture to the Industrial College of the Armed Forces, Fort Lesley J. McNair, Washington, DC, 27 Jan 64, 8, 32, 12, NDU Library; Raymond J. Snodgrass, *The Concept of Project Management* (Alexandria, VA: AMC Historical Office, June 1964), 89–95, 126–128; *Arsenal for the Brave*, 15–18; AMC Oral History Program, *Reflections of Former AMC Commanders* (Alexandria, VA: AMC Historical Office, 1989), 10; Herbert A. Leventhal, "Project Management in Army Materiel Command, 1962–1987," AMC Historical Office, 1992, 10.

12. *Reflections of Former AMC Commanders*, 156–157.

13. Samuel G. Cockerham, "Huey Cobra—A Case Study in Weapon System Decision Making," 31 Mar 67, thesis no. 35, Industrial College of the Armed Forces, 28–33, NDU Library. This looks similar to the Air Force approach described in chapter VI, but the Army's practice often diverged from its formal procedures.

14. Department of Defense, *DoD Annual Report for FY 1963*, 119.

15. S.L.A. Marshall, *Men Against Fire: The Problem of Battle Command* (New York: Morrow, 1947). Marshall, an officer in the Army Reserve, had been a combat historian in World War II.

16. Semiautomatic meant firing one round for each squeeze of the trigger. Fully automatic meant firing in a continuous burst as long as the trigger was squeezed and there were rounds in the magazine.

17. Edward C. Ezell, *The Great Rifle Controversy* (Harrisburg, PA: Stackpole, 1984), 137, 167, xix. Development of the AK–47 is described in C.J. Chivers, *The Gun* (New York: Simon & Schuster, 2010).

18. Ezell, *Great Rifle Controversy,* 135–138.

19. Ibid., 140–142.

20. Ibid., 144–148.

21. Ibid., 148–150, 157.

22. Ibid., 151–152.

23. Ibid., 322 fn 22. While Winchester manufactured more than 80 percent of an M–14 in-house, H&R subcontracted a much greater percentage of the components.

24. Ibid., 202–203; James N. Davis, "How the Army Got Its Rifle Changed," 1986, unpublished paper provided to the author. Gibson reported to the chief of ordnance and, after AMC's creation, to Lieutenant General Besson.

25. Ibid., xii, 203.

26. Davis, "How the Army Got Its Rifle Changed." Lesser difficulties continued. Slippages occurred at Springfield due to deficiencies in the firing pins and at Winchester due to a labor strike and to readjustments of the receiver line and tooling. By mid-1962, the Army's M–14 inventory totaled 409,740 plus 63,500 diverted to the Marine Corps. Memos, AsstSecDef Morris to Sec McNamara, "Monthly Highlights—Major Programs—April and May 1962," 16 Apr, 21 May 62, A–11, box 973, OSD/HO.

27. In 1958, bids by Winchester and H&R were $68.75 and $81.03, respectively; their FY 1960 production prices were $118.61 and $124.27. Ezell, *Great Rifle Controversy*, 144, 153.

28. West Virginia's delegation capitalized upon the fact that John F. Kennedy's victory in that state's presidential primary had been crucial to winning the nomination.

29. Ezell, *Great Rifle Controversy*, 153–154.

30. Ibid., 155–156; Denis H.R. Archer, ed., *Jane's Infantry Weapons, 1976* (London: Jane's Publishing Group, 1976), 242.

31. Chivers, *The Gun*, 274–275; Thomas L. McNaugher, *The M–16 Controversies* (New York: Praeger, 1984), 51–55; Ezell, *Great Rifle Controversy*, 169.

32. SALVO tests involved firing, swiftly and against partly hidden targets, several small-caliber projectiles from a weapon with light recoil. Many more hits were scored that way than by single shots from an M–1. Ezell, *Great Rifle Controversy*, 168; McNaugher, *M–16 Controversies*, 55–56.

33. Ezell, *Great Rifle Controversy*, viii, 174–180.

34. McNaugher, *M–16 Controversies*, 59, 63–66; Ezell, *Great Rifle Controversy*, 180–183.

35. Chivers, *The Gun*, 277; Ezell, *Great Rifle Controversy*, 183. Colt was a subsidiary of Fairbanks Whitney Corporation.

36. McNaugher, *M–16 Controversies*, 79–81.

37. Chivers, *The Gun*, 281–283. Since the rifle "never again seems to have registered quite the lethality it produced" during this combat test, McNaugher (*M–16 Controversies*, 108, fn 34) suggests that Colt at such an early stage of production could not meet Stoner's barrel twist specification (one turn in 14 inches), thereby giving the bullet a low spin rate that rendered it very unstable, producing a deadly tumbling when it entered the body.

38. Davis, "How the Army Got Its Rifle Changed."

39. Ezell, *Great Rifle Controversy*, 188. The characterization of Lieutenant Colonel Hallock is taken from Davis, "How the Army Got Its Rifle Changed."

40. Chivers, *The Gun*, 272–274; House, Cte on Armed Svcs, *Report of the Special Subcommittee on the M–16 Rifle Program*, 90 Cong, 1 sess, 5327–5329.

41. Ezell, *Great Rifle Controversy*, 189; McNaugher, *M–16 Controversies*, 91.

42. McNaugher, *M–16 Controversies*, 91–92; Davis, "How the Army Got Its Rifle Changed."

43. Ezell, *Great Rifle Controversy*, 191; McNaugher, *M–16 Controversies*, 92–95; *Report on the M–16 Rifle Program*, 5329–5330.

44. Email, Gen. Paul F. Gorman, USA (Ret.), to Walter S. Poole, 19 Mar 04. During the winter of 1962–1963, then-Major Gorman was working in the Office of the Deputy Chief of Staff for Operations. McNaugher, *M–16 Controversies*, 96.

45. McNaugher, *M–16 Controversies*, 97–98; Chivers, *The Gun*, 290–291; R. Blake Stevens and Edward C. Ezell, *The Black Rifle* (Toronto: Collector Grade Publications, 1987), 120.

46. House, Committee on Armed Services, *Hearings Before the Special Subcommittee on the M–16 Rifle Program*, 90 Cong, 1 sess, 90 H2336–0.4 (Washington, DC: GPO, 1967), 4487–4488, 4492, 4544–4545, 4550, 4700, 4756–4757, 4800–4801, 5003–5004, 5011–5013.

47. McNaugher, *M–16 Controversies*, 97–103 (quotation, 103); Chivers, *The Gun*, 292.

48. This basic order would be enlarged piecemeal during 1964–1965. Stevens and Ezell, *The Black Rifle*, 134; Ezell, *Great Rifle Controversy*, xix (quotation).

49. McNaugher, *M–16 Controversies*, 119–122. The Force Planning and Analysis Office was essentially dismantled soon after it completed this study. Ibid., 130 fn 15.

50. Chapter XI describes the jamming controversy.

51. McNaugher, *M–16 Controversies*, 122–127; Ezell, *Great Rifle Controversy*, 227–228.

52. R.P. Hunnicutt, *Patton* (Novato, CA: Presidio Press, 1984), 11–12, 149; Army Materiel Command, "Development of 152mm Full-Tracked Combat Tank, M60A1E1," Jan 66, 1; "Report of the ARCOVE," 20 Jan 58, 11, 14; both documents provided by Dr. Robert S. Cameron, Armor Branch Historian, U.S. Army Training and Doctrine Command.

53. Hunnicutt, *Patton*, 149–155. Work on a T95 main battle tank ended in 1960; the pilot chassis were used as test beds to develop components for future tanks. R.P. Hunnicutt, *Abrams* (Novato, CA: Presidio Press, 1990), 90.

54. Hunnicutt, *Patton*, 157, 165 (Design and technical differences between M48A2s and M60s are described on 158–159); Christopher S. Foss, ed., *Jane's Armour and Artillery, 1981–1982* (London: Jane's Publishing Group, 1982), 90–91.

55. Elizabeth J. DeLong, James C. Barnhart, and Mary T. Cagle, *History of the Shillelagh Missile System, 1958–1982* (Redstone Arsenal, AL: U.S. Army Missile Command, August 1984), 37, 13–15, provided by Dr. Cameron.

56. DeLong, Barnhart, and Cagle, *Shillelagh*, 18–22.

57. Memo, G.T. Croskery, ODDR&E, to Mr. McLucas, "Shillelagh Missile Problem and Concept," 13 Jun 60; memrcd by G.T. Croskery, "SHILLELAGH Missile System," 9 Jun 61; both in fldr Shillelagh (fldr #1) Late 1960 and CY 1961, 68–A–0234, RG 330, Archives II. Alex Daverede of the National Archives directed the author to this file.

58. Memo, G.T. Croskery, ODDR&E, to Mr. McLucas, "Shillelagh Missile Problem and Concept," 13 Jun 60; memrcd by G.T. Croskery, "SHILLELAGH Missile System," 9 Jun 61; both in fldr Shillelagh (fldr #1) Late 1960 and CY 1961, 68–A–0234, RG 330, Archives II. DeLong, Barnhart, and Cagle, *Shillelagh*, 15–17, 38, 35, 43–44, 7, 48, 50, 52, 56.

59. DeLong, Barnhart, and Cagle, *Shillelagh*, 20; "M551 Weapon System Chronology," provided by Dr. Cameron.

60. Hunnicutt, *Patton*, 168–169, 179, 171, 174 (170 and 174 detail how M60A1s differed from M60s and M60E1s); DeLong, Barnhart, and Cagle, *Shillelagh*, 59–62.

61. DeLong, Barnhart, and Cagle, *Shillelagh*, 62; memo, DDR&E Brown, ASA (R&D) Finn Larsen, and ASA (I&L) Ignatius to Sec McNamara, "Compression of the SHILLELAGH/ARAAV Program," 9 Dec 61, fldr Shillelagh (fldr #1), Late 1960 and CY 1961, TOCV, 68–A–0234, RG 330, Archives II.

62. Memo, DDR&E Brown to Sec McNamara, "Status Report on SHILLELAGH," 16 Jun 62, fldr Anti-Tank Weapons (1963), 68–A–0234, RG 330, Archives II.

63. DeLong, Barnhart, and Cagle, *Shillelagh*, 62–63, 66–67, 73–75, 69; memo, "Compression of the SHILLELAGH/ARAAV Program." Aeronutronic claimed to have made itself more efficient by shifting from being "five separate companies" to an organization built around centralized, functional support. John B. Lawson, address, "Aeronutronic's Organization for Effective Program Management," 15–17 May 63, in "Management Studies, Administrative and Technological Histories, 1940–1967," box 10, 71–A–2207, RG 402, Archives II.

64. ARGMA was abolished in December 1961 and its functions transferred to the Army Ordnance Missile Command. In August 1962, AOMC was discontinued and the Army Missile Command was established. DeLong, Barnhart, and Cagle, *Shillelagh*, 18.

65. Ibid., 22, 24, 26, 30, 31, 32. The project office grew from 32 personnel in December 1964 to a peak of 111 in December 1967.

66. General Motors later reassigned the work to its Allison Division with no change of personnel. The contract also covered production of M109 self-propelled 155mm howitzers so that start-up and overhead costs could be shared.

67. DeLong, Barnhart, and Cagle, *Shillelagh*, 76–79, 82. Missile deliveries ran as follows: 7,837 in FY 1966, 7,880 in FY 1967, 16,188 in FY 1968, 27,784 in FY 1969, 20,955 in FY 1970, and 7,550 in FY 1971, for a total of 88,194. Ibid., 79.

68. R.P. Hunnicutt, *Sheridan: A History of the American Light Tank*, vol. II (New York: Presidio Press, 1995), 101; House, Investigating Subcte of the Cte on Armed Svcs, *Review of Army Tank Program*, 91 Cong, 1 sess, 8, 10, 12–14.

69. *Review of Army Tank Program*, 17–20, 31; DeLong, Barnhart, and Cagle, *Shillelagh*, 117; "M551 Weapon System Chronology," 12; Hunnicutt, *Sheridan*, 249. The Sheridan carried two of the seven components in a Shillelagh's guidance and control set—the power supply and the rate sensor, used for firing conventional ammunition. DeLong, Barnhart, and Cagle, *Shillelagh*, 101.

70. *Review of Army Tank Program*, 8–9.

71. For these, a letter contract of January 1966 was followed by a firm fixed-price contract 12 months later. U.S. Army Weapons Command, *Procurement History and Analysis of M60 Tank Family*, 28 Jan 69, 224, 231.

72. *Review of Army Tank Program*, 34–37; DeLong, Barnhart, and Cagle, *Shillelagh*, 93–94.

73. *Review of Army Tank Program*, 433, 437; Hunnicutt, *Patton*, 101, 188, 193. The M60A2 was distinguished by being the first U.S. tank with a gyro-stabilized turret, allowing it to fire accurately while on the move. Information supplied by Dr. Blair Haworth, U.S. Army Center of Military History.

74. Hunnicutt, *Sheridan*, 141. The Sheridans at the National Training Center were modified to look like Soviet armored fighting vehicles.

75. Hunnicutt, *Patton*, 149–155; Richard M. Ogorkiewicz, *Technology of Tanks* (Surrey, UK: Jane's Information Group, 1991), 73–75, 35–36; Hunnicutt, *Abrams*, 162.

76. Hunnicutt, *Abrams*, 102–116; Thomas L. McNaugher, *Collaborative Development of Main Battle Tanks*, RAND N–1680–RC (Santa Monica, CA: RAND, August 1981), 4–6.

77. Interview, Lt. Gen. Welborn G. Dolvin, USA (Ret.), by Joseph Mihalak, 1 Dec 87, 10, U.S. Army Tank-Automotive Command; McNaugher, *Collaborative Development*, 4–6; memo, AsstSecDef Morris to SecArmy et al., "Monthly Highlights—Major Programs—October 1963," 31 Oct 63, A–11, box 974, OSD/HO.

78. Dolvin was dual-hatted, reporting to the Army chief of staff as program manager for the U.S.–West German effort and to General Besson as project manager for the MBT70. He also sent weekly progress reports directly to Secretary McNamara. Dolvin interview, 13, 11. Dolvin held this post until October 1966. His successor, Maj. Gen. Edwin H. Burba, filled the position until June 1968.

79. McNaugher, *Collaborative Development*, 8–10. A Source Selection Board headed by the deputy commanding general, AMC, chose General Motors over Chrysler and the FMC Corporation. Dolvin thought the board "pretty well knew what [Chrysler] could do. We were going into something brand new. We wanted a company with a maximum backing. And, [GM] made the best proposal." Dolvin interview, 20–21.

80. Dolvin interview, 3, 17.

81. McNaugher, *Collaborative Development*, 14, 13; interview, Brig. Gen. Bernard C. Luczak, USA (Ret.), by Joseph Mihalak, 17 Nov 85, 14, U.S. Army Tank-Automotive Command; Dolvin interview, 19.

82. McNaugher, *Collaborative Development*, 10–12.

83. Ibid., 13.

84. Dolvin interview, 11–13, 15, 17; McNaugher, *Collaborative Development*, 13, 17. However, the French AMX13 light tank did incorporate an autoloader.

85. Hunnicutt, *Abrams*, 120.

86. Memo, AsstSec Enthoven to Sec McNamara, "MBT–70," 12 Jul 67, fldr DCP MBT–70 1969, box 2, 70–A–6284, RG 330, Archives II. Some of Enthoven's arguments were open

to challenge. The MBT70's gun/launcher was more advanced than earlier 152mm weapons and was slated to have a kinetic-energy antiarmor round. The Sheridan had very little, if any, overlap between the maximum range of its conventional round and the minimum range of Shillelagh. Information provided by Dr. Blair Haworth, U.S. Army Center of Military History.

87. Hunnicutt, *Abrams*, 120; memcon, "Schmidt-McNamara Meeting, 4:30 PM, 9/21/67," fldr Germany 333, Aug-Sep 1968, ISA Country Files, 72–A–1498, RG 330, WNRC. Dr. Edward Drea found this document and provided a copy.

88. "Main Battle Tank (MBT–70)," nd, fldr MBT Correspondence–1969, box 2, 72–A–6294, RG 330, Archives II; McNaugher, *Collaborative Development*, 18, 23; Hunnicutt, *Abrams*, 130.

89. Memo, N.R. Augustine to Mr. Fowler, 13 Jan 70, w/att "Engine Selection Criteria;" fact sheet by Lt. Col. Hochmuth, "CAE 1100 Engine," 6 Jan 69, fldr MBT Correspondence–1969, box 2, 72–A–6294, RG 330, Archives II; Hunnicutt, *Abrams*, 136–137, 154.

90. McNaugher, *Collaborative Development*, 21, 23, 26 (quoted passage, 23). Luczak believed that GM executives who came to Washington on other business called on him briefly so they could bill the government for their trips. Luczak interview, 15–16. During 1964–1965, Colonel Luczak had presided over final review and termination of the Mauler missile system, described later in the chapter.

91. Luczak interview, 10–11. According to McNaugher, the United States took responsibility for a few of the technically advanced systems (Shillelagh, variable-compression diesel engine, primary fire control loop), West Germany for more of the less difficult (secondary armament, transmission, suspension, loader). *Collaborative Development*, 17.

92. Dolvin interview, 26; Luczak interview, 26.

93. The Soviet T72, which entered production in 1971–1972, was rated by the U.S. Army as superior to the M60A1 and equal to the M60A3, which did not go into production until 1978. *Jane's Armour and Artillery, 1981–1982*, 50, 94.

94. Mary T. Cagle, *History of the TOW Missile System*, Historical Monograph Project Number DARCOM 85M (Redstone Arsenal, AL: U.S. Army Missile Readiness Command, 1977), 12–15. Short-term requirements were filled by 106mm recoilless rifles and French wire-guided SS–11 and ENTAC missiles.

95. Ibid., 17–21.

96. Ibid., 16–26.

97. Ibid., 33, 40, 18, 41, 51, 200, 36.

98. Ibid., 45–46, 76, 82.

99. Ibid., 55–56.

100. Ibid., 67–68, 71–74.

101. Ibid., 74, 84–85. To introduce competitive procurement, Chrysler in January 1969 was given a contract for an "educational buy" of 200 missiles during FY 1971. However, in November 1971 Hughes won a four-year "winner-take-all" competition for a firm fixed-price contract that reduced the missile's unit price 42 percent below previous costs. Ibid., 111, 113.

102. Ibid., 40; DeLong, Barnhart, and Cagle, *Shillelagh*, 117. Between FYs 1968 and 1976, Army and Marine Corps purchases came to 134,210 TOW missiles and 5,637 launchers. Cagle, *TOW*, 117.

103. General Creighton Abrams called TOW's employment in Vietnam an unqualified success. In 1972, TOWs mounted on UH–1 helicopters destroyed many enemy tanks. Jack S. Ballard, *Development and Employment of Fixed-Wing Gunships, 1962–1972* (Washington, DC: Office of Air Force History, 1982), 243.

104. Mary T. Cagle, *History of the Redeye Weapon System*, Historical Monograph Project Number AMC 78M (Redstone Arsenal, AL: U.S. Army Missile Command, 1974), 6–7.

105. Ibid., 15–17.

106. Ibid., 36, 56, 46–50, 78.

107. Ibid., 36, 41, 46–47, 56, 77–78, 81–88, 90, 96–97, 100.

108. Ibid., 26, 29, 107–108, 112–120, 125.

109. Ibid., 131, 28–29, 121, 142.

110. Ibid., 155, 207.

111. Christopher Chant, *Air Defence Systems and Weapons: World AAA and SAM Systems in the 1990s* (Amsterdam: Elsevier Science, 1989), 105, 128.

112. This phase is described in Mary T. Cagle, *History of the Mauler Missile System*, Historical Monograph Project Number AMC 44M (Redstone Arsenal, AL: U.S. Army Missile Command, December 1968), 13–21.

113. Ibid., 29–39, 47 (quotation, 36–37).

114. Ibid., 63–69.

115. Ibid., 106–107, 97–100. For an analysis of PERT in the Navy's Polaris program, see chapter VIII.

116. Ibid., 174–179, 190–193.

117. Hawk was intended for defense at low and medium altitudes. Because its radars and associated vehicles were separate from missile launchers, the Hawk system had only limited mobility.

118. Ibid., 231–235, 227. Patriot did not become operational until 1986.

119. Ibid., 237–245, 213, 247 (quoted portion, 241). Costs of research, development, and test and evaluation came to $197 million. Ibid., 248.

120. Mary T. Cagle, *History of the Chaparral/FAAR Air Defense System*, Historical Monograph Project Number DARCOM 82 M (Redstone Arsenal, AL: U.S. Army Materiel Development and Readiness Command, May 1977), 3–5, 10. "Chaparral" derived from the Spanish *chaparro*, describing dense thickets of shrubs and dwarf evergreen oaks. The word seemed apt because, in each division, a large number of fire units were supposed to create a dense, almost impenetrable air defense.

121. Ibid., 3–5, 10, 13.

122. Over Missile Command's objections, General Besson established a single project manager for Chaparral and Vulcan in Washington, DC. The assistant managers at Missile and Weapons Commands, who had to handle most of the detailed work, complained about duplication and inadequate manning levels, particularly in the engineering staff. Ibid., 35, 19–20, 22, 59–60, 66, 82.

123. Ibid., 36–37, 46, 50–51, 55, 193.

124. Ibid., 50, 63, 66, 109, 194, 107; Chant, *Air Defence Systems*, 125.

125. Mary T. Cagle, *History of the Sergeant System*, Historical Monograph Project Number AMC 55M (Redstone Arsenal, AL: U.S. Army Missile Command, 1971), 22, 32, 200, 34, 41, 43.

126. Ibid., 44–46, 55, 58.

127. Ibid., 46, 50, 55–56, 58, 59, 61. JPL observed that it had been phased out of the Corporal program, then after a few months brought back for a considerable length of time. Ibid., 62.

128. Ibid., 158–159, 83–85. ABMA and ARGMA were abolished as separate headquarters in 1961, their functions merging into the Army Ordnance Missile Command. Ibid., 86.

129. Ibid., 180–181, 267, 188, 197, 200.

130. Cagle, *Sergeant*, 212, 216, 221, 225–227, 232–234 (quoted passage, 202–204). Between FYs 1950 and 1970, the Army spent $510,962,000 to develop and produce 528 missiles (including 300 for the War Reserve) with eight sets of tactical ground equipment. Ibid., 241.

131. *U.S. Army Combat Forces Journal* 4, no. 11 (June 1954): 22–27, reprinted the article originally appearing in the April 1954 issue of *Harper's Magazine*.

132. Richard P. Weinert, Jr., *A History of U.S. Army Aviation—1950–1962* (Fort Monroe, VA: Office of the Command Historian, U.S. Army Training and Doctrine Command, 1991), 181–182, 115–119. For a succinct review, see Edgar F. Raines, Jr., "Organic Tactical Air

Transport," *Military Review* 80, no. 1 (January-February 2000): 84–89.

133. This was a critical breakthrough. Helicopters with piston engines carried small payloads because a reciprocating engine weighed about three pounds for each horsepower it produced; much of its power was expended just lifting itself. That was why, during the Korean War, helicopters were limited largely to observation and medical evacuation. A turbine engine's power-to-weight ratio was much better. Most engines had the turbine and the compressor solidly attached to a shaft that connected them, so that loss of rotor speed or turns could cause an uncontrolled plunge. The solution came with development of "free-turbine" engines in which the turbine was not connected to a shaft, allowing operation at maximum efficiency independent of the rotor system. William R. Fails, *Marines and Helicopters, 1962–1973* (Washington, DC: History and Museums Division, Headquarters, U.S. Marine Corps, 1978), 42–43.

134. A UH–1H with 1,400 horsepower reached Army units in 1968. However, the "D" model had by far the largest production run. Chris Bishop, *UH–1 "Huey" Slicks 1962–1975* (Oxford: Osprey, 2003), 4–7, 9, 13–14; Weinert, *History of Army Aviation*, 203–205. The UH–1 was actually the HU–1 until 1962, when a tri-service system of designations was introduced.

135. Weinert, *History of Army Aviation*, 208–209. The Chinook's sales potential led Boeing to purchase Vertol in 1960. Philip Siekman, "The Big New Whirl in Helicopters," *Fortune* (April 1966): 125, 127. The production figures come from Butler, *Army Aviation Logistics and Vietnam,* 403-404.

136. Weinert, *History of Army Aviation*, 205–206.

137. Ibid., 206–207.

138. Ibid.

139. House, Subcte for Special Investigations, Cte on Armed Svcs, *Review of Army Procurement of Light Observation Helicopters*, 90 Cong, 1 sess, 6–10.

140. Ibid., 6–10, 15, 33; Siekman, "Big New Whirl," 128.

141. *Review of Army Procurement of Light Observation Helicopters*, 10, 27. In January 1966, the Army awarded its first total package procurement—1,825 packages of radios designed specifically for the OH–6A. House, *Hearings on Military Posture*, 9121–9122.

142. In March 1968, Bell received a $123.1 million contract to produce 2,200 OH–58s by FY 1972. Butler, *Army Aviation Logistics and Vietnam*, 389.

143. Tolson, *Airmobility*, 16–24.

144. Weinert, *History of Army Aviation*, 182–193; Tolson, *Airmobility*, 18–24, 51–56; Bishop, *Bell UH–1*, 9–13. Huey production figures come from Butler, *Army Aviation and Vietnam*, 403–404.

145. Cockerham, "Huey Cobra," 19, 26.

146. Tolson, *Airmobility*, 29–30; Cockerham, "Huey Cobra," 19–20, 97.

147. Cockerham, "Huey Cobra," 50–56.

148. Quoted in Siekman, "Big New Whirl," 204.

149. Cockerham, "Huey Cobra," 96.

150. Ibid., 26, 96, 23–24, 63–70.

151. Ibid., 72–83, 87–88.

152. Ibid., 87–91.

153. Ibid., 88–92, 101. According to Butler, *Army Aviation and Vietnam*, 404–406, Cobra purchases came to 110 in 1966, 420 in 1967, and 308 in 1968.

154. Cockerham, "Huey Cobra," 98–100.

155. James Clifford, "AH–56A Cheyenne," *On Point* 13, no. 1 (Summer 2007): 17–20.

156. For the Army's experience with concurrency in the 1950s, see chaps 4 and 11 in Converse, *Rearming for the Cold War.*

157. Between 1960 and 1968, U.S. forces received 4,947 M113s; another 9,839 were allocated to foreign military sales. Output of the diesel M113A1 between 1964 and 1979 totaled 23,576. Also, the M113 series provided the basic chassis for a wide variety of vehicles (for

example, antiaircraft, missile, cargo, and communications equipment carriers). R.P. Hunnicutt, *Bradley* (Novato, CA: Presidio Press, 1999), 85, 89, 94, 106–118.

158. Boyd L. Dastrup, *The Field Artillery: History and Sourcebook* (Westport, CT: Greenwood Press, 1994), 65; Christopher F. Foss, ed., *Jane's Armour and Artillery, 1979–1980* (London: Jane's Publishing Group, 1980), 355.

I. Frank Besson, speech to AUSA Convention, 10 October 1962, fldr Army Organization, 1962, box 585, OSD/HO; Lt. Gen. F.S. Besson, Jr., "Project Management within the Army Materiel Command," in *Science, Technology, and Management*, ed. Fremont E. Kast and James E. Rosenzweig (New York: McGraw-Hill Book Company, 1963), 91–98; James E. Hewes, Jr., *From Root to McNamara* (Washington, DC: U.S. Army Center of Military History, 1975), 350; "General Frank S. Besson, Jr.," biography, U.S. Army Transportation Museum, available at: <http://www.transchool.lee.army.mil/Museum/Transportation%20Museum/generalbesson.htm> (accessed 22 May 2012); "Frank S. Besson, Jr.," in *A Brief History of AMC and Biographies of the Commanding Generals* (Alexandria, VA: Historical Office, U.S. Army Materiel Command, December 2000), 10–11; *Arsenal for the Brave: A History of the United States Army Materiel Command, 1962–1968* (Alexandria, VA: Historical Office, Headquarters, U.S. Army Materiel Command, 30 September 1969), 7–19.

II. Robert W. Coakley and Richard C. Kugler, assisted by Vincent H. Demma, "Historical Summary of the Evolution of U.S. Army Test and Evaluation System—World War II to the Present," Office of the Chief of Military History, December 1965, 1–15; Sammy J. Cannon, Robert N. Crittenden, and Arthur R. Woods, "Army Test and Evaluation Revisited: An Appraisal of the Present System," U.S. Army War College, 1974, 7–19; U.S. Army Materiel Command, *U.S. Army Materiel Command: America's Arsenal for the Brave* (Alexandria, VA: U.S. Army Materiel Command, 1983), 19–21.

CHAPTER VI

The Air Force Shifts Emphasis

The 1960s were increasingly frustrating years for many senior Air Force officers. Convinced that strategic nuclear superiority could deter aggression at any level, they disliked the shift in national security policy from massive retaliation to flexible response. Curtailment of the role of nuclear weapons cost the Air Force its place as the centerpiece of military strategy. Designing and fielding aircraft in response to changing requirements led to unexpected tensions and problems. In exercising the enhanced statutory responsibilities provided to him by the DoD Reorganization Act of 1958, Secretary McNamara intruded into areas previously reserved for senior Air Force officers. Additionally, in their view, the cost-effectiveness analyses employed in OSD resulted in a failure to develop advanced weapons technologies, thereby dangerously diminishing the U.S. lead over the Soviet Union in that area.

GENERAL SCHRIEVER AND SYSTEMS COMMAND

As the decade began, the Air Force was trying to sort out its organization for R&D, production, and procurement. General Bernard Schriever would play a large role in crafting the solution. Under the Air Force's organization for acquisition in the 1950s, the Air Research and Development Command (ARDC) bore responsibility for a weapon system until the Air Staff approved production in quantity, at which point the Air Materiel Command took over. Dividing R&D and production and procurement proved awkward and was a source of tension between the two commands. Thus, for example, despite ARDC's responsibility for R&D, the commander of AMC and the deputy chief of staff for materiel on the Air Staff jointly controlled 80 percent of R&D funds and regularly prepared Air Force R&D budget recommendations.[1]

In May 1959, General Curtis LeMay, the vice chief of staff, tasked a Weapon System Management Study Group to assess the entire Air Force acquisition process. General Samuel E. Anderson, who commanded AMC, chaired the group; Schriever was also a member. Three proposals emerged: first, combine ARDC and AMC; second, retain the two commands and broaden their shared responsibility to include all aeronautical and electronic systems; and third, create separate commands, one to manage acquisition and the other to furnish logistical support, including supply and maintenance. Schriever, who had just become commander of ARDC with three-star rank, pressed for the last proposal. He reasoned that those involved in R&D and production developed analytical thought patterns and accepted calculated risks, while logisticians were more conservative because they had to guard against gaps and shortfalls in deliveries. Therefore, Schriever proposed to end the AMC–ARDC competition for resources by having one command for R&D, production, and procurement—which he defined as "acquisition"—and another devoted to logistic support.[2]

Sharp disagreements occurred among members of the study group. In mid-1960, the chief of staff, General Thomas White, opted for only modest change, preserving the division of responsibility between ARDC and AMC and, with it, longstanding jurisdictional problems. Indeed, the dual management structure was extended to encompass all aeronautical and electronic systems. Significant problems persisted, including ongoing competition between ARDC's Ballistic Missile Division and AMC's Ballistic Missile Center for personnel and resources.

The catalyst for significant change in the Air Force's organization for acquisition came from resolution of the issue of military responsibility for space. Since 1957, when the Soviets launched Sputnik, concern had been growing that the United States was failing to exploit the military uses of space. With General White's approval, Schriever appointed a task force of scientists and industrialists to study that problem. Before the task force completed its work, though, the Air Force found itself owning the military space mission and acquiring a new acquisition structure.[3]

Days after the Kennedy administration took office, General White and Secretary of the Air Force Eugene Zuckert urged Secretary McNamara and Deputy Secretary Roswell Gilpatric to give responsibility for space to the Air Force. McNamara and Gilpatric agreed, but not until the Air Force put its systems management organization in order. General White instructed Col. Otto J. Glasser, who had worked for the general officer study group established by LeMay, to prepare a proposal in strictest secrecy. What resulted was Schriever's original plan to create one command for acquisition and another for logistic support. Glasser briefed General LeMay, now the chief of staff, then at LeMay's order gave the same presentation to AMC's General Anderson. As Glasser remembered, "Anderson went into a towering rage . . . made some very unkind remarks about my ancestry . . . and stormed out of the room." LeMay called him back, and Glasser listened to "one four-star give the greatest chewing out I have ever heard to another four-star." LeMay told Anderson that he was no longer welcome in the Pentagon and would have to be represented by his deputy, Lt. Gen. William F. McKee. McNamara quickly approved the restructuring plan. On 6 March 1961, all military space research was assigned to the Air Force.[4]

The reorganization announced on 17 March abolished ARDC and AMC, replacing them with the Air Force Systems Command and the Air Force Logistics Command (AFLC). The Air Force Systems Command had its headquarters at

Andrews Air Force Base in Maryland and was led by Schriever, who gained a fourth star. Broadly, AFSC would handle the acquisition of all systems from development, test and evaluation, and production through installation and checkout, delivering complete, timely, and operable systems to the using commands.[5] It would have responsibility for more than one-third of the Air Force budget and concentrate authority in one commander to an extent unprecedented in Air Force history. Thus, a single agency now controlled all phases of the Air Force's ICBM programs (including contracting for base construction). Even the Army Corps of Engineers Ballistic Missile Construction Office at Inglewood, California, came under the direction of AFSC's Ballistic Missile Division.[6]

Air Force Logistics Command took over AMC's headquarters at Wright-Patterson Air Force Base in Dayton, Ohio. Under General Anderson, who moved laterally from commanding AMC, AFLC performed general supply management tasks such as distribution, warehousing, and procuring spare parts and common-use items not tied to weapon systems, such as electron tubes.

There was a wrinkle to Schriever's plan, however. To underscore the importance and independence of basic research, its management was moved from ARDC to a new Office of Aerospace Research, nominally accorded equal status with AFSC and AFLC. Like Schriever and Anderson, the Office of Aerospace Research's two-star commander reported directly to the chief of staff.[7]

Schriever disapproved of separating research from systems development. Previously, management responsibility for each major weapon system had shifted from ARDC to AMC just before the start of production, after the completion of research and development. Under the new arrangement, a single organization oversaw development and production, while basic research was left to its own. Schriever and his staff worried that civilian leaders might assign research critical to major weapon systems to the Office of Aerospace Research. Consequently, in April 1962, Schriever added to AFSC a Research and Technology Division responsible for planning and managing his command's basic research, applied research, and advanced technology programs.[8]

By December 1961, General Schriever had appointed program managers for more than 60 weapon systems. Eleven programs were deemed especially critical: Atlas, Titan, and Minuteman ICBMs; B–70 strategic bomber; SAC's command and control system; the Midas early warning satellite; field booster development; Dyna-Soar manned spacecraft; Skybolt air-launched ballistic missile; Discoverer satellite; and Saint satellite rendezvous and inspection system. These programs were authorized to use special "red-line" channels that allowed their managers to work directly with Air Staff officers, who could arrange for unresolved problems to be brought before the chief of staff and the secretary of the Air Force for quick resolution. But by 1962, after General McKee succeeded Anderson at AFLC, the need for red-lining went away. At monthly meetings, McKee and Schriever worked out problems involving interface between their commands to ensure that disagreements did not come before the Air Staff.[9]

General Bernard Schriever (*National Museum of the U.S. Air Force*)

General Bernard A. Schriever (1910–2005)

Bernard Schriever was born in Germany in September 1910 and came to the United States early in 1917 to join his father, who had been interned along with the rest of the crew of a German merchant marine ship seized in New York during World War I. The family settled in San Antonio, where relatives lived. He graduated in 1931 from Texas A&M, where he was a Reserve Officer Training Corps cadet, and joined the Army Air Corps. During World War II, he flew B–17s in the Pacific and rose rapidly in rank, becoming commander of the advanced headquarters of the Far East Air Service Command before war's end.

Working with scientists in the postwar years in a succession of Air Staff positions, Schriever became convinced that technology's promise was so great that the Air Force had to push its frontiers as far and as fast as possible. In August 1954, then-Brigadier General Schriever was put in charge of the Air Force's ICBM development effort. Provided substantial resources and allowed considerable latitude, he produced the first operational ICBM (Atlas) and land-based IRBM (Thor). In 1959, he was promoted to head the Air Force Research and Development Command and in 1961 was selected to lead the newly established Air Force Systems Command. In these posts, his achievements included introducing dozens of weapon systems, including satellites and a second-generation ICBM (Minuteman), and establishing space as a military frontier.

Still, Schriever's achievements fell short of his hopes. In his judgment, Secretary McNamara ignored military advice and shortchanged critical areas of R&D. Project Forecast, carried out under Schriever's direction, anticipated technological breakthroughs of a revolutionary nature. Some of its ideas were pursued, but McNamara cut funding for others that failed his test of cost-effectiveness. A dismayed Schriever elected to retire on 31 August 1966, several years before his mandatory retirement date. Thereafter he held many consultative posts, serving on the President's Foreign Intelligence Advisory Board, the Defense Science Board, and the Ballistic Missile Defense Organization Advisory Committee.[1]

In March 1963, Schriever launched a study, Project Forecast (see chapter IV), to guide the Air Force's technological effort through 1975. Circulated in February 1964 with Schriever's full endorsement, the Forecast study predicted that dramatic breakthroughs lay ahead. Materials, for example, always had been a major limiting factor in aircraft development. Recent advances in composite materials indicated that operating temperatures could be increased by several hundred degrees. If boron composites proved practical, according to Forecast, combining them with advanced design concepts could almost revolutionize air-breathing propulsion technology, raising thrust-to-weight ratios from 5:1 to more than 10:1 in turbofan engines. Thus, the proposed Advanced Manned Strategic Aircraft (AMSA), incorporating boron composites and oxide dispersion alloys in its structure, with four cryojet engines using new alloys and a slot retractable wing, would weigh only 60 percent as much as the subsonic B–52 but fly at speeds from Mach 0.8 up to hypersonic levels, five or more times the speed of sound.[10]

Some of the highest hopes raised by Forecast, however, went unfulfilled, at least by 1975. Hypersonic as well as VTOL tactical and transport aircraft lay much further in the future. Schriever blamed McNamara's style of management for the failure to realize such advances. OSD put in place procedures, formalized in July 1965 by DoD Directive 3200.9 (see chapter III), that defined acquisition as a three-phase process. The first, concept formulation, included exploratory development, to solve problems that did not qualify as major projects, and advanced development, which covered testing of all components and subsystem hardware. In Schriever's view, exploratory development received adequate support, but advanced development suffered badly from OSD's refusal to fund experimental prototypes, the point in the cycle at which systems analysts often did their cost-effectiveness comparisons and recommended program termination.[11]

Another, perhaps deeper, source of tension arose between OSD and General Schriever. Having enjoyed years of autonomy while running missile programs, Schriever now expected to exercise absolute authority over Air Force acquisition. That did not come about, he later maintained, because "in the Pentagon they started getting into every . . . nit-picking detail that you can possibly imagine." McNamara's staff would "talk to people in the command at all levels. . . . Most of the time we didn't even know that they were wandering about. In no circumstances were we ever provided with copies of their reports." In fact, creating a highly centralized Systems Command made it easier for OSD to inquire into the Air Force acquisition process. Strong-willed and impatient, Schriever later described OSD analysts as "a bunch of amateurs" who "laid all these vulture eggs that have hatched later on," adding that "if I seem to have little respect for McNamara, that's precisely correct."[12] The case studies below, however, suggest more complicated explanations for the problems Air Force acquisition faced in the 1960s.

PARADOXES OF THE AEROSPACE INDUSTRY

The Air Force, having no counterpart to Army arsenals and Navy shipyards, depended on the private sector for aircraft and missile acquisition. During the 1950s, a single contractor would be given primary responsibility for developing and producing a complete weapon system.[13] That single firm, normally the airframe contractor, also bore responsibility for integrating all elements of the weapon system. The Air Force first implemented this policy in 1952 in its contract with Convair for development of the B–58 strategic bomber.[14]

In the mid-1950s, the U.S. aircraft industry was still fairly diversified. Six companies were producing fighters for the Air Force, five were making fighter/attack aircraft for the Navy and Marine Corps, and five were turning out aircraft engines. A wave of contract cancellations occurred during 1957–1959 as the Air Force completed its buildup to 137 wings, but these were offset by missile and satellite contracts that turned aircraft manufacturers into aerospace firms. Soon afterward, sales of commercial jet airliners began to grow and kept growing due to the rising popularity of civilian air travel. While the output of military aircraft fell from 4,078 in 1959 to 1,970 in 1963, civilian production climbed from 6,860 in 1958 to 8,155 in 1963 and then surged to 16,277 in 1966.[15]

Concurrently, the number of government-owned, contractor-operated plants steadily declined. Boeing bought the plant at Renton, Washington, where it assembled B–52s; by 1964, the value of all contractor-owned machine tools exceeded those supplied by the government.[16] Yet no companies, even the largest, made a smooth passage through the 1960s. North American Aviation, which produced more military aircraft during the 1950s than any other firm, delivered its last F–100 Super Sabre in 1959. No fighter business followed, and its B–70 bomber never went beyond two prototypes. North American became the prime contractor for the second stage of the Saturn V moon rocket and the Apollo spacecraft, but a capsule fire that killed three astronauts in January 1967 brought biting criticism of the company. Its Autonetics Division, meantime, had incurred large cost overruns on the Minuteman II guidance and Mark II avionics systems. In March 1967, North American merged with Rockwell-Standard Corporation.[17]

Although McDonnell replaced North American as the largest manufacturer of military aircraft, with production of its F–4D Phantom peaking at two per day in 1967, the company became essentially a single-product firm.[18] Douglas Aircraft produced four types of planes that were flying from Navy carriers in the late 1950s. But its A–4D Skyhawk alone remained in quantity production, and DoD canceled the company's Skybolt air-launched ballistic missile project in 1962. Although sales of Douglas DC–8 and DC–9 commercial jetliners climbed, lagging deliveries caused buyers to delay their payments. By October 1966, Douglas was in such financial straits that creditors required it to seek a buyer. James S. McDonnell, already a large shareholder, arranged the 1967 merger that created the McDonnell Douglas Corporation. Between 1930 and 1960, the Grumman Aircraft Engineering Corporation built 40 percent of the Navy's fighters. But with the McDonnell contract for the F–4, Grumman lost its place as principal producer of Navy fighters; its future would rest with the F–111B and, when that was cut back, with the F–14 fighter.[19]

Boeing became the industry's star performer, winning a major contract for Minuteman ICBMs. By the early 1960s, it was the world's largest aircraft firm, with more than 100,000 employees. But Boeing's run of B–52s ended in 1962, and the Convair Division of General Dynamics won the F–111 contract. Boeing filled its last military aircraft order, for KC–135 tankers, in January 1965. The KC–135 had been funded partly by DoD and partly by Boeing because the company expected its 707 jetliner, a near twin of the KC–135, to find a large commercial market. A medium-range 727 and a short-range 737 followed the highly successful 707. Boeing delivered its one thousandth commercial airliner in June 1967.[20]

Between 1958 and 1964, when military orders were falling, aircraft firms hired fewer engineers. Then the boom in civilian airliners combined with Vietnam War requirements to squeeze manufacturing capacity. The output of military aircraft rose from 1,970 in 1963 to 3,609 in 1966, while production of civilian aircraft also doubled from 8,155 in 1963 to 16,277 in 1966.[21] Orders for commercial jets imposed on the forging and extrusion segment of the industry a load equal to or greater than that from military orders.[22] A trend away from light metal construction to more and larger forgings and extrusions aggravated the problem. Between autumn 1965 and autumn 1966, the time between placing and delivering an order lengthened by more than 50 percent in many areas of aircraft production.[23]

Assistant Secretary of Defense Paul Ignatius arranged a DoD-industry conference in October 1966 centering on the difficulties with forgings and extrusions. Aerospace executives highlighted their manpower problems, particularly losses due to the military draft. Several companies claimed that they could raise output by 30 to 40 percent, but only if they could retain skilled workers. Their executives recommended giving draft exemptions to key categories like machinists, hammer men, and die-sinkers, listing the forging industry as an "Essential Activity" and its skills as "Critical Occupations." By February 1967, these and other measures made enough progress that Defense Department officials saw no immediate need to do more.[24]

Vietnam also compelled the administration to decide the extent to which military demand should enjoy priority over civilian production. Bottlenecks in forging, extrusion, casting, and production of electronic components and machine tools led firms to complain that their commercial production was being crippled. The secretary of the treasury appealed to McNamara that selling airliners abroad would ease the balance-of-payments drain. Since President Johnson also worried about the outflow of gold, that argument proved to be decisive, and DoD extended some support to filling commercial orders.[25]

Aircraft production for 1968 totaled 4,000 military and 14,976 commercial aircraft, the highest since 1946. But large volume did not assure any one company's financial health. Large capital investments obliged aerospace firms to carry higher debt-to-equity ratios than other industries.[26] When Boeing developed a 747 jumbo jetliner, it needed major orders from two or more airlines simply to cover the costs of bringing the 747 into production. The first 747, making its maiden flight in February 1969, performed below specifications. Pan American Airways delayed acceptance and, as its contract allowed, keyed payments to Boeing's progress toward meeting the required standards. That delay forced Boeing to assume greater debt, leading to a financial crisis and severe retrenchment.[27]

Lockheed fared worse. Its successes with the C–130 and C–141 transports were not repeated with the supercargo C–5A. By late 1968, a $2 billion overrun looked likely, and the total package procurement contract allowed Lockheed no relief. Lockheed's L–1011 airliner, although more technologically advanced than the 747, also turned into a money loser. In 1971, the government rescued Lockheed, granting the company $400 million to recover the C–5A's development costs and guaranteeing a $250 million loan for the L–1011. Similarly, Grumman's fixed-price contract for the Navy's F–14 fighter turned sour. A declining base from which to allocate overhead costs, troubles with the TF30 engine, and a rate of inflation higher than that stipulated in the total package procurement contract led to Grumman losing $1 million to $2 million per plane. When banks suspended Grumman's credit lines in 1972, another government bailout became necessary.[28]

Why were companies going broke while orders for aircraft boomed? Weapon systems designed to employ the latest technological advances, including composite materials and electronic packages of great complexity, encountered numerous hurdles in development and even in production. Efforts to overcome technological problems forced regular cost increases. Inflexible fixed-price contracts made matters worse. Between 1963 and 1968, long-term debt as a percentage of working capital rose from 47 to 100 percent for Boeing, from 18 to 59 percent for Lockheed, from 57 to 133 percent for McDonnell Douglas, and from 42 to 72 percent for Grumman. Ever-greater numbers of aircraft, whether civilian or military, had to be manufactured before loss turned into profit. Yet when burgeoning costs compelled cutbacks in planned production, there could be no "learning curve" by which profits rose during the latter part of a long run. These factors combined to eliminate all but the largest and strongest corporations.[29]

REORIENTING TACTICAL AIRCRAFT

By 1960, after years of emphasis on nuclear missions, air-to-air combat had become a secondary mission. The Air Force's "Century Series" of aircraft, which included F–100 and F–105 fighter-bombers as well as the F–101, F–102, F–104, and F–106 interceptors, had been tailored more for nuclear than for conventional missions. Tactical Air Command (TAC) filled its inventory with multipurpose aircraft, but instead of emphasizing air-to-air combat, its doctrine emphasized deep interdiction missions as well as attacking airfields and other ground targets.[30]

The F–105B Thunderchief, a TAC mainstay, entered operational service in August 1958. Republic Aviation, on its own initiative, had developed the supersonic F–105 as the successor to its subsonic F–84. The F–105B's primary mission was low-level delivery of tactical nuclear weapons. Republic planned its next model, the F–105D, as an all-weather attack aircraft. Since new electronic systems would increase its weight by several thousand pounds, the D version needed a more powerful engine to maintain the same level of performance as the B. Fortuitously, Pratt and Whitney found a way to increase the thrust of its J75–P19 engine by water injection. But installing a new engine required a partial redesign of the F–105's fuselage and intake ducts. These and other modifications, according to Republic, made it difficult to use the B production line again. Fabrication time thus rose from 144 days for an F–105B to 214 days for an F–105D.[31]

Republic F–105D Thunderchief with full bomb load (*National Museum of the U.S. Air Force*)

When the Air Force accepted its first F–105D in September 1960, the primary armament was a nuclear bomb housed in the aircraft's internal weapons bay. The shift in 1961 to a strategy of flexible response required modifying F–105Ds so that they also could deliver an array of conventional weapons, including one 750-pound bomb carried on each of the Thunderchief's four wing stations. Later, the addition of multiple ejection racks raised bomb-carrying capacity to 16. The F–105B's subsystems had not been fully proven when F–105D production began. To avoid fielding a variety of configurations, the Air Force decided to process all modifications as a single package. While special projects brought Bs and Ds to a common standard, doing so practically wiped out the spare parts inventory.[32]

Republic produced 610 F–105Ds, but problems persisted when that model's production run ended in January 1964. During 1964, 38 F–105s were lost from fires or explosions attributed to excessive heat and fuel vapors in the engine section. Even in 1966, at least 30 major accidents were blamed on F–105 engine failures—evidence of overly hasty testing and evaluation.[33]

F–105s take off on mission to bomb North Vietnam, 1966 (*National Museum of the U.S. Air Force*)

In August 1964, Republic proposed installing, over four years, an advanced avionics system that would improve penetration for low-level attacks. But installation would have taken 100 F–105s out of service at any one time; with an air campaign in Southeast Asia looming, the Air Force could not spare so many. When Rolling Thunder, the carefully calibrated bombing of targets in North Vietnam, began in February 1965, the F–105's fire control system failed to deliver bombs with the accuracy expected. The Thunderstick II fire control system conceived in 1966 promised much more accurate delivery, but it was not fielded until 1972.[34]

Between 1965 and 1968, F–105s carried out more strikes against North Vietnam than any other Air Force aircraft. The F–105 also led in battle losses: the Air Force lost 397 of its 753 F–105Ds and F–105Fs in Southeast Asia. A contributing factor was the lack of self-sealing tanks, a deficiency resulting from the failure of the designers to focus on the plane's survivability in a lengthy conventional conflict. Main and emergency hydraulic lines ran so close together that a hit on one took out the other as well. Modifications were rushed during 1967.[35]

The last Thunderchief, a two-seater F–105F, was delivered in January 1965. Thus, a unique situation existed—the major instrument of the air campaign against North Vietnam had gone out of production. In May 1968, Republic proposed reopening the Thunderchief production line and rebuilding its inventory. The company would first produce 300 F–105Fs, minus the "Wild Weasel" electronics gear for striking radar and surface-to-air missile sites with which 30 F–105Fs already had been outfitted. Republic would then modify the remaining 344 F–105Ds with Thunderstick IIs, improved engines, and more internal fuel. The Air Force refused, rating the inventory too small to justify the expense and pointing out that the Thunderchief was nearing obsolescence.[36]

As F–105s dropped out of the inventory, McDonnell F–4 Phantoms took their place, enjoying the largest production run of the 1960s. The Thunderchief could dogfight, but it was basically an attack aircraft. The Phantom originated as an interceptor with some capability for hitting ground targets. McDonnell Aircraft had created the F4H–1 for the Navy, to protect carriers by engaging enemy aircraft beyond visual range. In 1958, three years before the first F4H–1s reached Navy squadrons, McDonnell executives began promoting the F4H–1 to Air Force officers. Since the F4H–1 could fly slowly enough to land on carriers, they argued that it was also suitable for low-level strafing and bombing.[37]

Navy F4H–1 Phantom II after setting world altitude record for aircraft of 98,560 feet, 6 December 1959 (*Naval History and Heritage Command*)

Opportunities opened in 1961 when the Kennedy administration started increasing Air Force tactical fighter wings from 16 to 21. Promoting economy through commonality, Secretary McNamara decided that the Air Force and Navy would jointly design a supersonic multirole aircraft, the F–111. Until F–111s entered service, at least five years in the future, the Air Force needed an interim airplane to fill the gap. The F4H–1 was an obvious candidate.[38]

By mid-1961, the F4H–1 had set many world records, its production line was flowing smoothly, and a fixed-price contract controlled costs. McDonnell stood ready to accelerate its efficient rolling assembly line. Each aircraft was affixed to a master jig suspended from an overhead rack, with the night shift moving aircraft to the next station so that day workers could add and inspect parts without having to dislocate their tools.[39]

Harold Brown, then director of defense research and engineering, pressed the Tactical Air Command to evaluate the F4H–1. In November 1961, TAC staged a fly-off between the F4H–1 and the F–105. The critical tests involved seeing which aircraft could fly more slowly without stalling while escorting helicopters and strafing targets and which aircraft could more easily carry two dozen 500-pound bombs. McDonnell was better prepared for these tests because the Marine Corps already was evaluating Phantoms for similar missions. Nevertheless, the Phantom and the Thunderchief performed equally well. But other factors worked in McDonnell's favor. Most importantly, Phantoms could replace RF–101s as fast, low-flying reconnaissance aircraft, carry a wider assortment of weapons, and still be cost-competitive with the F–105.[40]

In December 1961, the Air Force decided to buy 24 Phantoms from the Navy through a Military Interdepartmental Purchase Request (MIPR); it also allocated $50 million to develop 2 reconnaissance prototypes. Six months later, in July 1962, the Air Force programmed FY 1963 funds for 280 Phantoms and 24 reconnaissance versions, roughly twice what the Navy and Marine Corps purchased. Nevertheless, until FY 1973, the Air Force continued to procure all of its F–4s through Navy channels.[41]

To press commonality further, McNamara established a Senior Interservice Configuration Board. He also standardized aircraft designations so that the Navy-Marine Corps version of the Phantom became the F–4B and the Air Force version was designated the F–4C. The Air Force, in fact, kept tailhooks on its F–4Cs because arresting wires were being used on short runways. The main difference between the two was that the Air Force version incorporated Litton's self-contained inertial navigation systems in place of the Navy directional radio signals that linked the Phantoms to carriers or shore stations.[42]

In 1962, McDonnell increased its output from 12 to 15 aircraft per month, but all Phantoms were slated for the Navy until FY 1964. The Air Force proposed letting Republic build complete F–4Cs under license.[43] McDonnell reacted by hiring another 2,500 workers, increasing fabrication by its night shift, and awarding 8 additional subcontracts. Republic won $18 million to build the aft fuselages, Douglas $5.6 million for outer wings, and Beech Aircraft $5.56 million for doors and wing appendages. Consequently, the Air Force received its first F–4C on 27 May 1963, 65 days ahead of schedule. McDonnell's output of F-4s rose to 30 per month that year.[44]

In July 1963, the Air Force boosted its backlog of orders to 1,342. Jig stations started crowding McDonnell's plant at St. Louis, but the Defense Department refused to fund McDonnell's expansion while other airframe companies had slack. McDonnell responded by dividing production into smaller packages and shifting more work, especially parts fabrication, to subcontractors. By 1964, the company was fabricating only 45 percent of airframe parts, and subcontractors were handling more than 80 percent of the total airframe price.[45]

In 1962, OSD asked the Navy and Air Force to create a joint agency to integrate the F–4's logistic support. When the two services agreed only to coordinate their separate agencies, Assistant Secretary of Defense Thomas Morris required each to bid for the role of "F–4 Integrated Material Manager." Morris wanted centralized, not committee, management. The Air Force Logistics Command held an advantage because it had created an F–4 System Support Office at the Ogden Air Materiel Area in Utah. Also, the command had instituted systems-oriented maintenance policies that OSD deemed excellent. Most importantly, the Air Force now outstripped the Navy in planned F–4 procurement. Accordingly, in February 1963, Deputy Secretary of Defense Gilpatric chose the Air Force to manage logistics for all items specific to the F–4. The Air Force Logistics Command also took on responsibility for revamping the Navy's supply system to bring it in line with that of the Air Force. It closed out the Navy's MIPR contracts for spares and broke out items from McDonnell's prime contract, buying them directly as government-furnished equipment. Even so, the Navy continued buying parts unique to its F–4B, such as refueling probes, and items common to all its aircraft, like fasteners and lubricants.[46]

The Rolling Thunder campaign in Vietnam exposed weaknesses in the Phantom's capabilities. Phantoms did better than Thunderchiefs in air-to-air combat, claiming to have destroyed 128.5 MiGs with only 33 F–4s lost.[47] But F–4Cs carried only air-to-air missiles that swirling dogfights often rendered unusable. Designers proposed that a gun replace one of the four missile stations on the next model. It turned out, however, that installing a gun and ammunition shifted the Phantom's center of gravity such that firing one of the forward missiles made the aircraft unstable. For the new F–4D, consequently, an unsatisfactory gun pod had to be mounted on its centerline hard points or store stations.[48]

During 1966, the lead time between placing an order and delivering an F–4 rose from 17 to 23 months and from 12 to 16 months for its J79 engines. Bottlenecks included forgings and extrusions, bearings, and the precision manufacture of structural parts, electronic components, and copper wire. Early in 1967, during a meeting of the Defense Industry Advisory Council, Assistant Secretary of the Air Force Robert Charles remarked that there was no shortage of machine-building equipment and that new machines would pay for themselves in three years. Why, then, were contractors not placing more orders for new tools? Industry executives responded that money was tight and many prime contractors depended on the same subcontractor for large forgings and extrusions. Even so, McDonnell Douglas produced almost 800 F–4Ds in less than two years, peaking at 50 per month between January and June 1967. Successful as a war-rushed product, the F–4D nonetheless experienced many of the F–4C's failings. The F–4E, which made its maiden flight in June 1967 and was equipped with a built-in cannon, became the Air Force's preferred model.[49]

Among the F4–E's improvements over the F–4D was its 20mm gun. The first F–4Es arrived in Southeast Asia in late 1968. (*National Museum of the U.S. Air Force*)

Rolling Thunder required bombing with unprecedented accuracy. The F–4C carried an inertial guidance system optimized for delivering a single nuclear weapon. In Vietnam, however, Phantom pilots flying at night or through monsoon weather had to follow the wing of another plane (usually a Marine A–4) that tracked targets with help from a ground-based radar director. Such "buddy bombing" was done in tight, straight-line formations that were more vulnerable to attack. To free the Phantom from its "buddy," Litton and Sperry Gyroscope tested mixes of long-range and inertial navigation systems, improving the accuracy of both in the process. With the resulting "Pave Phantom" system, an F–4E pilot could enter the inertial coordinates of the target into his bombing computer. Then, signals from the Long-range Aid to Navigation (LORAN–C) system would set the boundaries of any errors in the inertial positioning. A navigation computer corrected the course and told the pilot when to drop his bombs. However, Rolling Thunder ended before Pave Phantom could be fielded.[50]

Because the Eisenhower administration had ruled out large-scale conventional conflicts, the Air Force inventory included multipurpose aircraft, but no planes specifically designed for the close air support of ground troops. Even before U.S. ground units began fighting in Vietnam, OSD and the Army pressed the Air Force to fill this gap. In May 1963, the Navy had initiated a design competition for a subsonic light attack aircraft. Ten months later, Ling-Temco-Vought won the contract to deliver 7 A–7 Corsair IIs for testing, followed by 35 production models. By the spring of 1965, OSD systems analysts were recommending that the Air Force also buy A–7s. The Air Force countered that multipurpose aircraft like the F–4 were superior in the tactical support role. A plane's thrust-to-weight ratio was crucial in calculating its maneuverability and acceleration, and the ratio of the F–4 was approximately twice as good as that of the A–7. But a mid-1965 computerized study showed that the A–7 compared well against both a stripped-down F–4 and the Northrop Corporation's lightweight F–5 interceptor. Moreover, the A–7 could carry a larger bomb load and was nearing production. Most importantly, at $1.4 million per plane, an estimate provided by the manufacturer and endorsed by OSD systems analysts, it would be cheaper than an F–4.[51]

Ling-Temco-Vought A–7D of the 354th Tactical Fighter Wing, probably at Korat Royal Thai Air Base, Thailand, in 1972 (*National Museum of the U.S. Air Force*)

The commitment of combat troops to Vietnam during 1965 made the issue urgent. At hearings of the House Armed Services Committee, the Air Force came under attack for lacking a specialized close support plane. Chief of Staff General John P. McConnell and Secretary of the Air Force Harold Brown recognized that constraints like those in Rolling Thunder could compel the Air Force to provide close support without having achieved complete air superiority. Accordingly, they agreed to acquire A–7s. On 19 November 1965, Secretary McNamara set the Air Force buy at 56.[52]

Some of the A–7's alleged advantages proved ephemeral. Diverting part of the Navy's early production turned out to be infeasible. Switching to a more powerful engine, substituting an Air Force gun, and adding a computerized weapon delivery system lifted the price above $3 million by 1972, compared with $2.4 million for an F–4E. The Navy commissioned its first A–7A squadron on 1 February 1967; Corsairs flew their first combat mission from USS *Ranger* in December. The Air Force accepted its first A–7D in December 1968 but, with Rolling Thunder over, did not deploy a wing to Southeast Asia until the North Vietnamese offensive of 1972.[53]

Helicopter gunships appeared competitive with A–7s. In February 1966, the Army let contracts for program definition of the Cheyenne, an advanced aerial fire support system intended to carry 8,000 pounds of ordnance, reach 210 knots, and possibly perform dive-bombing runs (see chapter V). Seeing mission and budgetary threats, the Air Staff in September 1966 directed "immediate and positive steps to obtain a specialized close air support aircraft" tailored for low-intensity conflict. Among tactical aircraft designed by the Air Force since World War II, the A–X would be the first that was not multipurpose.[54]

Hoping to have a close air support plane ready for delivery by December 1970, the Air Staff sought a plane that would be responsive, lethal, survivable, and simple. Companies received RFPs in May 1967. Two months later, the Air Force awarded study contracts to McDonnell Douglas, Northrop, Grumman, and General Dynamics. Air Force Systems Command wanted to compress contract definition into a scant four months. The contractors responded in September, but reviews and revisions by the Air Staff and the DDR&E set the schedule back six months. Meanwhile, in September 1967, the Cheyenne made its first flight. In June 1968, the secretary of the Air Force sent OSD a concept formulation package for the A–X. It specified a 30mm antitank cannon, ordnance capacity of 16,000 pounds, and extensive survivability features. To stay cheaper than Cheyenne, though, the A–X would not have all-weather radar like that of the F–111, a sophisticated inertial fire control system like that of the A–7, or even a fraction of the Cheyenne's avionics gear.[55]

In December 1968, the DDR&E completed a Development Concept Paper that questioned whether all the prerequisites for A–X contract definition had been satisfied. For example, should competitive prototyping precede selection of a basic configuration? The Air Force wanted to move ahead immediately because the technical approach involved very little advanced technology, allowing rapid development at low risk and cost. But the DDR&E objected that the A–X's proposed configuration closely resembled that of the A–7; a smaller, less costly, quick-reaction aircraft seemed more appropriate. The deputy secretary of defense called for further study, allocating only $12 million for contract definition. After the next administration turned to competitive prototyping, a new RFP went out, emphasizing low cost and weapon system effectiveness. Cost overruns helped kill the Cheyenne, but the A–X survived to become the A–10 Thunderbolt (often called the Warthog because of its ungainly appearance), entering the operational inventory in 1976. By then, of course, the war in Southeast Asia was over.[56]

Test pilots walk past two Fairchild Republic A–10A prototypes (*National Museum of the U.S. Air Force*)

The Air Force had to resolve the question of whether the next generation of high-performance aircraft should be multipurpose like the F–4 and F–111. The contrary case for specialization gained traction when Col. John R. Boyd, a fighter pilot and something of a maverick, worked out a theory of energy maneuverability. Briefly, Boyd's theory related what he called a fighter's "energy" to fighter tactics. He showed how maneuverability, not simply faster speed at higher altitude, would translate into better performance. In dogfights over North Vietnam, MiG–21 interceptors sometimes displayed more maneuverability and survivability than F–105s and F–4s.[57]

Air Force headquarters had been studying a multimission F–X that would weigh more than 60,000 pounds. Colonel Boyd, with the support of others, set out to stop what he called the overweight, underwinged, overly expensive, overly complex, ineffective F–X. Then, at an air show in July 1967, the Soviet MiG–25 displayed a speed and ceiling estimated to be well beyond that of any Air Force tactical aircraft in service. A different type of threat came from the Navy, which claimed that its latest aircraft design could match the F–X's performance. Previously, in 1966, a joint review of commonality ordered by Secretary McNamara highlighted how the Air Force's emphasis on maneuverability contrasted with the Navy's need for mission versatility. Fearing a repetition of the F–4 purchase, Air Force leaders decided to counter U.S. Navy strategy by presenting an air superiority fighter uncompromised by secondary mission requirements. On 28 September 1968, after McNamara's departure, Deputy Secretary of Defense Paul H. Nitze approved contract definition for what would become the F–15 Eagle—a single-seat, twin-engine, 40,000-pound aircraft capable of reaching Mach 2.3. Reversing the trend of the McNamara years, the Air Force would develop its own air superiority fighter.[58]

In sum, OSD pressed for multimission commonality, but the Air Force preferred specialization. While OSD won in the short term, the Air Force prevailed over a longer stretch. The excellence of the F–15 for air superiority and the A–10 for tank killing could be seen as vindications of specialization.[59] Nonetheless, interservice rivalry affected acquisition decisions. Specialization also helped the Air Force fend off mission encroachments by the Army and Navy.

NO NEW MANNED BOMBER

Many of the top Air Force generals were longtime bomber pilots who remained convinced that bombers were an essential part of the strategic retaliatory force. But they faced obstacles in the 1960s that proved insurmountable. First, ICBMs threatened to make manned bombers obsolete. Second, the cutting-edge technology needed to justify new bombers appeared out of reach.

The Boeing B–52 was a workhorse of the aerial campaign in Vietnam (*OSD/HO*)

Judged by operational performance, the B–52 Stratofortress was the best bomber produced during the Cold War. Between 1953 and 1962, Boeing delivered 744 eight-engine B–52s that flew at subsonic speed and reached intercontinental range.[60] As the B–52's successor, the Air Force envisioned a bomber that would fly faster than Mach 3 and bomb from altitudes of 70,000 to 75,000 feet with an accuracy of 1,500 feet. Meeting those goals called for a quantum jump in performance, requiring hundreds of state-of-the-art advances in scores of component systems. The Air Force selected North American's bomber proposal over Boeing's, reflecting the company's readiness to accept developmental risks in order to pursue outstanding operational performance.[61]

Developing what came to be known as the B–70 Valkyrie turned into a roller-coaster ride. In March 1958, the Air Force accelerated the program, aiming for a first flight by December 1961. The cost, at that point, was estimated at $6.4 billion for 250 aircraft. Later in 1958, however, the administration decided against committing large sums until a prototype had proven itself. In 1959, the whole project came close to being scrapped when a high-energy fuel program to extend the B–70's range as much as 33 percent was canceled. So was the F–108 Rapier interceptor, funding for which had covered the costs of engines, fuel systems, and escape systems common to F–108s and B–70s. Moreover, with first-generation ICBMs approaching readiness, President Eisenhower doubted whether a new bomber made any military sense. With only $75 million allocated for FY 1961, development of many subsystems stopped, and a single prototype was permitted. But Congress, in which support for the B–70 was strong, boosted the FY 1961 appropriation to $265 million, upgrading the project to a development and testing program. Late in October 1960, with a close election looming, the administration added $110 million so that as many as 12 prototypes could be built.[62]

North American XB–70A Valkyrie at rollout, 11 May 1964 (*National Museum of the U.S. Air Force*)

Another abrupt change followed with the advent of a new administration. What the Air Force viewed as technological obstacles to be overcome, Secretary McNamara appraised from the standpoint of cost-effectiveness. After matching missiles against bombers, McNamara concluded that missiles almost always could destroy targets faster, better, and cheaper. Agreeing, President Kennedy in March 1961 proposed scaling back the B–70 to a few prototypes, with program costs not to exceed $1.3 billion. Again, Congress balked. In August, the Senate called for a production plan. McNamara responded by voicing thorough dissatisfaction with how North American had handled B–70 development.[63]

North American XB–70A Valkyrie in low-level pass (*National Museum of the U.S. Air Force*)

Matters came to a head in 1962. The Air Force tried to placate critics by recasting the program as RS–70, a reconnaissance strike aircraft. Among the Joint Chiefs, only General LeMay advocated a full-scale effort—a split that strengthened McNamara's hand. When the administration vowed to spend only $171 million in FY 1963, the House Armed Services Committee "directed, ordered, mandated, and required" that it spend the $491 million already appropriated. President Kennedy and the committee chairman, Rep. Carl Vinson, worked out a compromise: restudy the program in exchange for softening the committee's wording from "directed" to "authorized." A study group headed by General Schriever then proposed a $1.6 billion development plan that would lead to the RS–70's first flight in little more than two years. McNamara disapproved, seeing no great value in a weapon system whose primary mission involved finding targets that had survived a nuclear exchange. He did, however, agree to add $50 million for developing sensor components.[64]

Technical troubles persisted. Almost $40 million of the $50 million allocated for sensors had to be diverted so that work on three prototypes could continue. Development of an engine inlet control system that was needed to slow the aircraft to subsonic speed lagged so badly that North American terminated the subcontractor and took over the work itself. Leaks permeated the stainless steel honeycomb panels, which were used extensively throughout the airplane. Nickel plating eliminated most imperfections, but repairs on the fuel tanks had to be airtight. A ¾-inch mismatch between the wings and the wing stubs required fabrication of special adapters, costing time and money. The Air Force converted the contract from cost-plus-fixed-fee to cost-plus-incentive-fee, but cost and schedule overruns persisted.

In December 1963, General LeMay told President Johnson that he considered the program to be dead. Trying to stay within a $1.5 billion limit, the Air Force cut prototypes from three to two. The first XB–70A flew on 21 September 1964. The second prototype reached Mach 3 but crashed in June 1966. The Air Force retired the remaining aircraft a year later.[65]

Even before the B–70 atrophied, developmental planning for an alternative, the Advanced Manned Strategic Aircraft, had begun. It was to attain a more modest speed of Mach 2.2 at high altitude and Mach 1.2 for low-level penetration. This clear effort to minimize developmental risks did not erase doubts in OSD. Every year between 1966 and 1968, the JCS unanimously recommended moving AMSA into engineering development, the first phase of contract definition. And every year McNamara refused, fearing that the plane then would head irrevocably toward full-scale development and production. Applying the test of cost-effectiveness, he found that a fleet of 210 FB–111s priced out at $1.9 billion, whereas 200 AMSAs, although more capable, were estimated at $9 billion to $11 billion. Aware that Congress would not tolerate outright cancellation, McNamara approved small sums for R&D on propulsion and avionics, keeping the project alive but at a virtual standstill.[66]

A Development Concept Paper issued in November 1968 analyzed options for accelerating the program if the administration decided to initiate full-scale development. Holding a three-year design competition garnered the most support within DoD; options either to defer a decision for another year or compress contract definition into 15 months garnered none. So funding tripled, and AMSA, reborn in 1969 as the B–1, moved toward full-scale development. However, cost overruns and technical troubles would plague the B–1 as badly as they had the B–58 and B–70.[67]

LONG-RANGE AIRLIFT: C–141 SHINES, C–5A STUMBLES

By the Eisenhower administration's last year, the importance of strategic mobility had gained attention at the highest levels. In March 1960, the Army and Air Force chiefs of staff agreed that airlift should be sufficient to deploy immediately one or two reinforced Army battlegroups anywhere in the world. Airlift also should be capable of lifting one infantry or one airborne division within 7 to 10 days and another division in two to four weeks. Studies and exercises demonstrated the inadequacy of existing capabilities. On 1 July 1960, Congress forced action by approving $70.42 million for 25 short-range transports, $200 million for 50 Lockheed C–130 turboprops and 50 Boeing C–135 jets (both of which were mid-range transports), and $50 million to start developing a long-range cargo aircraft.[68]

Making strategic mobility a reality would require aircraft with longer range and greater carrying capacity. In February 1959, the Air Force head of the Military Air Transport Service (MATS) submitted a Qualitative Operational Requirement for a medium-size transport able to carry a 35,000-pound payload at least 3,000 nautical miles. Recommendations from Air Materiel Command, Tactical Air Command, the Army, OSD, and the Federal Aviation Administration (FAA) put more demanding language into the requirement. On 15 August 1960, Air Force headquarters issued Specific Operational Requirement 182–1 calling for a transport with a range approximating 4,000 nautical miles (5,500 in the Pacific area), a payload of 50,000 pounds, and takeoff and landing distances not exceeding 6,000 feet. To minimize development time and costs, the requirement stipulated that the aircraft should be a relatively simple, conventional design, well within the state of the art, and devoid insofar as possible of special systems.[69]

When briefed on 8 September, Air Force Council members asked whether modified C–130s or Douglas DC–8 airliners could do the job.[70] The Air Staff reviewed available commercial designs and judged them to be unacceptable, even with extensive modifications. Accordingly, on 10 November, the council endorsed building 132 turbofan jet transports for about $1 billion. The deputy secretary of defense approved.[71]

On 21 December 1960, an RFP was sent to Boeing, Convair, Douglas, and Lockheed-Georgia. Contractors, the RFP emphasized, must avoid pushing the technological envelope:

> It is not necessary that each new weapon system have higher orders of complexity to achieve acceptable mission effectiveness. On the contrary, it is frequently the complexity and higher-than-budgeted cost which either results in premature program termination or marginal effectiveness in operational service.

Lockheed C–141 Starlifter in flight, October 1964 (*U.S. Air Force Air Mobility Command*)

After reviewing the responses, a Source Selection Board drawn from AMC, ARDC, MATS, and the FAA chose Lockheed-Georgia. Lockheed's estimate for basic airframe weight, 6,000 pounds below that of its nearest competitor, impressed the board. Normally, the company that could build the lightest airframe would incur the lowest cost. Also, Lockheed proposed a basic structure much like that of its C–130, as well as borrowing subsystems initially developed for that aircraft. The Air Force Council, the chief of staff, and the secretary of the Air Force endorsed the board's choice. On 13 March 1961, the White House announced that Lockheed had won a contract to develop what became the C–141.[72]

By May 1961, MATS reported that the C–141 would have a guaranteed performance of 475 knots, carrying a 50,000-pound payload for 4,000 nautical miles. Even though much of the system depended on existing knowledge and proven techniques, the development and integration of subsystems required a major engineering program. Using PERT, which displayed activities and their interdependencies to chart progress and identify obstacles as early as possible, smoothed the path. PERT revealed, for example, that forgings would become available for machining before the prime contractor had either completed machining drawings or selected a vendor. The contractor promptly diverted resources to stay in step. Before 1 June 1962, as the schedule specified, all forgings were delivered, a vendor had been selected, and machining was under way.[73]

Negotiation of a fixed-price contract was completed in April 1962. Incentive provisions applied to weight, payload, range, and takeoff and landing distances. Eleven months later, the Air Force issued a multiyear letter contract for 127 C–141As, now nicknamed Starlifters. The new transport made its first flight on 17 December 1963, slightly ahead of schedule; the first squadron became operational in mid-1964. An expanded contract in June 1966 allowed for the purchase of an additional 152 Starlifters for a total of 284.[74]

Staying within the state of the art still resulted in major advances in capability. While basically a cargo carrier, the C–141 could accommodate 19 payload configurations ranging from one Minuteman ICBM or 10 cargo pallets to 127 troops or 80 litters. Starlifters flying in the Pacific during 1966 logged 93 percent reliability in departure times and 76 percent reliability for completing missions on time, well above the average for transports. Unfortunately, the navigation system, intended to be the most sophisticated and most accurate ever installed on a transport, did not live up to promise; the compass failed to fulfill expectations, and an astrotracker was canceled when the contractor could not meet specifications. The LORAN–C system proved incompatible with the navigation computer. An inertial navigation system replaced the LORAN–C from 1976 to 1978. Yet the Starlifter was a clear success overall, staying in the active inventory past the century's end.[75]

Front view of Lockheed C–5A Galaxy, visor raised, ready to receive cargo at Cam Ranh Bay Air Base, South Vietnam, September 1970 (*U.S. Air Force Air Mobility Command*)

Despite its improved capabilities, the C–141 could not carry especially heavy items such as medium tanks and bridging equipment. During 1961, systems analysts in OSD considered but rejected buying either stretched C–141s or Boeing 707 airliners modified for that purpose. Boeing started designing an elongated version of its C–135, labeled the CX–4, that featured a maximum payload of 180,000 pounds, a cargo compartment 17.5 feet wide with 2,300 square feet of floor space, and six C–141-type engines.[76]

While the commander of MATS judged Boeing's CX–4 design acceptable, General Schriever sought a more ambitious design. He envisioned a supercargo transport able to fly anywhere in the world and return without refueling. Project Forecast, completed in February 1964, bolstered his vision by anticipating, among other technologies, much more powerful and fuel-efficient engines. On 25 March, the Air Force issued a Specific Operational Requirement that included many of the capabilities that Schriever wanted: fly a 50-ton load for 5,500 nautical miles and a 100-ton load for 2,700 nautical miles; provide 2,900 square feet of floor space; carry four engines, each with 40,000 pounds of thrust; take off within 8,000 feet with a maximum load and 4,000 feet when empty. In April, five airframe and three engine firms received RFPs for what was labeled the CX–HLS (Heavy Logistic Support). From these, Boeing, Lockheed, and Douglas were awarded three-month study contracts, while similar contracts for engine studies went to Pratt and Whitney and General Electric.[77]

Lockheed built a wooden simulator to test cargo dimensions and loading techniques. Tanks and other items that had never been airlifted before were driven into the simulator, chained down, and then unloaded within set times. These and other tests not only demonstrated the CX–HLS's feasibility but also spurred design changes such as drive-through loading, a larger cargo compartment, and high-flotation landing gear for unimproved airstrips.[78]

In October 1964, the Air Force recommended moving directly to contract definition so that detailed specifications could be spelled out. First, though, the project had to prove its superiority over alternatives. In OSD, systems analysts judged the prepositioning of equipment on land and at sea to be a quicker, cheaper way of bringing materiel to the battlefield. They agreed to support the CX–HLS only when it added a capability for landing on short, soft fields. That, in turn, required the development of kneeling landing gear (permitting lowering of the aircraft's cargo floor to truck-bed height) in which new, untried boron fibers had to be used. The Military Aircraft Panel of the President's Science Advisory Committee, comprised of academic and industrial scientists, recommended deferring a decision. The Army, it suggested, might develop lightweight aluminum armored vehicles far more cheaply than the Air Force could develop a CX–HLS. Nonetheless, in December 1964, Secretary McNamara approved contract definition for what was now designated the C–5A Galaxy.[79]

C–5A Galaxy in flight, June 1970 (*U.S. Air Force Air Mobility Command*)

Previously, in November 1963, a System Program Office had been set up at Wright-Patterson Air Force Base, Ohio, under the Aeronautical Systems Division of Air Force Systems Command. The SPO bore responsibility for refining specifications for the CX–HLS/C–5A and then overseeing its development and production. On 11 December 1964, it sent five firms an RFP that ran to 1,287 pages. The ensuing four-month competition was described as the most strenuous in aerospace history. Each firm devoted significant resources to it with the hope that a C–5A contract would also give them a substantial advantage in the commercial market for large jet transports. The contract was particularly attractive because unreimbursed overhead costs and common commercial R&D activities could be charged to a contractor's C–5A account. Boeing assigned over 1,300 people to the project, Lockheed 1,750, and Douglas 1,800.[80]

Boeing, which had transferred technology from its KC–135 tanker to its 707 airliner, had a large backlog of commercial orders and a reputation for high-quality engineering. Although Douglas's standing with the Air Force was less satisfactory due to the poor track record of the C–133, collaboration with Martin Marietta and North American Aviation kept the company in the running. Lockheed dominated the military transport field. The volume of its work promised economies in production that would make it the lowest bidder.[81]

During the competition, these companies peppered the SPO with 1,783 queries. It responded with 294 changes in requirements plus 1,600 pages of clarifications and revisions. Believing that bidders would be overwhelmed, the SPO's director sent his counterpart in each company a wooden hara-kiri sword accompanied by a wry note: "Why wait?" Nevertheless, in April 1965, each of the companies submitted proposals that deserved the label of "encyclopedic." Douglas's submission was typical, its report running 60,000 pages in 625 volumes—with the Air Force demanding 40 copies of all submissions.[82]

A Source Selection Board consisting of two brigadier and two major generals had been established in November 1964. Under its aegis, a 400-person evaluation group split into teams that developed precise standards against which to measure technical proposals. An independent government estimate, based on historical costs of the C–130, C–133, and C–141, analyzed cost proposals while models provided by the companies underwent wind tunnel tests at Langley Air Force Base, Virginia. Evaluators fed aircraft specifications into computers, simulating division-size airlifts to Europe and Southeast Asia. Identifying some 600 deficiencies, they asked competitors to judge whether fixes were feasible and to estimate their additional cost.[83]

On 23 August 1965, after four months of deliberation, the board recommended awarding the airframe contract to Boeing. Even though Boeing bid $330 million above Lockheed, the board discerned a superior technological sophistication in Boeing's design. Lockheed's proposal was deemed deficient in speed and lift, meaning that its plane could not take off and land within the required distances. The commander of AFLC also favored Boeing, but General

Schriever and the MATS commander voted for Lockheed. Air Force engineers faulted the Douglas design for having excessive aerodynamic drag. Extensive flight-testing would be needed to confirm or refute that criticism, and the Air Force was unwilling to risk long delays.[84]

Deferring a decision, Secretary of the Air Force Zuckert asked each firm to revise its proposal. Although Boeing and Douglas slightly reduced their bids, they still exceeded Lockheed's price. To shorten takeoff and landing distances, Lockheed increased the aircraft's wing area from 5,600 to 6,200 square feet, thereby raising gross weight from 700,000 to 728,000 pounds. After the Air Force Council, the commanders of MATS, AFLC, and AFSC, and three assistant secretaries of the Air Force reviewed revised designs, a large majority voted for Lockheed. On 23 September 1965, Secretary Zuckert and the Air Force chief of staff so recommended and Secretary McNamara announced the award to Lockheed seven days later. General Electric won the engine contract.[85]

Lockheed's low price was due to the fact that the C–5A contract was the first to apply total package procurement (see chapter III). Typically, after competitive bidding, an R&D contract covering about 20 percent of costs would be awarded. Almost invariably, the government would accept the R&D contractor's bid for the follow-on production. Robert Charles, assistant secretary of the Air Force (installations and logistics), argued that TPP would hold down costs by extending competition from the R&D phase to the whole acquisition cycle. Coming before the start of engineering development, TPP would provide a complete, firm program price plus performance guarantees within a single contract.[86]

For the C–5A, TPP would cover the aircraft itself, training equipment, ground equipment, and sufficient spares to cover testing by the contractor and by Air Force Systems Command. According to Charles, TPP would discourage "buying in" because the contractor could not recoup its R&D losses by hiking prices for the production run; it also would tighten design and configuration discipline as well as motivate economical production, product reliability, and simplicity of maintenance. There was one critical caveat. TPP would work only if a weapon system's production costs could be estimated with some certainty without extensive prior development and if the system needed no major innovations that went beyond the industry's technical knowledge. The Air Force, OSD, and Lockheed judged the C–5A to be such a system.[87]

In October 1964, the Air Force had estimated the cost of 120 C–5As at $2.24 billion, plus $570.5 million for the engines. A fixed-price incentive contract with Lockheed, completed in October 1965, covered DDT&E of five aircraft; production of 53 C–5As (designated as Run A), along with spare parts and aerospace ground equipment; and options for two more runs (Run B of 57 and Run C of 85) of additional aircraft. The target price of $1.95 billion, which included a 10 percent profit, applied to 115 aircraft: 5 in DDT&E, $514 million; 53 in Run A, $892 million; and 57 in Run B, $538 million. Overruns and underruns of the target price would be shared between the government and Lockheed on an 85/15 basis, up to a ceiling of 130 percent of the target price. The government could adjust the 85/15 ratio, assigning Lockheed as much as 50 percent of how far it underran and 30 percent of how far it overran the target price. In the latter event, the target cost, target price, and ceiling price would increase by about 3.2 percent.[88]

Since TPP placed unprecedented risk on the contractor, industry sought a safeguard. During the contract competition, one executive suggested to Charles that $150 million be the maximum loss. That figure represented over 50 percent of the competitors' average net worth. The Air Force general counsel's office wrote a "repricing" formula that worked as follows: If the costs of DDT&E and Run A exceeded the 130 percent ceiling, then the price of Run B aircraft would increase by a percentage equal to 1.5 times the over-ceiling percentage. If the overrun reached 140.5 percent, as in fact it did, that factor would rise from 1.5 to 2.[89] The purpose was to let Lockheed recoup excessive losses from Run A. The danger, apparently not fully appreciated, was that the repricing formula might create a reverse incentive to raise the cost of Run A so that prices in Run B could be inflated.

Finally, the contract devoted 14 single-spaced pages to performance guarantees. The C–5A had to fly 112,600 pounds of cargo for 5,500 nautical miles. During flight tests, it would have to demonstrate a reliability of 85 percent on 3 aircraft during 1,080 hours of flight. The contractor had to correct design deficiencies at its own expense. Lockheed bore responsibility for delivering the total system by late 1969. For late deliveries, a penalty of $12,000 per plane per day would be applied to the first 16 C–5As. Small wonder, then, that the contract was touted as the toughest ever signed. When some expressed doubt that its terms could be enforced, Charles vowed that he would take Lockheed to court for any breach of contract.[90]

Execution of the contract began impressively. Lockheed created a separate C–5A division, with nine assistant program managers reporting to a corporate vice president. A computerized system, christened "Sentinel," integrated program planning, control, and reporting. On a visit to the company's Marietta, Georgia, plant, Assistant Secretary of Defense Paul Ignatius was impressed by a pervasive "zero defects" mentality.[91]

On the Air Force side, the main tasks of the SPO were reporting progress on meeting cost, schedule, and performance goals, adjusting funding to needs, providing government services and supplies, and negotiating new requirements that arose during development. The Air Force Plant Representative Office (AFPRO) would confine itself to tracking schedules and costs, then measuring technical developments against established milestones. If a serious problem was perceived, the AFPRO would notify the SPO and, where appropriate, suggest remedies to Lockheed. To do otherwise, the Air Force reasoned, would be granting incremental approval for contract changes, allowing Lockheed to saddle the government with responsibility for correcting any shortcomings.[92]

Problems accumulated quickly. First, escalation in Vietnam deluged Lockheed's suppliers with urgent, competing requirements. Unable to secure the precise items it needed for test programs, Lockheed fell back on substitute materials that had to be retrofitted and retested. Second, a continuing rise in commercial orders also placed greater demand on sources of material, which postponed the delivery of forgings. In addition, an engineer shortage obliged Lockheed to pay overtime and subcontract work to engineers in England. Finally, reflecting an inflationary economy, wage and price increases quickly exceeded the "normalcy bands" written into the contract, with no compensating changes permitted until 1968. Within a year, these factors cut Lockheed's expected profit from 10 to 4.6 percent.[93]

Early in 1967, the Air Force began to pinpoint critical deficiencies in test models. The aircraft's empty weight was too high, its takeoff distances too long, its initial cruise altitude too low, and its range and payload characteristics inadequate. On 1 February, the Air Force sent Lockheed a rare "cure notice," warning that the contract might be terminated for default unless it corrected problems or made satisfactory plans, submitted within 30 days, for solving them. Promising to initiate 110 design changes by July, Lockheed averted cancellation. To compensate for the aircraft's weight—the prototype C–5A ran about 12,000 pounds overweight—Lockheed engineers wanted to make General Electric hike the thrust of each engine from 41,000 to 45,000 pounds. The SPO, backed by Charles and his superiors, refused. They were determined to enforce the contract, proving that the Air Force would not revert to cost-plus practices. But this choice turned out badly. Lockheed decided to cut weight by chemical milling of structural parts. Thinning the wings caused cracks several years later, which led critics to label the C–5A the "billion-dollar blunder."[94]

Making its first flight on 30 June 1968, the C–5A met or exceeded almost all performance requirements except landing, where it ran 200–250 feet longer than specified. While the aircraft's empty weight was approximately 1,000 pounds too high, its operating weight met the standard. As Charles later emphasized, the C–5A's performance came to 101 percent of the original requirement, compared to 87 percent for the much-praised C–141.[95]

Yet troubles kept coming. Although Lockheed's year-end report submitted in February 1968 showed no serious cost problems, Air Force Systems Command concluded otherwise. Appearing in April 1968, its analysis projected a $570 million increase, with $477 million attributed to Lockheed, $44 million to General Electric, and $49 million to Air Force additions. Matters came to a head during the autumn of 1968. In September, at the Air Force's request, Lockheed estimated that the 58 aircraft from DDT&E and Run A would cost $2.24 billion, or $1.057 billion above the target. The SPO's estimate in October went even higher, up to $2.44 billion. Lockheed claimed to be in such poor financial shape that it could not even complete Run A unless the government went ahead with Run B. Proceeding with Run B would let Lockheed recoup some losses, because overruns had voided the ceiling price. Consequently, Run B's ceiling would be based on the actual cost of Run A, the repricing formula, and the number of additional aircraft ordered.[96]

Since 31 January 1969 was the deadline for exercising the Run B option, two decisions loomed. First, what should be the ultimate size of the C–5A fleet? Second, should the contract itself be changed? In OSD, Systems Analysis recommended stopping at Run A and compensating by raising the C–5A's flying hours in wartime from 10 to 15 per plane per day. The Air Force, on the other hand, wanted to buy more C–5As, negotiate a "most probable cost" for Run A, and apply that figure to Run B. Then C–5As from Run B, it thought, could be procured for $25 million each—a figure close to the original estimate but, as events would show, still much too low.[97]

On 11 January 1969, Secretary of the Air Force Brown urged Deputy Secretary of Defense Nitze to proceed part way with Run B. The Systems Analysis figure of 15 flying hours per day, Brown asserted, was achievable only under ideal conditions. Stopping at Run A would force Lockheed to terminate the contract, leaving the Air Force with 58 planes in various stages of completion. Since the repricing formula would not apply until more than 33 planes in Run B were purchased, Brown proposed buying only 23 at this point. Nitze agreed with exercising the option on Run B for all 57 aircraft but procuring only 23 during FY 1970, leaving the contract unchanged. Secretary of Defense Clark Clifford, who replaced McNamara on 1 March 1968, approved on 16 January.[98]

Already, though, the C–5A was turning into a public scandal. The deputy for management systems under the assistant secretary of the Air Force (financial management), A. Ernest Fitzgerald, had become deeply disenchanted with how the Air Force acquired weapon systems. Sen. William Proxmire, chairman of the Subcommittee on Economy in Government of the Senate's Joint Economic Committee, invited him to testify. When Fitzgerald appeared before the subcommittee on 13 November 1968, Proxmire asked whether "the costs . . . will be approximately $2 billion more than was originally estimated and agreed on?" Fitzgerald replied: "If the total amount of the estimated cost variance were to come to pass . . . if we were to buy the follow-on production runs using the repricing formula . . . your figure could be approximately right." Proxmire promptly gave that figure wide publicity and asked the General Accounting Office to conduct a review.[99]

What had gone wrong? Total package procurement had met most technical performance requirements but failed spectacularly to control costs. Daniel Haughton, Lockheed's chairman, claimed that the one caused the other. TPP, he told Congress, forced Lockheed to guarantee performance with little opportunity for tradeoffs. Cost control suffered death by a thousand cuts. As the GAO reported in June 1969, constant changes had a snowballing effect on costs.

For example:

> the design refinement of the wing, together with the redesign to reduce drag and the changes made to control weight, all contributed to late release of engineering data to subcontractors and to the contractor's manufacturing branch. This . . . disrupted the production schedule and additional costs were incurred to recover schedule. New tools had to be made, items had to be installed out of sequence, and more overtime was required. Also, the weight control program contributed to greater use of materials such as titanium, beryllium, and honeycomb which, in addition to costing more, also required changes in the manufacturing process, finer tolerances, and increased labor costs.[100]

Likening the C–5A to civilian airliners, a senior official reflected, overlooked the fact that most commercial developments were "near disasters . . . right up to the end." Companies that survived had saved themselves by selling more aircraft than they originally anticipated. Total package procurement, in his opinion, took away the flexibility that made such commercial programs viable.[101]

Cost overruns cut the Air Force's buy from 200 to 80, denying Lockheed the opportunity to recoup its losses during the latter half of the production run. In theory, TPP allowed the Air Force to avoid setting priorities among cost, schedule, and performance. In practice, Lockheed put performance first, compelling the Air Force and ultimately taxpayers to bear much higher costs.

* * * * *

Many Air Force officers believed that aircraft advances of the 1960s did not match the achievements of the previous two decades. They laid the blame on Secretary McNamara, seeing him and his analysts as exemplars of arrogance. General Schriever recalled that he "never once had a session with McNamara relating to a single major program decision, during the entire period they overlapped in the Department of Defense."[102] But their criticism had too narrow a focus. The lack of time was perhaps the greatest problem; switching to flexible response required a drastic reorientation. In early 1965, the Air Force was not well prepared to carry out against North Vietnam the kind of campaign prescribed by civilian leaders. Among the shortcomings of Phantoms and Thunderchiefs, bombing accuracy especially left much to be desired. Even the next three years of Rolling Thunder were not enough to permit major improvements. Superior fire control systems were ordered—Thunderstick II for the F–105D, Mark II for the F–111 (see chapters IV and VII), Pave Phantom for the F–4E—but their development demanded so much new technology that none saw combat before 1972.

For tactical and transport aircraft, so many special circumstances intruded that the Air Force acquisition process rarely received a fair test. McDonnell, with strong assistance from OSD, sold the Phantom to the Air Force. Congress and OSD pressured the Air Force to adopt the A–7. The C–141 followed Air

Force procedures faithfully. In terms of cost, schedule, and performance, it became the period's most successful acquisition. Was that cause and effect or just coincidence? Probably the former, a conclusion buttressed by comparison with the C–5A. The C–5A's cost overruns might have been detected earlier and any "billion-dollar blunder" averted if the Air Force had not self-imposed the rigidity of TPP and failed to probe into Lockheed's financial reports because of the fixed-price contract.

The Soviets, Schriever and other officers feared, were developing a much wider range of weapon systems and moving toward technological superiority. But the next few years did not bear out their fears. Hanoi had probably the strongest air defenses in the world, with much of the weaponry being Soviet-supplied. In December 1972, B–52s supported by F–4s and F–111s neutralized those defenses at a cost of 15 B–52s. In October 1973, during the Arab-Israeli War, an American airlift to Israel, chiefly by C–5As, outperformed a similar Soviet airlift to Egypt and Syria. Moreover, systems conceived in the 1960s—F–15s, "smart" bombs, and 707 airliners outfitted as airborne warning and control systems—would help maintain a U.S. qualitative lead during the 1970s. Thus, while the Air Force's short-term record was mixed, its longer term performance was impressive.

Endnotes

1. Michael H. Gorn, *Vulcan's Forge*, vol. I (Andrews AFB, MD: Headquarters, Air Force Systems Command, 1989), 27, 51, 40, 55; Jacob Neufeld, ed., *Research and Development in the United States Air Force* (Washington, DC: Center for Air Force History, 1993), 55.

2. Gorn, *Vulcan's Forge*, 28, 35, 48, 51–54, 63, 66; Neufeld, *R&D in the Air Force*, 69 fn 82.

3. Gorn, *Vulcan's Forge*, 69–70.

4. Ibid., 69–72; Futrell, *Ideas, Concepts, Doctrine*, 125, 164–166; interview, Lt. Gen. Otto J. Glasser, USAF (Ret.), by Lt. Col. John J. Allen, 5–6 Jan 84, AFHSO, Joint Base Anacostia-Bolling, Washington, DC, 93–99 (quotations, 98–99).

5. Air Force Regulation 23–8 (Air Force Systems Command) stated that "the over-all mission of AFSC is to advance aerospace technology, adapt it into operational aerospace systems, and acquire qualitatively superior aerospace systems and materiel needed to accomplish the Air Force mission." In *Air Force Systems Command History, 1 July 1965–30 June 1966*, vol. III, microfilm roll 2852, AFHSO.

6. Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore: Johns Hopkins University Press, 2002), 68–69.

7. Basic research in the 1960s typically was aimed at expanding knowledge of fundamental scientific principles and was not tied to specific projects or technological objectives. OSD PA Release, "Announce New Air Force Command for Missile and Space Programs," 17 Mar 61, box 82, OSD/HO; J.S. Butz, Jr., "An Eight-Month Report on How Red-Line . . . Is Working in Daily Practice," *Armed Forces Management* 8, no. 3 (December 1961): 26.

8. *Air Force Systems Command History, 1 January–30 June 1962*, vol. I, 22–26, microfilm roll 2851, AFHSO. The AFSC's other divisions were Ballistic Systems, Space Systems, Aeronautical Systems, and Electronic Systems. At Air Force headquarters, a new deputy chief of staff for research and technology was given staff cognizance over basic research and all applied research that was not part of a system. Futrell, *Ideas, Concepts, Doctrine*, 167.

9. Butz, "An Eight-Month Report," 25–26; interview, General Bernard A. Schriever by Lyn

Officer and James Hasdorff, 20 Jun 73, 25, K 239.0512–676, microfilm roll 24662, 904787–904789, AFHSO. General Anderson retired in July 1961, very shortly after General LeMay became chief of staff.

10. "Schriever Urges Bold Approach to Future" and "Project Forecast 'Envisions a New Era of Technology,' Not a Plateau," *Armed Forces Management* 11, no. 8 (May 1965): 37, 39, 42–44.

11. Johnson, *The Secret of Apollo*, 70–74.

12. Schriever interview, 20 Jun 73 (quotations, 29, 75–76, 36, 31, 37).

13. The Air Force defined a weapon system as consisting of the air vehicle, the associated airborne and ground-based equipment, and the skills and supporting facilities required to make it a unit of striking power. Maj. Gen. Donald H. Baker, USAF, "U.S. Air Force Procurement," lecture to the Industrial College of the Armed Forces, Fort Lesley J. McNair, Washington, DC, 26 Jan 55, 3, NDU Library.

14. Converse, *Rearming for the Cold War,* 482–483.

15. Pattillo, *Pushing the Envelope,* 200, 202, 240.

16. Aaron L. Friedberg, *In the Shadow of the Garrison State* (Princeton: Princeton University Press, 2000), 291–293.

17. Marcelle S. Knaack, *Post–World War II Fighters: 1945–1973* (Washington, DC: Office of Air Force History, 1988), 124–125; Knaack, *Post–World War II Bombers*, 559–573; W. David Compton, *Where No Man Has Gone Before: A History of Apollo Lunar Exploration Missions*, NASA Special Publication 4214 (Washington, DC: NASA, 1989), 88–89, 109, 113–114, 287 fn 10; Patillo, *Pushing the Envelope*, 262, 288.

18. The F–4D production figure comes from Knaack, *Post–World War II Fighters*, 275. Counting Air Force, Navy, Marine, and export versions, F–4 output reached 5,195 aircraft, a total surpassed only by the F–86. René J Francillon, *McDonnell Douglas Aircraft Since 1920,* vol. II (Annapolis, MD: Naval Institute Press, 1990), 181.

19. Pattillo, *Pushing the Envelope*, 229–238.

20. Ibid., 223–224, 261; memo, Deputy DDR&E Larsen to AsstSecDef (I&L) Ignatius, "Proposed Revision of ASPR on Industry Cost Sharing," 10 Nov 67, fldr 160 Contractor, box 9, 70–A–3493, RG 330, WNRC. DoD held that commercial rights to sell modifications to or identical with those developed on a government contract were the property of the contractor.

21. Pattillo, *Pushing the Envelope*, 240.

22. Forging involves forming metal by a mechanical or hydraulic press. Extrusion involves shaping metal by forcing it through a specially designed opening, often after heating the metal and/or the opening.

23. Rpt, "Industry-DoD Conference on Aircraft Forging/Extrusion Production Lead Times, 17–19 October 1966," tab 8 to memo, ExecSec, DIAC to SecDef and DepSecDef, "DIAC Meeting, 10–11 February 1967," nd, fldr 334–DIAC–1967, box 32, 72–A–2468, RG 330, Archives II.

24. Memo, AsstSecDef (I&L) Ignatius to AsstSecDef (Manpower) Morris, "Effect of Manpower Shortage on Aircraft Production Lead Times," 17 Nov 66, fldr 320.2, box 11, 69–A–3542, RG 330, Archives II; ExecSec, DIAC, "Summary Minutes–DIAC, 10 and 11 February 1967," fldr 334–DIAC–1967, box 32, 72–A–2468, RG 330, Archives II.

25. Paul R. Ignatius, *On Board* (Annapolis, MD: Naval Institute Press, 2006), 129–130.

26. Equity represents the value of a firm in excess of the claims against it, or the difference between assets and liabilities.

27. Pattillo, *Pushing the Envelope*, 277–278.

28. Ibid., 240, 263, 276–281, 302–303.

29. J. Ronald Fox, *Arming America: How the U.S. Buys Weapons* (Boston: Harvard University Press, 1974), 64–67.

30. Interview, Dr. Alexander H. Flax by James C. Hasdorff and Jacob Neufeld, 27–29 Nov 73, 21–22, 37, 41–42, microfilm roll 24667, 904822–904827, AFHSO. Flax was chief scientist of the Air Force from 1959 to 1961 and assistant secretary of the Air Force for research and development from 1963 to 1969.

31. Dennis R. Jenkins, *F–105 Thunderchief: Workhorse of the Vietnam War* (New York: McGraw-Hill, 2000), 45, 48.

32. Ibid., 52–54.

33. Knaack, *Post–World War II Fighters*, 193–198. Only 75 F–105Bs were produced. Jenkins, *F–105*, 45, 52–54.

34. Jenkins, *F–105*, 69, 58.

35. Knaack, *Post–World War II Fighters*, 199, 203; Kenneth P. Werrell, *Chasing the Silver Bullet*, 13–15, 286 fn 8.

36. Jenkins, *F–105*, 70.

37. Glenn E. Bugos, *Engineering the F–4 Phantom II* (Annapolis, MD: Naval Institute Press, 1996), 115–117.

38. Ibid., 98–99, 105, 116–117.

39. Ibid., 117–118, 111–112. A jig is used to maintain mechanically the correct positional relationship between a piece of work and the tool working on it.

40. Ibid., 118–120. Ultimately, fly-away cost per production aircraft came to $1.9 million for an F–4C versus $2.14 million for an F–105D. Knaack, *Post–World War II Fighters*, 267, 200.

41. Bugos, *Engineering the F–4*, 120.

42. Ibid., 120–122; Knaack, *Post–World War II Fighters*, 273, 278. Other notable changes in the F–4C were larger wheels, tires, and brakes, a receptacle for an in-flight refueling boom, a cartridge starter, a two-pilot capability, and radar with mapping displays for ground targets. Bugos, *Engineering the F-4*, 122–123.

43. *FRUS 1961–1963*, vol. 8, 451.

44. Bugos, *Engineering the F–4*, 123–124.

45. Ibid., 123–125, 112.

46. Ibid., 128–129.

47. Francillon, *McDonnell Douglas*, 222–225.

48. Flax interview, 200–201.

49. Memo, ExecSec, DIAC to DIAC, 25 Oct 66, tab 9 to memo, ExecSec, DIAC to DepSec and SecDef, "DIAC Meeting, 10–11 February 1967," fldr 334 DIAC–1967, box 32, 72–A–2468, RG 330, WNRC; Knaack, *Post–World War II Fighters*, 267, 275.

50. Bugos, *Engineering the F–4*, 160–161 (quoted portion, 161). The run of F–4Cs, all produced between FYs 1963 and 1966, was 583; that of RF–4Cs was 499, all produced between FYs 1964 and 1973; that of F–4Ds was 793, all produced between FYs 1966 and 1968. F–4E production for FYs 1967–1969 came to 388. Knaack, *Post–World War II Fighters*, 268, 272, 275. Between June 1961 and March 1967, 649 F–4Bs were delivered to the Navy and Marine Corps. Deliveries of a successor F–4J began in December 1966. Francillon, *McDonnell Douglas*, 184, 206.

51. Richard G. Head, "Doctrinal Innovation and the A–7 Attack Aircraft Decisions," in *American Defense Policy*, eds. Richard G. Head and Ervin J. Rokke, 3rd ed. (Baltimore: Johns Hopkins University Press, 1973), 435–436, 439.

52. Ibid., 441, 442.

53. Ibid., 431–445. A–7D purchases later were scaled back to 387. *Jane's All the World's Aircraft: 1974–1975* (London: Jane's Yearbooks, 1975), 380.

54. Douglas N. Campbell, *The Warthog and the Close Air Support Debate* (Annapolis, MD: Naval Institute Press, 2003), 61–62, 64 (quotation, 64).

55. Ibid., 68–70, 72, 143–145.

56. Mishler, *The A–X Specialized Close Air Support Aircraft*, 9, 20, 37, 24, 43, 57, 44, 58–61, 95–98; Campbell, *The Warthog and the Close Air Support Debate*, 66–73.

57. Jacob Neufeld, "The F–15 Eagle: Origins and Development," *Air Power History* 48, no. 1 (Spring 2001): 9–11 (quotation).

58. Ibid., 9–13; Werrell, *Chasing the Silver Bullet*, 59–66.

59. On the A–10, see George M. Watson, Jr., "You Can't Keep a Good 'Hog' Down: The Curious Saga of the A–10 Aircraft," *ITEA Journal* 31 (2010): 165–168. On the F–15, see Gary C.

West, *F–15C Eagle: Albatross or Bird of Prey?* (Maxwell AFB, AL: Air War College, Air University, April 1997), 41–42.

60. Knaack, *Post–World War II Bombers,* 291–292. The Air Force intended to equip B–52s with Skybolt missiles having a range of 1,000 miles, but cost and schedule overruns led McNamara to cancel the program late in 1962. Since the British had planned to prolong the lives of their Vulcan bombers by purchasing Skybolts, cancellation caused a brief crisis in Anglo-American relations. Kaplan, Landa, and Drea, *The McNamara Ascendancy,* 375–384.

61. Knaack, *Post–World War II Bombers*, 564; Brown, *Flying Blind*, 212–213; Mark A. Lorell with Alison Saunders and Hugh P. Levaux, *Bomber R&D Since 1945: The Role of Experience* (Santa Monica, CA: RAND, 1995), 28.

62. Knaack, *Post–World War II Bombers*, 566–569; Brown, *Flying Blind*, 217–219.

63. Knaack, *Post–World War II Bombers*, 569–570.

64. Ibid., 570; Brown, *Flying Blind*, 224; Kaplan, Landa, and Drea, *The McNamara Ascendancy*, 104–105; *FRUS 1961–1963*, vol. 8, 384 fn 2.

65. Knaack, *Post–World War II Bombers*, 571–573; Brown, *Flying Blind*, 212, 225; *FRUS 1961–1963*, vol. 8, 592.

66. Brown, *Flying Blind*, 240–244. AMSA was jokingly labeled "America's Most Studied Airplane."

67. Knaack, *Post–World War II Bombers*, 576–579, 593; Brown, *Flying Blind*, 245–247.

68. Kathleen Heintz, "The C–5A," Kennedy School of Government, 1976, pt A, 13–15; Walter L. Kraus et al., "C–141 Starlifter (January 1959-June 1971)," Office of Military Airlift Command History, January 1973, 369, 203, microfilm K300.04–19–23, roll K3075, AFHSO. The C–135 derived from Boeing's 707 airliner and its KC–135 tanker; 45 C–135s were manufactured during 1961–1962. Werrell, *Chasing the Silver Bullet*, 157–159.

69. Roger D. Launius and Betty R. Kennedy, "A Revolution in Air Transport: Acquiring the C–141 Starlifter," *Airpower Journal* 5, no. 3 (Fall 1991): 68–83.

70. The council consisted of the vice chief of staff, five deputy chiefs of staff, and the inspector general of the Air Force.

71. Kraus, "C–141," 20, 93; Elbert M. Stringer and George M. Wentsch, "The C–141 Aircraft: A Case Study in Decision Making from Conception through Source Selection," 9–12, 21–23, Special Collections, NDU Library.

72. Stringer and Wentsch, "C–141," 25–28 (quoted paragraph, 26).

73. Kraus, "C–141," 96, 377; Maj. Hans H. Driessnack, USAF, "How PERT Paid Its Way in the C–141A Starlifter Program," *Armed Forces Management* 11, no. 3 (December 1964): 44–46.

74. Kraus, "C–141," 375, 380; Werrell, *Chasing the Silver Bullet*, 161.

75. Stringer and Wentsch, "C–141," 31; Kraus, "C–141," 50, 256, 259, 266; Werrell, *Chasing the Silver Bullet*, 163, 167.

76. Heintz, "The C–5A," pt A, 16, 17, 21.

77. Ibid., pt A, 21, pt B, 1–2; Werrell, *Chasing the Silver Bullet*, 170–171.

78. Heintz, "The C–5A," pt B, 2.

79. Ibid., pt A, 18, 22–25, pt B, 2; John Mecklin, "The C–5: Part II—Ordeal of the Plane Makers," *Fortune* 72 (December 1965), in Hearings, Joint Economic Committee, *Economic Impact of Federal Procurement*, 89 Cong, 2 sess, 56–58.

80. John Mecklin, "The C–5: Part II—Ordeal of the Plane Makers," 59–61.

81. Heintz, "The C–5A," pt B, 1, 5–6; Mecklin, "The C–5," 58.

82. Mecklin, "The C–5," 56–59.

83. Heintz, "The C–5A," pt B, 6–7; Mecklin, "The C–5," 58–59.

84. Mecklin, "The C–5," 58–59.

85. Heintz, "The C–5A," pt B, 7–8; Mecklin, "The C–5," 59–61.

86. Heintz, "The C–5A," pt B, 3–4.

87. Ibid.; James S. Reese, "The C–5A Contract Repricing Formula," Harvard Business School, 1969, 1.

88. Heintz, "The C–5A," pt B, 10–12.

89. The adjustment procedure went as follows: (1) compute the actual costs of Run A as a percentage of target cost; (2) subtract 130 percent from the result of (1); (3) multiply the percentage result of (2) by a factor of 2; (4) multiply the target costs of Run B by 100 percent plus the result of (3), giving a new target cost for Run B; and (5) establish Run B's ceiling price at 130 percent of Run B's new target cost. Reese, "The C–5A Contract Repricing Formula," 2.

90. Heintz, "The C–5A," pt B, 9–12; "GAO Report on the C–5A Program," June 1969, printed in Hearings, House Cte on Govt Ops, *Government Contracting and Procurement*, 91 Cong, 1 sess, pt 4, 1282–1284; Robert Charles, "The Short, Misunderstood Life of TPP," app F, 51, to Heintz, "The C–5A."

91. Hearings, House Cte on Appropriations, *Department of Defense Appropriations for 1966*, 89 Cong, 1 sess, pt 4, 84.

92. Heintz, "The C–5A," pt B, 12; Hearings, *Government Contracting and Procurement*, pt 4, 1211–1213.

93. Hearings, *Government Contracting and Procurement*, pt 4, 1184; interview, Robert Charles by Lyn Officer, 21–22 Jan 74, 129, AFHSO; Heintz, "The C–5A," pt B, 13.

94. Heintz, "The C–5A," pt B, 13–14; Charles interview, 39–40. Wing failures that plagued the program during the early 1970s are described in Werrell, *Chasing the Silver Bullet*, 176–179.

95. Werrell, *Chasing the Silver Bullet*, 170; Charles interview, 92.

96. Hearings, *Government Contracting and Procurement*, pt 4, 1219–1220, 1284; Heintz, "The C–5A," pt B, 15–17.

97. Heintz, "The C–5A," pt B, 17, 18.

98. Ibid., 17–20.

99. A. Ernest Fitzgerald, *The High Priests of Waste* (New York: W.W. Norton & Co., 1972), 216–223 (quotations, 221).

100. Hearings, House Cte on Armed Svcs, *Hearings on Military Posture*, 91 Cong, 1 sess, pt 2, 3105; Hearings, *Government Contracting and Procurement*, pt 4 (quoted paragraph, 1284–1285).

101. Flax interview, 56.

102. Schriever interview, 36.

I. Jacob Neufeld, *Bernard A. Schriever: Challenging the Unknown* (Washington, DC: Office of Air Force History, 2005). His career prior to Air Force Systems Command is covered in Neil Sheehan, *A Fiery Peace in a Cold War: Bernard Schriever and the Ultimate Weapon* (New York: Random House, 2009).

CHAPTER VII

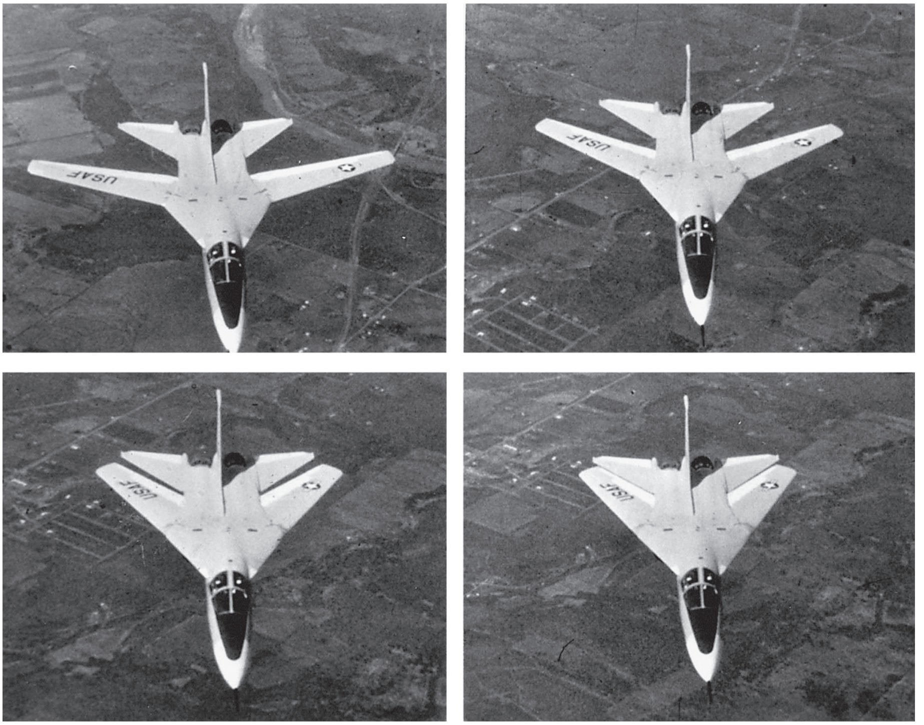
The F–111: A Series of Obstacles

Secretary of Defense Robert McNamara used the F–111 program to pursue an ambitious goal: to break down what he and his analysts saw as service parochialism, and an attendant waste of time and money, by making the Air Force and Navy buy the same airplane. He intended the F–111 fighter-bomber to become the major aircraft procurement program of the 1960s. Incorporating an innovative variable geometry wing, popularly labeled a "swing wing," the final product would stand as proof that commonality could be consistent with superior performance at lower cost. This assumption, however, did not take account of major differences in service requirements. While the Air Force wanted a strike aircraft able to deliver nuclear or conventional weapons, the Navy needed a fighter armed with air-to-air missiles to defend a carrier task force. Attempting to satisfy both of these needs with one aircraft raised the risk of cost overruns, schedule slippages, and performance shortfalls.[1]

A COMPLEX DESIGN CONCEPT

The F–111 originated in a demanding set of operational requirements that seemed achievable with new technology. In 1959, Air Force leaders began seeking a successor to the F–105 Thunderchief, designed primarily to deliver tactical nuclear weapons but also capable of aerial combat. The Thunderchief needed about 6,000 feet for its takeoff run;[2] only a few dozen overseas bases met that requirement. By hitting those few dozen with missiles, therefore, the Soviets could keep the entire F–105 force out of action. The commander of U.S. Air Forces, Europe asked for a plane that could cross the Atlantic without refueling, use short unpaved runways, reach twice the speed of sound (Mach 2), and fly at high subsonic speed for 400 NM at tree-top height to deliver nuclear or conventional payloads.[3]

No existing jet could perform all those missions. At subsonic speed, a plane operated most efficiently with a long wingspan and narrow chord (the distance from the front to the back of the wing). Conversely, at supersonic speed, a very short wingspan with a wide chord would reduce friction and drag. John P. ("Pete") Stack, an engineer working for NASA, devised a solution: build swing wings. Mounting pivots on the wing itself rather than inside the fuselage at the wing root would let part of the wing remain fixed while part of it swung back. As the angle of sweep grew, the proportion of lift provided by the stationary part of the wing would increase, greatly improving aircraft stability. Stack advised using titanium rather than the standard aluminum and stainless steel to fabricate the wing and mid-fuselage sections. While highly heat-resistant and able to endure great stress without fatigue, titanium weighed about half as much as steel but 60 percent more than aluminum. It also cost about four times as much as high-alloy steel. Equipping the plane to perform more missions would further increase its weight. Fortunately, development of the turbofan engine offered some relief. Unlike the turbojet, a turbofan split airflow between the core engine and a bypass duct. Air from this bypass provided thrust that lowered fuel consumption.[4]



Operation of the General Dynamics F–111A swing wings (*National Museum of the U.S. Air Force*)

On 14 July 1960, the Air Force issued Specific Operational Requirement (SOR) 183, initiating what became the Tactical Fighter Experimental (TFX) program. The SOR required a swing wing, stipulated a mandatory speed of Mach 2.2 and a desired speed of Mach 2.5 at altitude, and specified enough ferry range to cross the Atlantic, flying 3,300 NM without refueling or wing tanks. The low-level "dash" was cut from 400 to 200 NM, but the speed of that dash was raised from Mach 0.9 to Mach 1.2. The Navy had data indicating that Mach 0.9 was optimal for evading surface-to-air missiles and avoiding ground obstructions. Low-level dashing to deliver conventional weapons was ruled out because bombs would have to hang from hard points on the wings, creating too much drag. Increased speed meant higher drag and greater fuel consumption, requiring a larger plane that could carry more fuel. Essentially, the requirement for a long, low-level dash at Mach 1.2 dictated the design of the aircraft and underlay many of the later development problems.[5]

The Navy worked up its own requirement in parallel. Soviet aircraft—Tu-22 bombers and fighter-bombers able to reach Mach 2—could fire missiles at ships from well beyond visual range. In July 1960, Douglas Aircraft won a contract to design the F–6D Missileer as a subsonic fighter with long endurance, able to locate and destroy aircraft with Eagle air-to-air missiles fired from as far as 20 miles. Late that year, the Eisenhower administration decided to leave weapons development decisions to its successor, halting the TFX source selection competition and deleting F–6D funds but continuing development of the Eagle missile.[6]

Secretary McNamara saw a single multiservice, multimission aircraft as answering the needs of both services while promoting efficiency, economy, and improved conventional capability. The Air Force version could reach Mach 2.5 by swinging its wings back; pushing wings forward would give the Navy version greater loiter time by increasing lift and conserving fuel. On 14 February 1961, at McNamara's instruction, the director of defense research and engineering tasked the services with studying a joint tactical fighter based on Air Force SOR 183.[7]

The Navy quickly gave its assessment: "Drop the TFX (SOR 183) altogether."[8] Unconvinced, the DDR&E organized a Committee on Tactical Air to review the spectrum of requirements. In mid-May, it recommended that the Navy develop an inexpensive close support plane and that the Air Force oversee development of a bi-service TFX designed for fleet air defense as well as tactical interdiction. These initiatives promised to save $1 billion. On 7 June, McNamara authorized the Air Force to work closely with the Navy in developing an air superiority plane that would replace the Air Force F–105 and the Navy F4H–1 Phantom. He also canceled the F–6D Missileer as redundant.[9]

Getting the two services to work together closely was much easier said than done. The Navy wanted heavy carrier landing gear attached to a light airframe; the Air Force wanted a heavier titanium airframe that would withstand the tremendous stresses of intercontinental and low-level penetration missions. By August 1961, the services still had not settled on a single set of requirements. The Navy argued for separate TFXs, with the services coordinating development of subsystems and other components. Carrier aircraft requirements were unique, the Navy insisted, and compromise would produce an airplane "considerably below optimum for either service."[10] A key factor was "wind-over-deck"—how fast the carrier had to steam against the wind in order to launch the aircraft. If a ship steamed at 30 knots in a dead calm, for example, a wind-over-deck of 30 knots would be created. The heavier the plane, the more wind-over-deck it needed to take off. The lighter the plane, the more flexibility a carrier enjoyed in choosing courses and speeds to carry out launches and recoveries.[11]

Harold Brown, who in May had succeeded Herbert York as director of defense research and engineering, believed a joint program to be feasible. His office drafted a directive that Secretary McNamara signed on 1 September 1961: "A single aircraft for both the Air Force tactical mission and the Navy fleet air defense mission will be undertaken. . . . Changes to the Air Force tactical version of the basic aircraft to achieve the Navy mission shall be held to a minimum."[12] On 1 October, the services sent out requests for proposals to industry, accompanied by statements of work. The Air Force version of the aircraft, to weigh approximately 60,000 pounds, including a full internal fuel load and 2,000 pounds of internal stores, also had to be able to carry 10,000 pounds of conventional ordnance—6,000 pounds less than the Navy's F–4. Gross takeoff weight for the Navy version could not exceed 55,000 pounds, unless the Navy approved. For fleet air defense, the plane had to be able to carry six 1,000-pound missiles for 3.5 hours to a radius of 150 NM.[13]

GENERAL DYNAMICS AND THE PRIME CONTRACT

Because it would acquire the most TFXs, the Air Force selected the prime contractor for the system. Source selection began with an evaluation team assessing bidders' proposals. Four groups—technical, operational, management, and logistical—comprising about 250 experts reviewed the proposals; a Navy captain (equivalent to an Air Force colonel) assessed designs from the standpoint of carrier compatibility. Each of the four groups compiled raw scores by matching individual items against standards set by the source selection board and ranking each on a scale from 0 to 10. The evaluation team then turned raw into weighted scores. Of the 1,000 points possible, one-third were allotted to the technical area, one-third to operational matters, one-fifth to management capabilities, and one-ninth to logistical factors. Next, the source selection board reviewed the evaluation team's findings and forwarded a recommendation to concerned Air Force commanders and Navy bureau chiefs, who added their views. The Air Force Council then considered all comments. Chaired by the vice chief of staff, the council acted as the senior deliberative and advisory body for the chief of staff.[14] Its recommendation went to the uniformed and civilian heads of the Air Force and Navy. Because the TFX was a bi-service program, the final decision necessarily rested with Secretary McNamara.[15]

Six companies submitted designs. The evaluation team, while judging none acceptable without substantial changes, proposed giving Boeing and General Dynamics (collaborating with Grumman) contracts to carry out further study.

The Bureau of Naval Weapons, avoiding point scores, rated Boeing's proposal "acceptable with changes" but found the General Dynamics design "unacceptable without major changes." Boeing had chosen General Electric's MF295 engine, which would not be ready until 1967, well beyond October 1965, the intended date for delivering the TFX to operational units. General Dynamics planned to use Pratt and Whitney's TF30 engine—300 pounds heavier, 4 inches wider, and slightly longer than the MF295, but further along in development because it had been intended for the Navy's F–6D Missileer.[16]

The evaluation team wanted Boeing to redesign its airframe around another engine. It also asked General Dynamics to redesign its airframe in order to reduce an excessive wind-over-deck condition. At the next level, the source selection board unanimously recommended Boeing's design only. The Air Force Council, however, concluded that extending time and competition would save money over the long run. Development of the B–70 bomber, it believed, had benefited by having Boeing and North American continue funded competition for more than a year. The service secretaries sided with the council. Secretary McNamara approved late in January 1962.[17]

On 2 April 1962, Boeing and General Dynamics submitted revised proposals. At the source selection board, Air Force members recommended Boeing; the Navy member found neither design acceptable. When the Air Force Council convened on 24 May, all of its members rated Boeing the highest, but the Navy again judged both unacceptable. In fact, according to the chief of the Bureau of Naval Weapons, the new proposals missed performance and weight goals by a greater margin than the original submissions.[18] By redesigning to accommodate the TF30 engine, Boeing had increased aircraft weight by 4,000 pounds, creating an even greater wind-over-deck requirement. The chief of naval operations (CNO), Admiral George W. Anderson, opposed a firm recommendation for Boeing as premature since he saw "no indication that Navy requirements can indeed be met." The service secretaries proposed, and McNamara approved, giving the companies three weeks to correct shortcomings.[19]

The evaluation team received the next round of designs in mid-June. According to Albert W. Blackburn, who was monitoring the TFX for the DDR&E, the General Dynamics proposal gave the impression of having been put together in:

> an atmosphere of complete panic and confusion . . . with the result that they presented . . . four solutions to the Navy problem out of which [the Navy] selected two. . . . In one of these the Air Force fuselage was used with a brand new Navy wing and in the other the Air Force wing was used with a brand new Navy fuselage.

By Blackburn's account, many evaluators felt that the General Dynamics proposal had abandoned the whole concept of bi-service development. Boeing's presentation, by contrast, preserved a common design and impressed "even . . . the most critical of Navy technical observers that for the first time one of the competitors had . . . offered realistic solutions." The Air Force was ready to go with Boeing, refining its design as development proceeded. But the Navy, noting that companies had been allowed only three weeks to correct deficiencies, insisted that Boeing's redesigned wing needed more testing and analysis.[20]

The source selection board, the Air Force Council, and the two service chiefs recommended that Boeing alone undertake further design definition. Again, however, the civilian service secretaries decided to keep both firms working. On 13 July 1962, at McNamara's direction, Deputy Secretary of Defense Roswell Gilpatric advised Boeing and General Dynamics that they had to meet three conditions before a contract would be awarded: First, satisfy both services that tactical air capabilities would significantly improve. Second, minimize the divergences from a common design. Third, demonstrate "credible understanding of costs for both development and procurement," reconciling an obvious disparity between contractors' estimates and Air Force standards. At this point, planned procurement came to 1,491 Air Force and 235 Navy TFXs, which would make it the largest aircraft program of the 1960s.[21]

The next round of the competition applied a novel approach—giving the evaluation team authority to work directly with each contractor, as though each were a prime contractor, identifying deficiencies and extending as much help as possible without specifically designing the weapon system or revealing anything about one contractor's work to the other. The General Dynamics–Grumman team began well behind Boeing but closed much of the gap by switching its test models from stainless steel, needing 6 to 8 weeks for fabrication, to casting from fiberglass that took less than 10 days and allowed more wind tunnel experiments and quicker design improvements. General Dynamics narrowed its models to one weighing 2,000 pounds more than Boeing's design. Boeing, meantime, sacrificed commonality to satisfy Navy demands for a lighter aircraft.[22]

The team heard final presentations on 11 September 1962. According to Blackburn, "The General Dynamics presentation was inspired. Histrionically it could not have been better paced or more interestingly presented. The design was essentially new, the lines were smooth, and the data appeared to be well validated." Boeing's briefing was "dull by comparison" because, in Blackburn's view, "Boeing engineers had gone beyond the broad considerations of basic drag, range, and maximum [speed] and had gotten into the fine details of working on very small drag items and problems of stability and control."[23]

The evaluation team's scores showed the two companies almost in a dead heat: 654.2 for Boeing versus 662.4 for General Dynamics, out of a possible 1,000 points.[24] This time, the team and the Bureau of Naval Weapons rated both designs acceptable. On 2 November, the source selection board unanimously recommended Boeing; the user commands and bureaus followed likewise. Six days later, the Air Force Council decided that although either firm could design and produce TFXs successfully, Boeing enjoyed a "clear and substantial advantage." While "the level of carrier suitability and mission performance" favored Boeing, the council saw "no clear-cut choice in the naval configuration between contractors." Air Force Chief of Staff General Curtis LeMay endorsed those conclusions two days later, as did Admiral Anderson, the CNO.[25]

Boeing had begun with a built-in advantage. From the outset, the Air Force had leaned toward that company. Veterans of the Strategic Air Command filled many top posts in the Air Force, and their faith in Boeing—designer and producer of the B–17, the B–29, the B–47, and the B–52—was complete. Officers in the Bureau of Naval Weapons judged Boeing's design superior to the General Dynamics design, although it fell short even of the Navy's relaxed requirements.[26]

Civilian leaders, however, were not so easily convinced. Hearing the evaluation team's presentation on 9 November, Secretary of the Air Force Eugene Zuckert considered it to be not so much a briefing as a brief for Boeing.[27] How, he wanted to know, did rival designs compare in terms of commonality? How much technological innovation did each incorporate, and what risks did each incur? Boeing proposed three novel innovations: employ thrust reversers instead of speed brakes; place air inlet ducts behind the afterburner rather than under the wings; and use titanium for much of the fuselage. Zuckert, however, saw serious problems in all three proposals.[28]

A thrust reverser, Boeing argued, was the only deceleration device that could work effectively over the TFX's entire speed range. Precisely controlling the rate and angle of descent would also allow the plane to land on a short runway. Boeing had been using thrust reversers, in flight but not for landing, on subsonic airliners like its 747. At temperatures approaching 3,000 degrees, however, the plane would require completely new materials to guard against warps and leaks. Wary of the risk, Zuckert opted for General Dynamics's well-proven speed brakes, spoilers, and drag parachutes. Air Force officers favored the thrust reverser. Only later did the Air Staff reject replacing brakes with reversers.[29]

Boeing also maintained that its top-mounted air duct proved to be completely satisfactory on the 727 airliner and had been validated for the TFX by wind tunnel testing. If the TFX had to operate from unimproved airfields, top-mounted ducts appeared to lessen the dangers of damage from foreign objects, as well as flameouts caused by ingesting missile exhausts. The argument against top mounting was that friction between air and fuselage skin could distort the airflow and degrade engine performance, particularly when a plane maneuvered from a high angle of attack. Distortion at the engine face had to be held down to acceptable levels, and wind tunnel tests could not completely simulate all conditions. Comparing Boeing's top mounts against General Dynamics's "more straightforward" side inlets, Zuckert again assessed the risks of innovation to be unacceptable.[30]

To save weight, in the final round of competition, Boeing switched from conventional materials to titanium alloy for the wing carry-through and pivot support structures, specifying a thickness greater than any used before. No data on metal fatigue existed for titanium when used in such large sections. At that time, B–52s were experiencing wing failures due to metal fatigue caused mainly by the aircraft's shift to low-level missions. The TFX required "high-speed, low-level characteristics, the loads of a bomber, the agility of a fighter, the range of a transport . . . performance under austere conditions and a long service life." That was why, Secretary Zuckert later testified, "you have to be conservative in your selection of materials."[31] But the decisive voice probably came from Clarence "Kelly" Johnson, who had designed Lockheed's U–2 spy plane and was working on the A–11 interceptor (subsequently A–12) that later became the SR–71 strategic reconnaissance aircraft. The A–11, which would fly at Mach 3, used titanium extensively. Aluminum lacked sustained resistance to temperatures generated above Mach 2.5. The TFX, though, would have a maximum speed of Mach 2.5. Consequently, Johnson advised Zuckert that Boeing was "crazy" to specify titanium in the thickness and places proposed.[32]

Believing that the swing wing itself represented as great a technological leap as the TFX could bear, Zuckert leaned toward General Dynamics's proven solutions. General Dynamics, Zuckert later testified, "was most likely to provide the best plane, in the least time, and at the lowest cost."[33] On 13 November 1962, McNamara advised President Kennedy that "it looked as if General Dynamics would be chosen."[34] Secretary of the Navy Fred Korth joined Zuckert in recommending that General Dynamics–Grumman receive the contract. In their memorandum to McNamara, dated 21 November 1962, the two service secretaries made the following points: First, in terms of acceptability, no "overriding margin" existed between the competitors. Second, General Dynamics enjoyed a "distinct edge" in commonality of Navy and Air Force versions, with 85 percent of its parts considered identical compared to 60 percent for Boeing. Since Boeing intended to perform separate static tests for its two versions, probably even that 60 percent could not be preserved. Third, Boeing's cost proposal seemed excessively optimistic. Citing its experiences in developing and producing B–47s, B–52s, KC–135 tankers, and Bomarc surface-to-air missiles, Boeing had reduced its man-hour estimates for manufacturing by as much as 30 percent below the industry average. Korth and Zuckert did not consider these examples directly applicable to high-density, complex fighter aircraft, particularly an extremely advanced design incorporating thrust reversers, top-mounted inlets, and fuselage titanium. Boeing's research and development program, they were convinced, would not proceed anywhere near as smoothly as the company claimed. By contrast, General Dynamics's proposal applied an "extensive engineering and test effort to the development program and could be considered as being conservative."[35] Fourth, while Boeing had produced mostly subsonic bombers and transports, General Dynamics and Grumman offered extensive experience with high-performance, tactical, and carrier-based aircraft, making those firms "thoroughly familiar with all the problems of stability augmentation and supersonic operation."[36]

On 22 November, McNamara chose General Dynamics. By going with Boeing, he reasoned, "the prospects of saving $1 billion would have evaporated." He emphasized that "the effort to attain the highest degree of commonality lies at the heart of the entire TFX endeavor."[37]

No other contract award of the 1960s stirred up such a furor. Never before had a secretary of defense reversed a source selection board's recommendation. In April 1965, McNamara confined the source selection boards to making evaluations without recommendations, reserving decisionmaking either for himself or a service secretary. This change applied to programs involving $25 million or more for research and development and $100 million or more for production.[38] By centralizing decisionmaking, Secretary McNamara already had raised hackles among the services and in Congress, although in this case he was agreeing with two service secretaries. Democratic Sen. Henry M. Jackson of Washington, where Boeing had its headquarters, met with McNamara and found the secretary "less than cordial." Jackson then turned to Sen. John McClellan, chairman of the Committee on Government Operations and its Permanent Subcommittee on Investigations. McClellan asked for a delay in concluding the contract, which Gilpatric, on McNamara's behalf, briskly rejected.[39]

Allegations of impropriety appeared. Boeing's plant was in Seattle, Washington; the General Dynamics plant was in Fort Worth, Texas. Deputy Secretary Gilpatric had performed legal work for General Dynamics while in private practice; Secretary Korth had been a Fort Worth banker. Vice President Lyndon Johnson hailed from Texas; a joke of the day had it that the TFX should be renamed the LBJ. General Dynamics, moreover, was experiencing problems in other areas. Its 880 and 990 turbofan airliners, the latter produced without the benefit of a prototype, were big money losers. According to one observer, General Dynamics was being operated "as a holding company with no real control from the top."[40]

Hearings held by Senator McClellan's subcommittee, often rancorous in tone, ran from 26 February through 20 November 1963. After some sharp exchanges, McNamara let senators know that "when I got home at midnight . . . my wife told me that our twelve-year-old son had asked how long it would take for his father to prove his honesty."[41] While no evidence of impropriety surfaced, McClellan and most of his fellow senators concentrated on the issue of civilians overriding military judgment. General LeMay testified to Senator McClellan, "I thought we had such a clear-cut and unanimous opinion all up and down the line that I was completely surprised at the decision. I expected to have some reason [given] that wasn't apparent to me. . . . If there had been, I would have expected the Secretary [of the Air Force] to tell me about it. . . . He did not."[42] Admiral Anderson, in his testimony, regretted that:

> we did not reiterate and review our record of compromises and consequently did not make clear to [Secretary Korth] the importance of those areas in which the Boeing design appeared superior. . . .

> Those of us who learned the hard way . . . attach great significance to what might otherwise appear inconsequential differences between two competing pieces of military hardware. . . . This has also taught me a lesson, to perhaps . . . be more contentious in the future.[43]

Anderson never had such an opportunity. His tenure as CNO, which ended on 1 August 1963, was not renewed. With hindsight Anderson felt sure that, by contradicting his civilian superiors, his TFX testimony terminated his career. As many military officers saw it, civilians were putting cost-saving commonality ahead of operational performance. McNamara's inability to win congressional support confined the TFX's backers mostly to senior DoD civilians.[44]

TEETHING TROUBLES

On 21 December 1962, Secretary McNamara awarded General Dynamics a $28 million letter contract for research, development, and test and evaluation of 23 F–111As, as the Air Force version of the TFX was now designated. The Air Force, having the great bulk of the planned procurement, established a system program office at Wright-Patterson Air Force Base, Ohio, to oversee the acquisition. Col. Charles A. Gayle, who had led the Air Force evaluation team, headed the SPO until October 1963, when Brig. Gen. J.L. Zoeckler succeeded him. The SPO reported to the Aeronautical Systems Division of the Air Force Systems Command. A small Navy contingent dealt with common development concerns and maintained liaison with the Navy's technical bureaus.[45]

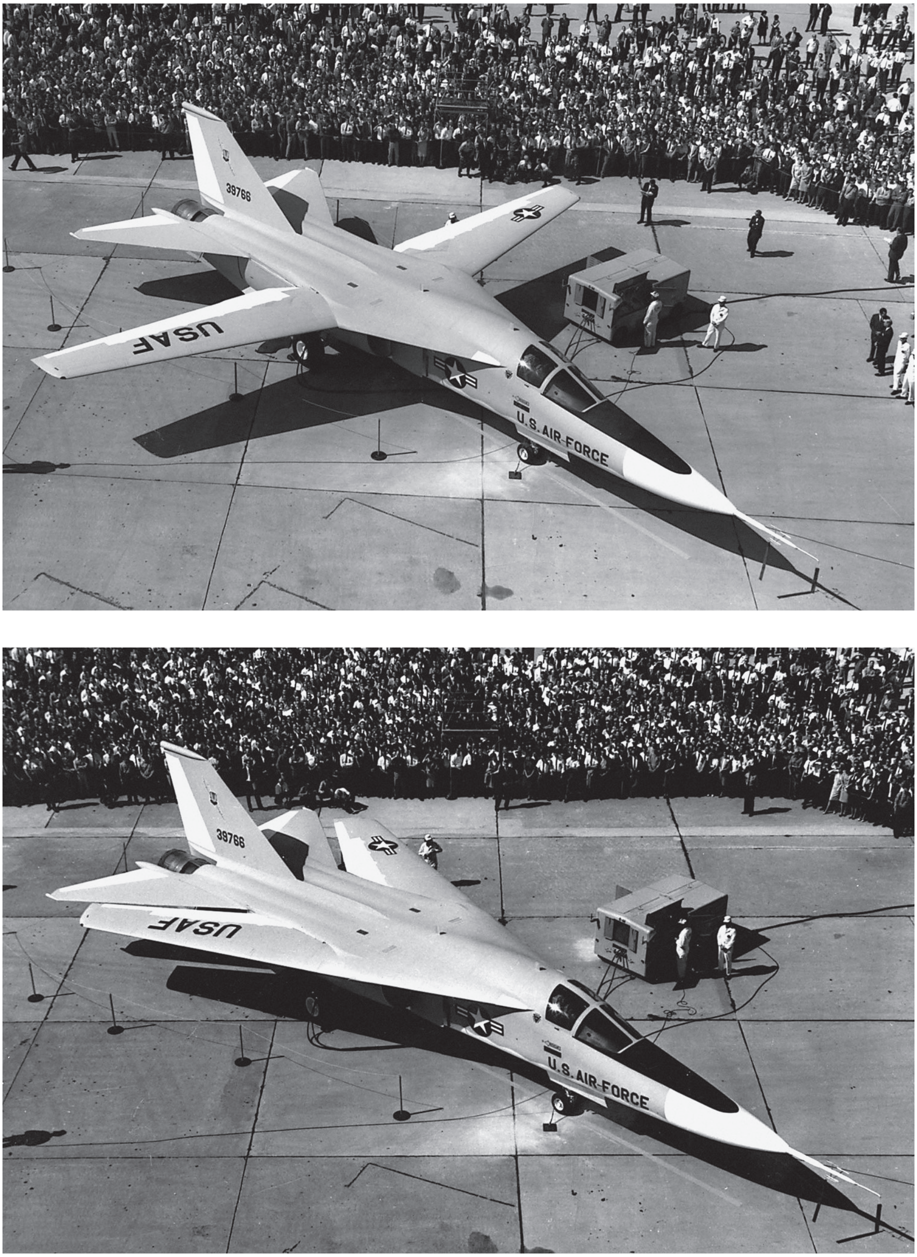
According to contractual requirements, the F–111A's first flight test would take place in December 1964, and delivery of the first production units would occur in 1967. But testing, even with a model in a wind tunnel, revealed problems that defied quick solutions. The stresses in a fixed-wing aircraft were transmitted to the aircraft's skin and fuselage. On a swing-wing F–111, the stress-bearing skin of the outer wing panels could not be connected to the skin of the wing roots. Consequently, wing stresses concentrated around the wing pivot, requiring an extremely heavy wing mounting. When fully swept back, a significant portion of the wings remained tucked inside the fuselage and the thick "glove" or wing root, adding weight to the aircraft without improving capabilities. Furthermore, the glove and fuselage space needed to accommodate folded wings, and the break where the wing met the glove enlarged the F–111's radar cross section and increased aerodynamic drag. During March and April 1963, wind tunnel tests at NASA's Langley Research Center in Virginia revealed a high drag that, in the dense air at sea level, would reduce the F–111's range in supersonic dash drastically.

The F–111 Aerodynamics Consulting Group, a joint review committee organized to assess and recommend aerodynamic improvements to the aircraft, reported in October 1963 that General Dynamics's figures were optimistic and that performance would run well below contractual requirements. By that time, General Dynamics projected an increase in the empty weight of the Navy version, the F–111B, from 38,000 to 46,000 pounds. Adopting an innovation from Boeing's proposal, General Dynamics now proposed adding the thrust reversers that senior civilians previously considered too risky. The SPO objected, believing that the thrust reverser could seriously complicate integrating the engine with the tail end of the airframe, thereby reducing range and performance.[46]

In January 1964, Secretary McNamara called for a comprehensive program review. The Bureau of Naval Weapons remained pessimistic, pointing out that the empty weight and weight growth of the F111–B was the greatest of any Navy design up to that point. Weight growth, the bureau asserted, was grossly degrading every characteristic of the F–111B. Piecemeal corrections might even make matters worse.[47]

Again, civilians took an optimistic view. Harold Brown, joined by the Air Force and Navy secretaries, advised McNamara against delaying or stopping work on the F–111B. They suggested that a Super Weight Improvement Program (SWIP), backstopped by alternative designs, probably could trim away enough pounds to make the plane viable. McNamara agreed. A 4,000-pound weight reduction, achieved between January and June 1964, and other modifications lowered the commonality between F–111As and Bs to 78.8 percent.[48]

On 3 February 1964, Brigadier General Zoeckler rejected the Navy's recommendation to delay completing a letter contract for research, development, and test and evaluation. Assistant Secretary of the Air Force Robert Charles wanted to employ penalty and incentive provisions in a fixed-price contract, giving the contractor a greater impetus to tackle production costs at an early point. Thus, if the F–111B undershot the contract limit of 38,804 pounds by 1,000 to 2,000 pounds, Grumman and General Dynamics would be rewarded with 0.2 percent of the total contract ($875,000). If aircraft weight overran that limit by as much as 2,000 pounds, a penalty of 0.1 percent ($437,500) would be applied. Likewise, if takeoff distance proved to be 400 to 600 feet less than the required minimum of 2,900 feet, the contractor would win a 0.1 percent reward; if over by 200 to 500 feet, the penalty also would be 0.1 percent. Charles believed that cost-sharing, setting a target profit and a ceiling price, and adding a correction-of-deficiencies clause would provide the government with ample protection.[49] Secretaries Zuckert and McNamara approved Charles's approach. On 22 May 1964, Air Force and General Dynamics representatives signed a contract with a target cost of $441 million plus a target profit of 9 percent, $39 million, bringing the target price to $480 million. The sharing arrangement for over- or under-running target cost stood at 90 percent for the government and 10 percent for the contractor, with a ceiling price set at 120 percent of the target cost.[50] The Air Force's first F–111A rolled out of its hangar on 15 October 1964, and an initial flight test followed on 21 December. "For the first time in aviation history," McNamara publicly declared, "we have an airplane with the range of a transport, the carrying capacity and endurance of a bomber, and the agility of a fighter pursuit plane."[51]



General Dynamics F–111A with wings extended (*top*) and wings swept (*bottom*) at aircraft rollout, 15 October 1964 (*National Museum of the U.S. Air Force*)

The Navy's F–111B fared much less well as its weight and cost kept climbing. The first F–111B weighed 47,000 pounds empty, which meant that its gross takeoff weight would be approximately 78,000 pounds. Most carriers could not raise planes from the hangar deck to the flight deck if they weighed over 70,000 pounds. Loading fuel and weapons on the flight deck was not desirable in combat. On 26 August 1964, Brown tasked an ad hoc group with appraising progress on the F–111B and its associated Phoenix air-to-air missile. Much like the Aerodynamics Consulting Group one year earlier, it warned that the contractors would not meet deadlines and performance requirements. The assumption had been that one F–111B would replace two F–4s because an F–111B could stay aloft longer with more than twice the payload of an F–4. That was true, the group concluded, only if the extra payload could justify the extra cost—and it was not apparent that the F–111B in its current configuration could do so.[52] Brown, in turn, advised Secretary McNamara that the F–111B/Phoenix faced serious trouble and required urgent examination.[53]

Navy F–111B (foreground) parked alongside an Air Force F–111A (*U.S. Naval Institute*)

Early in 1965, the DDR&E proposed changing the Air Force SPO into a joint Air Force–Navy office. Allowing more autonomy, with Grumman reporting directly to the secretary of the Navy, might ease the Navy's antipathy to Air Force management. Without bold steps, Brown predicted that the Navy, by October 1966, would declare the F–111B's record of flight tests unsatisfactory and leave the program.[54]

By the beginning of April 1965, Deputy Secretary of Defense Cyrus Vance approved restructuring the program office. At that point, claiming that $200 million would be saved, General Dynamics threatened to withdraw all F–111 work from Grumman and transfer it to its own plant in Fort Worth. Although Grumman was performing the final assembly of F–111Bs, a much larger part of its contractual work involved manufacturing the tails and landing gear for F–111As. As the prime contractor, General Dynamics enjoyed the right to propose any reorganization that would give the government a net saving. By June, the OSD comptroller calculated that savings would reach only $4 million to $5 million. Meantime, however, Grumman decided to satisfy General Dynamics by opposing any major changes in program management. The upshot was that the SPO retained much the same form. Zoeckler was promoted to major general. Rear Adm. W.E. Sweeney became deputy director with responsibility for the Phoenix missile, which Hughes Aircraft had been developing outside the SPO. However, the SPO did not function as an integrated organization; Sweeney retained control of Navy funding and the F–111B program.[55]

On 12 April 1965, the Air Force concluded a letter contract with General Dynamics to produce 431 aircraft for a total target price not exceeding $1.68 billion and a ceiling price not exceeding 125 percent of the negotiated target price. The next day, Zuckert informed Secretary McNamara that the F–111A fell short of some requirements, particularly for the low-level dash (106 miles instead of the 210 specified), but was clearly adequate to satisfy Air Force needs. The Air Force, he continued, anticipated an improvement normal in any aircraft. Should the plane fail to meet specifications, the Air Force intended to employ the correction-of-deficiencies clause. But because the Air Force and the contractor believed that Navy requirements would be met, Zuckert judged firm commitments for both versions to be justified.[56]

General Dynamics FB–111A prototype in flight (*National Museum of the U.S. Air Force*)

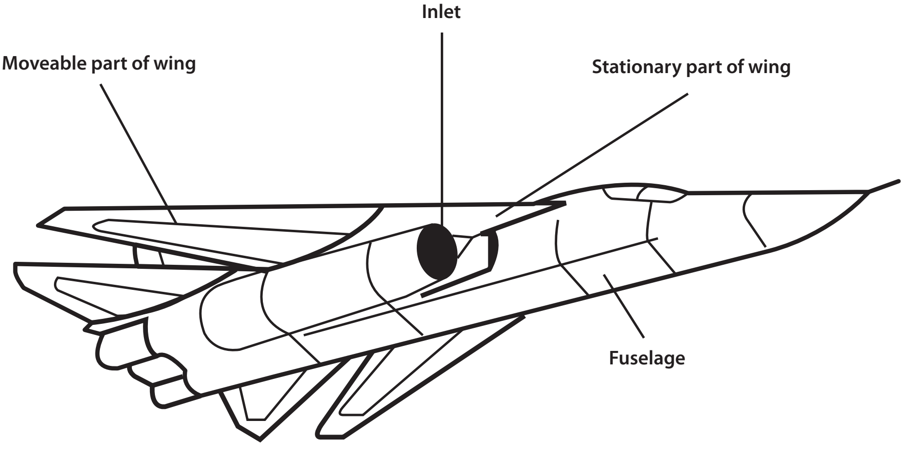
Secretary McNamara pressed for a third F–111, a strategic bomber version of the F–111A, designated the FB–111A. Faced with cancellation of the B–70 bomber, working to prevent B–52 structural failures from the stress of low-level flying, and alarmed by McNamara's deferral of an Advanced Manned Strategic Aircraft, the Air Force concurred. In November 1963, General Dynamics suggested two versions. Wind tunnel tests, funded separately from those for the F–111A, followed. Early in 1965, OSD compared the projected cost and performance of supersonic FB–111As with those of subsonic B–52s and supersonic B–58s. Matched against improved Soviet air defenses, FB–111As carrying SRAMs offered a cheaper alternative than modifying older B–52s or restarting B–58 production. In June 1965, the Air Force approved developing an FB–111A, expecting the first of 210 to become operational during FY 1969.[57] Five months later, Secretary McNamara announced that FB–111As would replace all B–58s as well as early B–52s—the C through F models produced between 1956 and 1959.[58]

Even without top-mounted air ducts or thrust reversers, integrating the engine and the airframe proved to be difficult. The F–111 was the first combat aircraft to use afterburning turbofan engines, which had different airflow characteristics than turbojets and were particularly sensitive to airflow distortion. Designers knew that large area inlets with "rounded cow lips" would best provide a smooth airflow. Yet to minimize drag during a supersonic dash and optimize airflow at high angles of attack, General Dynamics designed quarter-round inlets located at the wing-fuselage juncture. During 1964, General Dynamics supplied Pratt and Whitney with inlet distortion data drawn from wind tunnel tests. Relying on an index that weighted radial distortion equally at all distances from the compressor's center, Pratt and Whitney judged that the levels of airflow distortion were acceptable and that stall-free operations were likely.[59]

That judgment proved optimistic. The contract specified that, while flying at Mach 2.2, an F–111 had to be capable of making an instantaneous 15-degree change in its angle of attack. Test pilots performed this maneuver successfully at Mach 1.6, but engine stalls occurred repeatedly at higher speeds. When senior Air Force officers were briefed, one whistled in surprise, saying that he saw no need to perform such a maneuver at 60,000 feet since the F–111 was not an air superiority fighter. No matter the logic, McNamara did not allow a deviation from the original performance requirement.[60]

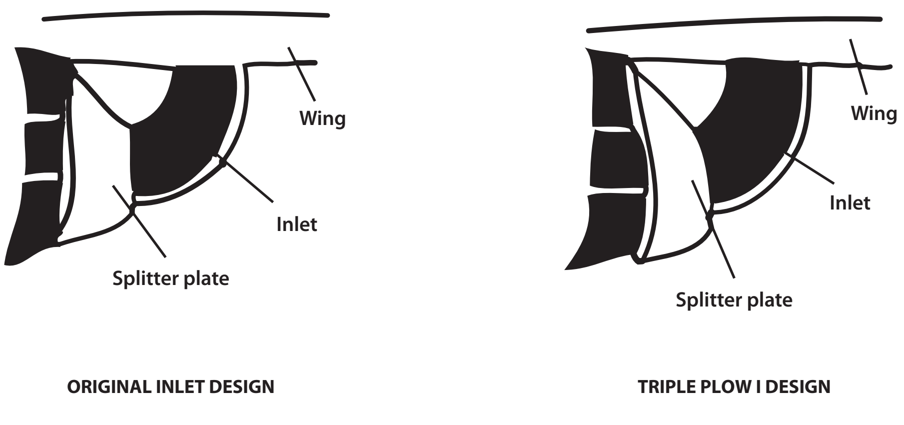
Further wind tunnel tests, conducted at AFSC's Arnold Engineering Development Center in Tullahoma, Tennessee, isolated and identified the cause of stalling. Turbulence in the boundary layer of air, created by friction of the airflow along the fuselage, posed no problem in subsonic flight. But at supersonic speed, during a maneuver involving a sharp change in the angle of attack, the boundary layer of airflow increased, entering the engine nacelle and creating a turbulent airflow into the compressor, causing the compressor blades to stall and the engine to shut down. The solution, called Triple Plow I, lay in moving the inlets to increase the separation of the inlet from the fuselage and so prevent the thick boundary layer from entering the inlet (see figures 7–1, 7–2). That modification, however, increased drag and reduced range.[61]

Figure 7-1: LOCATION OF INLETS ON F-111



Source: Robert Coulam, *Illusions of Choice: The F–111 and the Problem of Weapons Acquisition Reform* (Princeton: Princeton University Press, 1977), 177 (used with permission).

Figure 7-2: THE CHANGE TO TRIPLE PLOW I



Source: Coulam, *Illusions of Choice,* 177 (used with permission).

Who should pay for correcting the problem remained an issue. Developed and procured under a Navy contract with Pratt and Whitney, the TF30–P–1 was provided to General Dynamics as government-furnished equipment. Pratt and Whitney claimed that its engine met all specifications contained in the interface documents that both contractors had approved. As often happened in such situations, each contractor charged that a defect in the other's design was responsible for the problem; the government could not prove otherwise. Pratt and Whitney pointed to boundary layer problems; General Dynamics countered that its inlet design met the interface criteria provided by Pratt and Whitney. In the end, the government paid to correct the deficiency.[62]

While the stalling troubles were being studied and solved, dozens of funding and contractual commitments had been moving forward.[63] In September 1965, two months after Pratt and Whitney's engine passed the 150-hour Military Qualification Test, the SPO laid out milestones for development and production: 10 Air Force F–111As in FY 1965, 55 in FY 1966, 132 in FY 1967, and 210 in FY 1968. Purchases of Navy F–111Bs would start with 4 in FY 1966 and reach 20 in FY 1968. Performance requirements allowed few retreats from the original specifications. F–111A requirements included an empty weight of 38,667 pounds, a takeoff distance of 2,780 feet, a speed of Mach 2.2, and a supersonic sea-level dash of 210 NM. F–111B requirements included an empty weight of 38,804 pounds, a desired speed of Mach 2.5, and 4-hour endurance to loiter at 150 NM from the launch point.[64]

THE TRAVAILS OF "ICARUS"

A convergence of problems threatened to push all schedules back. An F–111B prototype made its first test flight on 18 May 1965 and reached supersonic speed by 1 July. A higher thrust engine was needed, however, to offset the weight growth and improve acceleration and rate of climb. Detailed design studies for an improved engine began in August 1965. Late in November, Secretary of the Navy Paul Nitze informed McNamara that fabricating a more powerful TF30–P–12 engine for the F–111B would take about two years. Even so, Nitze warned that SWIP modifications and engine improvement alone were not enough to meet Navy specifications.[65]

The F–111A also experienced problems. The Air Force began receiving flight test data from General Dynamics early in December 1965. By late January 1966, pilots from the Air Force Flight Test Center at Edwards Air Force Base, California, were rating the F–111A as definitely underpowered.[66] One of the F–111 prototypes flew at Mach 2.5 in July 1966, but an independent review group appointed by the Air Force reported the next month that neither the F–111A nor the F–111B would meet the services' operational requirements without major design changes.[67]

Secretary McNamara responded by creating Project Icarus. Every week or two, usually on Saturday, senior civilians—but no senior military officers—met with their counterparts from industry.[68] In addition to McNamara, the usual attendees were Deputy Secretary of Defense Cyrus Vance (until 30 June 1967); Paul Nitze, secretary of the Navy (through June 1967, thereafter as deputy secretary of defense); Paul Ignatius, secretary of the Navy (from September 1967); Harold Brown, secretary of the Air Force (from October 1965); John Foster, director of defense research and engineering; Roger Lewis, president and CEO, General Dynamics; Frank W. Davis, president, Fort Worth Division, General Dynamics; and Arthur E. Smith, executive vice president, Pratt and Whitney. The program managers—Major General Zoeckler, his successor Maj. Gen. Lee V. Gossick, and Rear Admiral Sweeney—were sometimes asked to attend.

McNamara told the group that he wanted to keep coming together "until either these meetings were doing no good or the problems were solved." Broadly, the agenda for an Icarus meeting would identify shortcomings and the measures planned to solve them, the time needed to carry out fixes and retrofits, the reasons for contractor and service differences in performance estimates, the instances where deviating from original specifications seemed desirable, and cases where solutions to existing problems created new obstacles.

Icarus, which ran from August 1966 until January 1968, was unique because senior officials constantly delved into engineering details that normally were the province of technical experts. It also constituted the only McNamara-era equivalent and forerunner of the Defense Systems Acquisition Review Council and the Defense Acquisition Board that loomed so large in later decades.

At the opening session of Icarus on 25 August 1966, McNamara defined what he saw as the basic problem. With all versions of the F–111 currently unsatisfactory and 1963 specifications yet to be met, "production simply cannot proceed until performance is assured." He worried particularly about forecasts that the F–111 would fall below requirements for its low-level dash, combat radius, and ferry missions. Roger Lewis, General Dynamics CEO, countered that the F–111's apparent weaknesses were its strengths. Since advancing the state of the art was what caused these problems, solving them would result in a superior aircraft. McNamara repeated that the 1963 specifications had to be met and lesser performances would not do.[69]

At the 10 September meeting, Secretary of the Air Force Brown noted that even though added aircraft weight reduced the low-level dash requirement from 210 to 188 NM, both contractor and Air Force estimates were much less than that. Nozzle improvements, Brown hoped, would cut turbulence from the boundary layer of air. Placing fuel tanks in the F–111's wing cavities, furthermore, might solve the current shortfall in range, thereby providing the capability to reach targets in East Germany and Poland from bases in Western Europe. McNamara acknowledged that failure to highlight the F–111's conventional mission was a DoD error, "a fall-out from the day when emphasis was almost exclusively on tactical nuclear missions." When conferees discussed ways of reducing weight in the F–111B, McNamara remarked that with the F–111A, "the problem essentially was when to go into production. The F–111B problem on the other hand was whether we had an aircraft at all."[70]

A week later, Secretary Brown said that he saw little hope of meeting the low-level dash specification, the requirement Frank Davis of the General Dynamics Fort Worth Division deemed the most challenging. Turning to the F–111B, Secretary of the Navy Nitze said that Navy and General Dynamics test pilots gave very different evaluations. With the F–111B at its current weight, according to the Navy, waving off a pilot from a carrier deck landing could lead to the pilot being ordered to eject. Davis disagreed. At McNamara's direction, John Foster, the DDR&E, started working with the Navy, the Air Force, and contractors to identify problem areas.[71]

When Icarus reconvened on 29 September 1966, Foster claimed that "performance estimates were coming closer together. Things are being resolved." McNamara asked why the program office had not done the things that the DoD principals were now addressing.[72] Worried that a tacit rewording of the specifications was taking place, McNamara also wondered whether lack of a signed production contract was causing problems.[73]

By the 22 October meeting, prospects had darkened again. As the F–111B grew heavier, higher approach speeds for deck landings became necessary. On 10 September, Frank Davis had remarked that a carrier pilot could not have too much visibility. But improving visibility would raise the acceleration and wind-over-deck requirements. Also, rearranging the cockpit would mean redesigning the escape capsule at a cost of $20 million to $60 million. Roger Lewis argued that since the F–111 was an advanced aircraft, many of its problems could not be treated in a "black-or-white" fashion and a more flexible approach was necessary. McNamara replied that "there was at least one critical 'black and white' issue and that was whether we had a Navy aircraft or not." Often, he said, "people confuse specific performance parameters with the end objective desired." Asking everyone to focus on attainable objectives, McNamara now indicated a willingness to reduce the F–111's performance specifications further, but he wanted to be certain that even these lower goals were achievable.[74]

McNamara, at the 17 November session, directed attention to what he called "a disgraceful cost position." He noted that the 1962 General Dynamics proposal of $5.5 billion for 1,704 aircraft had now become $10.8 billion for 1,278 aircraft. To make matters worse, McNamara added, projections forecast a doubling of the contractors' profits.[75] It could be said, though, that the secretary was comparing apples with oranges—1,704 aircraft with nearly 90 percent commonality against 1,278 in 5 models with no more than 60 percent commonality.[76]

During November and December 1966, Icarus members faced two new problems. The first involved the Mark II avionics system (see chapters IV and VII). According to Secretary Brown, the F–111 required air combat capability as good as or better than the Air Force's F–4E Phantom fighter-bomber and ground attack capability as good as or better than the Navy's A–6 Intruder attack aircraft. Those criteria could be met only by the Mark II.[77] Slated for installation starting with the 236th aircraft at McNamara's direction, the Mark II promised a huge improvement in capability for attacking ground targets. But neither Mark IIs nor the D model of F–111s being designed for them would be ready by June 1969, when scheduling called for the 236th F–111 to roll out. McNamara also decided to equip FB–111s with Mark IIs, pushing that program back six months. Strategic Air Command objected in vain that the FB–111's whole purpose had been to field an interim bomber quickly.[78]

The second problem concerned engine production, which was falling behind airframe output. According to Roger Lewis, General Dynamics could construct 28 airframes per month, while Pratt and Whitney could produce engines for only 15.[79] Secretary of the Navy Nitze likened the problem to a chicken-and-egg situation, with engine and airframe production each dependent on the other. Reacting vigorously, Lewis called the engine shortfall "astonishing" and contrary to General Dynamics's working assumption of 28 engines per month. When Secretary Brown stated that "if 30, 40, or 50 aircraft were slipped from FY 1968 to FY 1969 and then made up, the situation would be in hand," Davis responded that any schedules would have to be verified.[80]

Icarus meetings during January 1967 made little headway. Alexander H. Flax, assistant secretary of the Air Force for research and development, reported that modifying the side inlets had not solved the stalling problem. Frank Davis admitted that "there must be some reason why the configuration in flight does not behave as in the wind tunnel, but [he] was at a loss to explain why." An F–111 had reached Mach 2.5 while flying one narrow angle of attack but only Mach 2.0 while flying along a broader angle.

At the same time, the cost of the Mark II avionics system kept rising. In June 1966, when Autonetics won the contract, it was recognized that the Mark II specification did not fit or function with the F–111. General Dynamics and Autonetics, a division of North American Aviation, agreed that improvements would cost between $148 million and $220 million. When Autonetics proposed modifications that reached $250 million, General Dynamics declared that amount unacceptable. The first order of business, Davis argued, should be to establish a baseline for the Mark II's performance, then evaluate differences between the specification and Autonetics's proposal and determine the true incremental costs.[81]

General Dynamics delivered the last of 5 F–111B prototypes in mid-September 1966 and the last of 18 F–111A prototypes on 31 December.[82] By the end of December, 7 production-run F–111s were on the assembly line, and parts were being fabricated for 48 more. General Dynamics had hired 18,000 people, building toward a goal of 24,000 employees.[83]

During the 28 January 1967 meeting, Davis cited September 1967 as the deadline for starting to deliver aircraft from the production run. McNamara replied that no one should be "mesmerized" by that date. When Davis reminded him that the work force would total 50,000 by 1 May, McNamara countered that 50,000 people would have to be put out of work if an acceptable aircraft was not in sight.[84] Yet McNamara's threat rang hollow because political realities made a production stoppage unlikely. Moreover, treating performance requirements as unalterable goals prevented the tradeoffs that were needed to meet minimum requirements.[85]

At the 16 February meeting, Secretary Brown reported that F–111As with improved TF30–P–3 engines finally had reached higher altitudes and higher Mach numbers without stalling. He felt reasonably confident that Mach 2.2 or 2.3 could be reached by September, when the production run was slated to start. What, McNamara asked, was the initial specification for maximum air speed? Mach 2.5 for a five-minute dash, Brown answered, but he saw no evidence that the TF30–P–3 would give such a performance. Had the engine and airframe contractors, McNamara inquired, promised to reach a given performance level? Assistant Secretary of the Air Force Flax and his Navy counterpart, Robert Frosch, answered that trying to hold a contractor to a given level could prove to be difficult. Because engines were government-furnished equipment, for example, specifications had been written in terms of test stand rather than installed engine performance.[86]

Turning to the Mark II, Secretary Brown warned that General Dynamics was writing a contract with North American Rockwell, Autonetics's parent, that asked less of North American than North American had agreed to do for the Air Force. General Dynamics, Brown emphasized, should be pushed to hold North American to the same standard. Major General Zoeckler said he had impressed that point on Autonetics and let contractors know that the 237th aircraft would not be accepted unless it carried a satisfactory Mark II system. Foster cautioned that completing a satisfactory system might take an extra year.[87]

At the Icarus meeting on 16 February, Secretary Brown asked whether the specification had indeed promised a speed of Mach 2.5. When Davis agreed that it did, Brown asked whether that goal could be met. Davis replied that he wanted to be certain of reaching Mach 2.0 and Mach 2.2, "while paying premiums on those things necessary to get to Mach 2.5." As for the TF30–P–3 engine, Foster said that if the engine met the test stand specifications, General Dynamics had the responsibility to match that engine with the airframe and reach required speeds.[88]

For FB–111A bombers, DoD tried to impose single-contractor responsibility. Since the TF30–P–3 engines used in F–111As could not provide enough thrust, the Air Force looked at the Navy's TF30–P–12, for which Pratt and Whitney was willing to guarantee laboratory-demonstrated but not in-flight performance. General Dynamics stood ready to guarantee total system performance but refused to take responsibility for solving the stalling problem and insisted on being able to specify any engine changes. At the Icarus meeting on 1 April 1967, Secretary Brown said that since neither firm would take responsibility, the only logical recourse for the government was to delay production. Frank Davis replied that, without knowing whether the basic problem lay in the duct system, the engine, or some combination of the two, neither contractor could write a stall-solving specification. Brown suggested that "as a principle, profit should be a function of risk," which involved accepting responsibility. Roger Lewis responded that quality products resulted from an optimization between the airframe and the engine. It was "simply impossible," he said, for General Dynamics to accept unequivocal responsibility for the whole program unless it also had authority over Pratt and Whitney. Without such authority, General Dynamics could do nothing "except write letters and complain."[89]

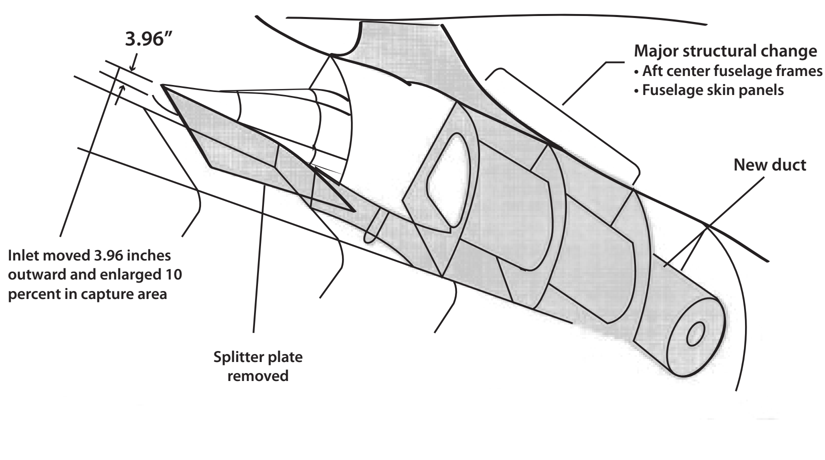
Senior Defense Department officials were engaging in circular reasoning. Secretary Brown argued, quite rightly, that profit was a function of risk. However, DoD shared the risk because it procured the engine and directed General Dynamics to develop an airframe using that engine. Since engines were government-furnished equipment, there could be no contractual basis for holding General Dynamics responsible for the stalling problem. Ultimately, the government would have to cover the cost of production delays. Hence, in the end, DoD paid to correct the engine stall problem.[90]

The Icarus meeting of 29 April 1967 marked a watershed. Secretary Brown reported that F–111A performance along the whole flight envelope was approaching an acceptable status. Triple Plow I, the inlet modifications described earlier, combined with improved TF30–P–3 engines, raised the stalling zone to Mach 2.0 in maneuvering flight and Mach 2.35 in level flight.[91] However, almost every measure taken to improve performance had reduced range. Ferry tips and extra fuel in the wing cavities could bring it back up, but Brown emphasized that a range of nearly 3,000 NM was needed. He would not be satisfied with 2,700 NM aircraft, beyond the 20 or 25 needed for crew training. Brown particularly wanted to avoid the mantra that "what's acceptable is what's available." In the same vein, Foster argued that "proceeding now ran counter to the philosophy of not accepting aircraft, or allowing production, until satisfactory performance was demonstrated." Nonetheless, Deputy Secretary of Defense Vance authorized General Dynamics to start production in May, "on the proviso that there was no agreement to accept the production output." At the same time, Pratt and Whitney won agreement to freeze its engine design, leaving time to iron out any kinks by September.[92]

A fixed-price incentive contract, signed on 15 May 1967, replaced the letter contract of April 1965 and covered the production of 493 aircraft. Initial deliveries were set at 93 F–111As in 1967, followed by 84 F–111As and 20 F–111Bs in 1968. A target cost of $1.671 billion applied to 469 F–111As and FB–111As; added to that, a target profit of $150.4 million (9 percent, as in the letter contract) brought the target price to $1.821 billion. The Navy's 24 F–111Bs were priced separately. The cost-sharing arrangement for the first 7 percent above or below target cost was 75 percent for the government and 25 percent for the contractor. Beyond 107 percent, sharing would be 85/15 up to a ceiling price that was 130 percent of the target cost. McNamara looked on that formula as equivalent to a firm fixed-price contract.[93]

By late June 1967, F–111s had flown at Mach 2.2; a ferry range of 2,900 NM and perhaps 3,300 NM appeared attainable.[94] The first F–111A featured an improved TF30–P–3 engine and Triple Plow I inlets flew on 24 September.[95] General Dynamics believed that Triple Plow I would allow F–111s to reach full performance requirements. Improving stall tolerances any further would require expensive structural changes to aircraft in full production, but General Dynamics worked under a fixed-price contract that did not clearly assign responsibility for such changes. Led by the SPO, engineers from General Dynamics, Pratt and Whitney, and the Arnold Engineering Development Center designed a cheaper solution: Triple Plow II, with inlets and ducts enlarged and moved slightly outboard (see figure 7–3). This modification, approved in February 1968, raised stall tolerances beyond Mach 2.4 at high altitudes, high angles of attack, and sharp turns. But Triple Plow II also increased aerodynamic drag, which substantially reduced the distance of a sea-level supersonic dash. F–111Es configured with Triple Plow II entered operational service in September 1969.[96]

Figure 7-3: THE CHANGES FROM TRIPLE PLOW I TO TRIPLE PLOW II



Source: Coulam, *Illusions of Choice,* 186 (used with permission).

Serious problems also remained in fielding the Mark II. At the Icarus meeting on 19 August 1967, Secretary Brown predicted that production would slip as much as seven or eight months and specification waivers would be needed on early deliveries. The Air Force, he warned contractors, would not accept Mark Is after the 236th aircraft and would reject Mark IIs that failed to work properly. Reacting sharply, Frank Davis reminded everyone present that General Dynamics had forecast schedule and cost complications, but the intense desire of Air Force officials for the Mark II[97] had dictated a demanding delivery schedule: "Now, if the Air Force was going to be legalistic in terms of meeting specifications . . . then General Dynamics would have no recourse but to refuse to sign the contract."[98]

Here, DoD held no winning cards. Since Autonetics could argue that both the government and the contractor had the technical knowledge to expect serious problems in meeting the Mark II's contractual requirements, the costs of termination could well have fallen on DoD. Consequently, Autonetics emerged as the winner, with the government obliged to accept major delays, large cost overruns, and significant performance shortfalls.[99] Indeed, Autonetics delivered the first Mark IIs on 21 November 1967. But problems surfaced during the system's first full test in June 1968. Costs spiraled to the point that only 96 F–111Ds, the first fielded in July 1971, were outfitted with Mark IIs. Even then, failures occurred so frequently that maintenance costs remained high and aircraft availability low.[100]

Because the swing wing concentrated structural loads in a single pivot, fatigue requirements had to be more stringent than in fixed-wing aircraft. But how much more? Fatigue life, in terms of flight hours, had to be determined by testing a complete, instrumented F–111A airframe. On 27 August 1968, one day after ground tests began, the wing carry-through structure failed. The cause was a defect in casting, which meant that the problem was one of quality control rather than design. The solution came from testing in a cold hangar, where the temperature dropped to 70 degrees below zero and the aircraft was stressed to 7.5 times normal gravity. The goal was to ensure that an F–111A could fly for 2,000 hours without risking a carry-through failure, after which time it would go into depot overhaul.[101]

Meantime, on 16 October 1967, the first F–111A from the production line reached an operational wing. In March 1968, six F–111As began flying combat missions from Thailand. Combat operations halted on 22 April 1968, after three planes had been lost. Wreckage of one was recovered; investigators pinpointed a weak weld in a tail rod. The remaining three returned to their Nevada base in November. When two squadrons returned to action from September through December 1972, they both demonstrated reliability and good bombing accuracy.[102]

F–111A of 474th Tactical Fighter Wing, which deployed six F–111As to Thailand early in 1968 to participate in combat operations (*National Museum of the U.S. Air Force*)

THE NAVY SCUTTLES ITS VERSION

Flight tests of the F–111B began in May 1965. Naval aviators compiled a long list of failures to meet specifications that they believed already had been ratcheted down so far that no leeway remained. Among other things, they wanted five more degrees of cockpit visibility. The contractor outlined a package of fixes, but bending the airframe was costly and bulging the canopy added complications for the escape capsule. All the modifications, which were begun early in 1967, added about 2,500 pounds to the aircraft's empty weight. They also increased fuel capacity by 2,000 pounds, raising the takeoff weight correspondingly.[103] Concurrently, a study directed by Rear Adm. Elmo R. Zumwalt, Jr., a future CNO, characterized the F–111B as the best fleet interceptor for the next decade. Yet many naval aviators, seeing Zumwalt as a protege of Secretary of the Navy Nitze, downplayed his findings.[104]

At an Icarus meeting in March 1967, Frank Davis claimed the F–111B's latest configuration "assured the highest probability that the aircraft would be 'well liked and useful to the Navy'." Secretary McNamara spoke enthusiastically: "If anything productive has come out of these meetings with the contractors . . . it has been this evolution of a satisfactory aircraft for the Navy."[105] On 1 June, however, a Navy evaluation labeled the F–111B in its current configuration unfit for service and incapable of carrier-based operations.[106]

First flight of Navy F–111B, 18 May 1965 (*Naval History and Heritage Command*)

Sen. John McClellan, an influential member of the Appropriations Committee, shared Navy officers' reservations and led a successful fight to block funding for long-lead-time items. The Domodedovo air show in Moscow in July 1967 gave the F–111B's critics more ammunition. The Soviets displayed six fighter prototypes, including a MiG–29 thought to be capable of reaching Mach 2.9. Their appearance, combined with experience from close air combat over North Vietnam, reinforced a feeling in the Navy that extended-range interception was outmoded. Accordingly, the Navy commissioned Grumman to evaluate F–111B capabilities against a heightened Soviet threat. Perhaps sensing the writing on the wall, Grumman labeled the F–111B inadequate for dogfighting and submitted an unsolicited proposal to build a smaller, lighter, swing-wing plane. A furious Roger Lewis told Paul Ignatius, who had succeeded Nitze as secretary of the Navy, that Grumman had sabotaged the F–111B and that its "unsolicited" proposal actually had been instigated by Vice Adm. Thomas F. Connolly, the deputy chief of naval operations (air). Although the Navy continued with the F–111B, it started studying a new type of fighter.[107]

Before the Senate Armed Services Committee, Secretary Ignatius defended the F–111B, but Vice Admiral Connolly testified that it was beyond saving.[108] The committee voted that serial production should not begin until Congress had reviewed suitability tests. Testing was pushed back, however, by the crash of a prototype and delay in delivering TF30–P–12 engines. In mid-October 1967, Assistant Secretary of the Navy Frosch publicly affirmed that the F–111B had reached "the state of development where we are satisfied that the basic problems have been solved, and that we have identified other design problems for which solutions are in progress." But, as others noted, "every time there was an improvement it got incorporated farther and farther down the production line so it looked like we were never going to get a representative airplane."[109] In November, the White House announced that McNamara would be leaving his post to become president of the World Bank. His departure meant the F–111B lost its only unyielding advocate.

At an Icarus meeting in mid-January 1968, Frank Davis cautioned that the F–111B's drag at higher supersonic speeds had proved to be greater than expected, apparently due to the Phoenix missiles hung on the wings. Contractors proposed either adding a third pivoting pylon or attaching the missiles externally on bomb bay doors. SPO engineers rejected both ideas, calculating that a third pylon would increase aircraft weight more than 500 pounds, while hanging missiles on bomb bay doors would be highly destabilizing. Secretary Ignatius said that the Navy also was concerned about the lack of agility implicit in less acceleration, apart from how that might hamper the interception mission. The Navy "wanted to proceed deliberately, and be careful that, while fixing one thing, a whole host of new problems were not created."[110]

In March 1968, with McNamara gone, the Navy recommended and OSD agreed to pare the FY 1969 procurement authorization from 30 F–111Bs to 8 and to add funds for the initial definition of an alternative "VFX." On 28 March, the Senate Armed Services Committee voted to stop F–111B development and procurement. Instead, it voted funds for the VFX, which would later become the F–14 Tomcat fighter. After the House Armed Services Committee followed suit, formal termination of the F–111B program took place on 9 July.[111]

Did problems inherent in the original design or intentional action from those biased against it cause the death of the F–111B? Navy leaders insisted it was the former. Carrier aviation called for specifications so unique that only Navy fliers understood them. The compromises required to achieve commonality made those specifications unattainable. Against original specifications of 62,788 pounds for takeoff weight and -8 knots for a wind-over-deck launching, the F–111B registered a takeoff weight of 79,000 pounds and +19 knots for a launch. In the opinion of a high-ranking Navy official, "It had become clear that, even if you could lick each individual problem, the complete aircraft would still be a 'dog'."[112]

The case for intentional action to kill the system, however, has some plausibility. Were the flight tests fair and objective? According to one author, "A negative bias . . . inhered in the flight tests, because of a skeptical Navy's control of the tests, because of the type of pilots who would be flying the tests, and because of a systematic technical feature of the tests." For example, changing the requirement from that of a "standard" day to a more demanding "hot" day increased the *measured* wind over deck by about three to four knots but kept the *specified* wind over deck unchanged. Doing so created an artificially inflated performance discrepancy. After the F–111's cancellation, at the insistence of Ignatius, the Navy conducted unpublicized carrier trials that the contractor considered a clear success. A Navy officer, however, attributed that success to the skill of the Navy test pilot.[113]

A DISAPPOINTING BALANCE SHEET

Research, development, and test and evaluation costs for the F–111 came to $1.657 billion, which was $1.176 billion above the target set in May 1964. Production of all F–111 models including the 23 prototypes totaled 562:

- 158 F–111As carrying Triple Plow I air diverters and Mark I avionics
- 96 F–111Ds with more powerful TF30–P–9 engines, Mark IIs, and Triple Plow IIs
- 94 F–111Es with Mark Is and Triple Plow IIs
- 106 F–111Fs featuring simpler avionics and TF30–P–100 engines
- 24 F–111Cs with Mark Is, which were sold to Australia
- 76 FB–111As for the Strategic Air Command with TF30–P–7 engines, Triple Plow IIs, and even more advanced Mark IIB avionics.

Production costs through mid-1973 totaled $5.5 billion for 541 aircraft, $3.2 billion above the May 1967 target cost. On average, fighter programs of the 1950s had exceeded their targets by 100 to 200 percent, so the F–111 overruns were abnormal but not unique.[114]

Measured against the initial operational requirement and contract specifications, the F–111 was successful in several respects: it achieved takeoff and landing distances around 3,000 feet, a sea-level speed of Mach 1.2, and a sustained speed of Mach 2.2 and burst speed of Mach 2.5 at altitude. Also, ferry range, unrefueled and without wing tanks, was sufficient for transatlantic flight. On the other hand, aircraft weight exceeded the SOR, while combat ceiling and navigation accuracy fell short of those standards. So did sea-level dash distance by a wide margin: only 30 NM in the F–111A, 20 in the F–111F.[115]

Many of the F–111's troubles can be traced to early, arbitrary decisions. SOR 183 imposed the swing wing, a decision that might better have been left to the competing contractors. Swing wings proved to be a passing phase in military aviation. The complicated and heavy gear box needed to move the wings cut into performance and fuel economy. Fixed, swept-back wings allowed a more efficient flight. After the Navy's F–14, which incorporated much of the F–111B's technology, only the Air Force's B–1B bomber used a swing wing.[116]

Specifying a supersonic low-level dash dictated the design of the F–111's fuselage, which created a conflict between Air Force and Navy requirements. Insistence upon 85 to 90 percent commonality left little leeway for performance tradeoffs. Trying to enforce contract specifications when the contractor and the SPO believed that necessary technology would be very risky and probably out of reach led to costly and mostly failed attempts to attain contract values. The Navy never warmed to the project, and the civilians' choice of General Dynamics over Boeing irritated Air Force officers while costing support on Capitol Hill. OSD's insistence on adding the trouble-plagued Mark II was a crowning blow.[117]

In any case, the record for one-size-fits-all weapon systems was not good. Fifty years earlier, Admiral Sir John Fisher pressed the British Royal Navy into building battle cruisers with the objective of combining in one vessel the firepower of the battleship with the maneuverability of the cruiser, saving money and extending global reach while preserving a powerful home fleet. Speed was gained by sacrificing armor, on the assumption that armor-piercing shells fired at long range would prove ineffective.[118] But German gunfire blew up three battle cruisers at Jutland in 1916. The space shuttle furnished a later example. It was obliged to serve both NASA and the Defense Department, yet DoD's launch requirements were radically different from those of NASA. Likewise, for the F–111, pursuing commonality left the Air Force with a version that was compromised by attempts to satisfy highly diverse requirements. Fitting awkwardly as an air superiority fighter and strategic bomber, its real success came in the specialized role of a low-level night penetrator.[119]

* * * * *

A bi-service effort involving major technological innovation must enlist the willing participation of everyone involved. The Air Force, at OSD's direction, had adopted the Navy's F4H–1 with minimal friction. But there was no commonality issue; the Air Force could fund the F–4 and make modifications as necessary. The F–111 alienated one constituency after another. Apart from sporadic appearances by Major Generals Zoeckler and Gossick and Rear Admiral Sweeney, no senior Air Force and Navy officers attended Icarus meetings. When Col. Robert E. Pursley, the military aide to the secretary of defense who took notes at the meetings, debriefed the SPO, he described mainly what was being done about the stalling problem. From the standpoint of SPO personnel, the actions taken by DoD principals at Icarus meetings solved none of the F–111's difficulties.[120]

There is a rough analogy between the travails of the F–111 and the troubles General Motors encountered over an air-cooled engine. In the early 1920s, top GM managers favored a new air-cooled engine promoted by the head of research. The heads of operating divisions, however, preferred an improved water-cooled engine. When the first air-cooled automobiles faltered, GM president Alfred Sloan stopped production. The air-cooled engine may have been right in principle and ahead of its time, Sloan reflected, but top management had become "more committed to a particular design than to the broad aims of the enterprise. And we were in the situation of supporting a research position against the judgment of the division men who in the end would have to produce and sell the car."[121] When Secretary McNamara imposed his own views with respect to the F–111, he went against the judgment of many of those who would have to fly and fight with the aircraft, with regrettable consequences.

Endnotes

1. Much of this paragraph draws upon ltr, Brig. Gen. Alfred L. Esposito, USAF (Ret.), to W.S. Poole, 14 May 06, 1. Esposito served as the system officer and program assistant for the F–111 on the Air Staff and as deputy program manager and then program manager in the F–111 system program office at Wright-Patterson Air Force Base, Ohio. His extensive critique of an earlier draft chapter provided information that corrects and expands upon the standard account by Coulam, *Illusions of Choice*.

2. This figure is taken from Knaack, *Post–World War II Fighters*, 205.

3. This paragraph and the next draw upon ltr, Esposito to Poole, 14 May 06; Gorn, *The TFX*, 3–4; Coulam, *Illusions of Choice,* 36–39, 91–93; Robert F. Art, *The TFX Decision* (Boston: Little, Brown, and Co., 1968), 17–22; and Senate, Cte on Govt Ops, *TFX Contract Investigation*, 88 Cong, 1 sess, pt 1, 15, 28–29, pt 6, 1350–1351.

4. Coulam, *Illusions of Choice,* 176; Senate, *TFX Contract Investigation*, pt 1, 15, 28–29.

5. Coulam, *Illusions of Choice*, 41–43; ltr, Esposito to Poole, 14 May 06, 3.

6. Coulam, *Illusions of Choice*, 43–45; Art, *TFX Decision*, 25–26; Senate, *TFX Contract Investigation*, pt 3, 718, pt 6, 1385.

7. David Milobsky, "Leadership and Competition: Technological Innovation and Organizational Change at the U.S. Department of Defense, 1955–1968," Ph.D. diss., Johns Hopkins University, 1996, 260; Senate, *TFX Investigation*, pt 6, 1462–1464.

8. Senate, *TFX Investigation*, pt 6, 1463. Instead, said the Navy, the services should procure aircraft appropriate to each mission: for close air support, Navy A–4Ds and A2Fs (later designated A–6); for air superiority, Navy F–4Hs followed by Missileer-Eagles; and as a follow-on attack aircraft, a swing-wing plane with some of the characteristics defined by Tactical Air Command.

9. Milobsky, "Leadership and Competition," 260; Senate, *TFX Investigation*, pt 6, 1462–1463.

10. Senate, *TFX Investigation*, pt 6, 1464. The Navy divided its aviators into two groups—supersonic fighter pilots and subsonic attack pilots—with separate lines of training and promotion. Air Force doctrine, by contrast, presumed all Tactical Air Command pilots capable of performing the full range of tactical missions. Coulam, *Illusions of Choice*, 265–266 fn 58.

11. Coulam, *Illusions of Choice*, 248 fn 21.

12. Senate, *TFX Investigation*, pt 2, 333–334.

13. Ibid., pt 6, 1385, 1486, 1464, 1385–1389; Art, *TFX Decision*, 43–46; Coulam, *Illusions of Choice*, 101–103; Gorn, *The TFX*, 14–16.

14. The Air Force Council's other members were the five deputy chiefs of staff and the inspector general of the Air Force.

15. Art, *TFX Decision*, 57–59, 105–106, 60–61.

16. Ibid., 62–65; Senate, *TFX Investigation*, pt 1, 56, pt 2, 377.

17. Senate, *TFX Investigation*, pt 1, 54–57, pt 2, 377–379, 488–489, pt 5, 1204; Art, *TFX Decision*, 63–65.

18. Senate, *TFX Investigation*, pt 2, 494.

19. Art, *TFX Decision*, 67–71; Senate, *TFX Investigation*, pt 2, 379.

20. Senate, *TFX Investigation*, pt 5, 1204–1205.

21. Ibid., 379–380; Coulam, *Illusions of Choice*, 61.

22. Senate, *TFX Investigation*, pt 1, 65–68, pt 5, 1206; Art, *TFX Decision*, 77.

23. Senate, *TFX Investigation*, pt 5, 1206.

24. Art, *TFX Decision*, 112. The evaluation team's complete evaluation is printed in Senate, *TFX Investigation*, pt 8, 1933–1965. Later, congressional investigators found that the evaluators had forgotten to weight the scores given to a fire control system, which would have put Boeing several points ahead. George Spangenberg, oral history, pt 3, 12, <http://www.georgespangenberg.com/history3.htm>.

25. Art, *TFX Decision*, 77; Senate, *TFX Investigation*, pt 3, 760–761.

26. Senate, *TFX Investigation*, pt 3, 697, pt 2, 506, 504.

27. Ibid., pt 8, 1905.

28. Ibid., pt 8, 1905–1907.

29. Ibid., pt 4, 942–945, pt 3, 814–815, pt 8, 1983–1985, pt 9, 2385–2386; Art, *TFX Decision*, 127–128; interview, Brig. Gen. Alfred L. Esposito, USAF (Ret.), by Elliott V. Converse III, Walton S. Moody, and Walter S. Poole, 14 Sep 05, 17–18, U.S. Army Center of Military History, Fort Lesley J. McNair, Washington, DC; email, Esposito to Poole, 17 Jun 06, 2.

30. Senate, *TFX Investigation*, pt 4, 940–946, pt 8, 1980–1984, pt 9, 2367–2368 (Zuckert quotation, 1981).

31. Ibid., pt 9, 2447. Working with titanium posed serious technical challenges. For example, iron and steel could be welded in a normal atmosphere, but nitrogen was needed to weld aluminum, and a whole new way of welding had to be devised for titanium.

32. Ibid., pt 3, 840–841, pt 4, 946, pt 9, 2442–2449; Art, *TFX Decision*, 130–131 (Johnson quotation).

33. Senate, *TFX Investigation*, pt 8, 1995.

34. Ibid., pt 9, 2511.

35. Ibid., pt 2, 352. Zuckert later claimed that Boeing's record on cost control was worse and General Dynamics's better than many supposed. Boeing's B–47 was the first all-jet swept-wing bomber, "but by our standards it had an orderly development program." Three contractors turned out 2,041 Stratojets, yet parent Boeing did not beat the other two on cost. Boeing's B–52 was "based in large part on the B–47" and production totaled 744, so "they should have been able to figure out their costs." Boeing's KC–135 grew from development work for its 707 airliner, borrowed technical knowledge from B–47s and B–52s, and also enjoyed a fairly long and stable production run. As to B–58s, the record of General Dynamics (Convair Division) looked more troubled and unduly expensive because the supersonic Hustler was "a radical development in comparison with the B–52" and had a run of only 116. Similarly, the F–102 was the first delta wing fighter, and Convair encountered "serious technical problems" trying to integrate government-furnished equipment, just as it did in the follow-on F–106. "Compared with these three airplanes, two [of them] first of a kind . . . the Boeing Co. had a relative breeze." In fact, Zuckert argued, Bomarc represented Boeing's only "real first," and Boeing's estimate of $60,000 a copy turned into $600,000 for the production run. Ibid., pt 8, 2166–2167.

36. Ibid., pt 2, 352.

37. Ibid., 382.

38. Art, *TFX Decision*, 164.

39. Kaplan, Landa, and Drea, *The McNamara Ascendancy,* 469–470.

40. Ibid., 469–471; Richard A. Smith, "How a Great Corporation Got Out of Control," *Fortune* 65 (February 1962): 120–122, 178–188 (quotation, 180).

41. Senate, *TFX Investigation*, pt 2, 445.

42. Ibid., pt 3, 780.

43. Ibid., 780, 775, 792.

44. The decision not to renew Anderson may have had little to do with his TFX testimony. Five of Anderson's six predecessors also only served two-year terms as CNO. Interview, Admiral George W. Anderson by W.S. Poole, 7 Nov 78, Joint History Office, Pentagon, Arlington, VA. Senator McClellan remained one of the program's severest critics; his subcommittee conducted a second series of hearings during March and April 1970.

45. Senate, *TFX Investigation*, pt 4, 1144–1145; Coulam, *Illusions of Choice*, 61.

46. Coulam, *Illusions of Choice*, 204, 59–60, 66–67; Fitzgerald, *The High Priests of Waste*, 132–133; Senate, Cte on Govt Ops, *TFX Contract Investigation—Second Series*, 91 Cong, 2 sess, pt 2, 344–349, pt 3, 631–632; Gorn, *The TFX*, 35; Esposito interview, 18.

47. Senate, *TFX Investigation—Second Series*, pt 2, 400–403.

48. Ibid., 435–437; Gorn, *The TFX*, 38–39. The Super Weight Improvement Program changes approved in July brought the F–111B's empty weight down to 43,162 pounds, an increase of 11 percent over the original design that still compared "reasonably well" with the development of other Navy aircraft. Coulam, *Illusions of Choice*, 272–273.

49. The clause defined a deficiency as "any condition or characteristic . . . which is not in compliance with the requirements of the contract." If the Procuring Contracting Officer determined that deficiencies existed, "the contractor shall—at a reasonable time and place as directed by the Procuring Contracting Officer—correct any such deficiencies at no change in the total target cost." Alternatively, "an equitable reduction in the target cost, target profit and target price shall be negotiated by the Procuring Contracting Officer and the contractor." Senate, *TFX Investigation—Second Series*, pt 3, 614. Senator McClellan's staff made much of apparent shortcomings in the "correction of deficiencies" and "acceptance" clauses (ibid., 631–637). However, as "Icarus" discussions described below would show, responsibility often proved to be hard to pinpoint and became clouded by other factors.

50. Ibid., 632–633, pt 1, 231; Gorn, *The TFX*, 37. The contract covered RDT&E with18 Air Force and 5 Navy prototypes.

51. Quoted in Knaack, *Post–World War II Fighters*, 226 fn 7.

52. Senate, *TFX Investigation—Second Series*, pt 3, 479–482.

53. Milobsky, "Leadership and Competition," 281–282; Senate, *TFX Investigation—Second Series*, pt 3, 490.

54. Gorn, *The TFX*, 42.

55. Senate, *TFX Investigation—Second Series*, pt 3, 527–536; ltr, Esposito to Poole, 14 May 06, 6.

56. Senate, *TFX Investigation—Second Series*, pt 3, 633–635.

57. Knaack, *Post–World War II Fighters*, 242–243.

58. Ibid.

59. Coulam, *Illusions of Choice*, 176–182. "Distortion" meant the average of all pressures across a compressor's face, describing a pattern of local peaks and valleys in terms of their location and magnitude.

60. Ltr, Esposito to Poole, 14 May 06, 7; Esposito interview, 12–13.

61. Ltr, Esposito to Poole, 14 May 06, 8, 6; Esposito interview, 12–13.

62. Email, Esposito to Poole, 17 Jul 06, 2; Coulam, *Illusions of Choice*, 179, 183, 184. For the F–15, in the 1970s, McDonnell Douglas as prime contractor bore total responsibility for integrating all subsystems and assuring that the integrated product met all performance requirements. Drewes, *The Air Force and the Great Engine War*, 22.

63. On 21 May 1965, Secretary Zuckert reserved for himself the power to change not only specifications covered by incentive contract provisions but also any "significant revision to the contractor's obligations." Senate, *TFX Investigation—Second Series*, pt 3, 634. Brigadier General Zoeckler, in turn, froze the design of F–111As and F–111Bs; a new Configuration Control Board had to review all changes.

64. Gorn, *The TFX*, 46–47. The program plan also prescribed management relationships, system costs, and operational concepts.

65. Senate, *TFX Investigation—Second Series*, pt 3, 500.

66. Coulam, *Illusions of Choice*, 277; Senate, *TFX Investigation—Second Series*, pt 3, 501–502, 505–507 (quotation, 507).

67. Senate, *TFX Investigation—Second Series*, pt 3, 620.

68. At the time, these were usually called "the Secretary's Saturday meetings." The term "Icarus," employed only by the SPO and the Air Staff, is used here for convenience. Email, Esposito to Poole, 24 Apr 06.

69. Memcon by Col. Robert Pursley, 25 Aug 66, fldr 1, box 16, 75–0104, RG 330, Archives II. Dr. Richard Hunt, a contract historian with the OSD Historical Office, located these records and made them available to the author.

70. Ibid., 10 Sep 66.

71. Ibid., 17 Sep 66.

72. The rebuttal would be that, when contractors interact directly with senior officials, the SPO loses control over the program. Ltr, Esposito to Poole, 14 May 06, 8.

73. Memcon by Pursley, 29 Sep 66, ibid.

74. Memcon by Pursley, 22 Oct 66, fldr 2, box 16, 75–0104, RG 330, Archives II.

75. Memcon by Pursley, 5 and 17 Nov 66.

76. Ltr, Esposito to Poole, 14 May 06, 9.

77. Memcon by Pursley, 19 Nov 66, 9.

78. Knaack, *Post–World War II Fighters*, 243.

79. Engine shortages were estimated at 136 in December 1968 and 227 in December 1969. To determine aircraft equivalents (two for each plane plus one spare), total engine shortages were divided by three—thus, there were 45 aircraft equivalents in December 1968 and 75 in December 1969.

80. Memcon by Pursley, 19 Nov and 3 Dec 66; Esposito interview, 25; email, Esposito to Poole, 17 Jul 06, 3. Ways of coping with an engine deficit included cutting dock time from four to three months and reducing the quantities of spares, which were not so critical for the twin-engine F–111. Also, Brown suspected that Pratt and Whitney wanted to delay deliveries so that more profitable civilian orders could be filled first. Gorn, *The TFX*, 50.

81. Memcon by Pursley, 14 Jan 67.

82. Gorn, *The TFX*, 51.

83. Memcon by Pursley, 5 and 17 Nov 66.

84. Memcon by Pursley, 28 Jan 67, 7–8.

85. Ltr, Esposito to Poole, 14 May 06, 9–11.

86. Memcon by Pursley, 16 Feb 67, 7–8. The reason for using test stand performance was that Pratt and Whitney, as an associate contractor, sold its engines to the government, and the government then supplied those engines to General Dynamics.

87. Memcon by Pursley, 16 Feb 67.

88. Ibid.

89. Memcon by Pursley, 1 Apr 67, fldr 3, 75–0104, RG 330, Archives II. Ultimately, the Air Force used still another version, the TF30– P–7, to power FB–111s. Knaack, *Post–World War II Fighters*, 244–245.

90. Ltr, Esposito to Poole, 14 May 06, 11–12; Coulam, *Illusions of Choice*, 220–221.

91. Coulam, *Illusions of Choice*, 184–185.

92. Memcon by Pursley, 29 Apr 67.

93. Senate, *TFX Investigation—Second Series*, pt 1, 232; Gorn, *The TFX*, 51.

94. On 22 May 1967, two F–111As flew 2,800 NM from Maine to Paris without refueling. Knaack, *Post–World War II Fighters*, 235.

95. Ibid., 229. The 31st production F–111A was the first to feature a TF30–P–3/Triple Plow I combination.

96. Memcon by Pursley, 26 May and 22 Jun 67; Knaack, *Post–World War II Fighters*, 229, 252, 238; ltr, Esposito to Poole, 14 May 06, 12. Maj. Gen. Lee V. Gossick succeeded Major General Zoeckler as head of the SPO in September 1967. He was followed by Brig. Gen. John S. Chandler in 1968 and then, in October 1969, by Brig. Gen. Alfred L. Esposito.

97. Actually, DDR&E had selected the Mark II, rather than a simpler Mark I, and McNamara insisted that it be installed on the first aircraft of the third wing of F–111s. Esposito interview, 24–25.

98. Memcon by Pursley, 19 Aug 67.

99. Ltr, Esposito to Poole, 14 May 06, 11, 13.

100. Senate, *TFX Investigation—Second Series*, pt 3, 562; Fitzgerald, *High Priests of Waste*, 156, 164; Knaack, *Post–World War II Fighters*, 238, 251–252, 255; ltr, Esposito to Poole, 14 May 06, 13.

101. Coulam, *Illusions of Choice*, 195–197; Senate, *TFX Investigation—Second Series*, pt I, 170–171, describes details of the test failures. Esposito interview, 19–22; ltr, Esposito to Poole, 14 May 06, 13, and email, 17 Jul 06, 3–4. Early in 1969, General Dynamics discovered that Selb Manufacturing, maker of the defective boxes, was paying inspectors to approve unauthorized weldings. Knaack, *Post–World War II Fighters*, 230.

102. Knaack, *Post–World War II Fighters*, 229–232; Thompson, *To Hanoi and Back*, 101, 268–269; Esposito interview, 36–37.

103. Memcon by Pursley, 5 and 19 Nov 66; Coulam, *Illusions of Choice*, 292–293. The F–111A's aft fuselage had been redesigned to fit the TF30–P–3 engine; the same section of the F–111B was modified differently to accommodate the TF30–P–12. Overall, the percentage of common parts fell below 70. Knaack, *Post–World War II Fighters*, 236 fn 27.

104. Memcon by Pursley, 12 Jan 67; Spangenberg oral history, pt 3, 14.

105. Memcon by Pursley, 11 Mar 67.

106. Senate, *TFX Investigation—Second Series*, 512.

107. Coulam, *Illusions of Choice*, 295, 297–299; Werrell, *Chasing the Silver Bullet*, 65; Ignatius, *On Board*, 162–163. After Connolly retired, he accepted employment with Grumman, which produced the successor F–14 fighter.

108. Ignatius, *On Board*, 162.

109. Coulam, *Illusions of Choice*, 304, 294–295; *Defense Industry Bulletin* 3, no. 11 (December 1967): 12; Spangenberg oral history, pt 3, 15.

110. Memcon by Pursley, 11 and 13 Jan 68; Gorn, *The TFX*, 55. Ignatius recalled running into "a brick wall. . . . The more I looked into it, the more I became convinced that the matter had reached such an emotional state that even if the F–111B turned out to be an excellent airplane, and it wasn't all that good . . . the Navy still wouldn't want it." Ignatius interview, 32.

111. Coulam, *Illusions of Choice*, 304–306; Knaack, *Post–World War II Fighters*, 237.

112. Coulam, *Illusions of Choice*, 244. In the opinion of Admiral David L. McDonald, CNO from 1963 to 1967, "You should never buy an airplane that doesn't have great growth factors. . . . So . . . it just stood to reason that if we were going to have to trim everything off the TFX to get it to operate when it was brand new we shouldn't buy it." "The Reminiscences of Admiral David Lamar McDonald, U.S. Navy (Retired)," November 1976, 430–431, Naval Historical Center, Washington, DC.

113. Coulam, *Illusions of Choice*, 286, 285, 306 (quotation, 286). Examples of tests being arranged to ensure a particular outcome are not rare. The pre-1914 British Navy provides a case in point. A civilian, Arthur Hungerford Pollen, invented a sophisticated fire control device for use aboard large warships. A well-connected Royal Navy officer, F.C. Dreyer, developed a cheaper derivative. The Navy arranged a trial that would show Dreyer's device to the best advantage, and he won the major contract. After World War I, however, the Navy acknowledged that Pollen's was superior and substituted most of his system. Jon T. Sumida, *In Defense of Naval Supremacy* (Boston: Unwin Hyman, 1989), 120–132, 305–316.

114. *Jane's All the World's Aircraft, 1978–1979*, 334; Knaack, *Post–World War II Fighters*, 233–234; Coulam, *Illusions of Choice*, 79–80.

115. Senate, *TFX Investigation—Second Series*, pt 1, 59. In the F–111D, E, and F models, weight was slightly higher and maximum speed reached Mach 2.4. Knaack, *Post–World War II Fighters*, 261–262; ltr, Esposito to Poole, 14 May 06, 15; email, Esposito to Poole, 19 Jun 06.

116. Dwayne Day, "Variable-Sweep Wings," U.S. Centennial of Flight Commission Web site, <www.centennialofflight.gov/essay/Evolution_of_Technology/variable_sweep_wings/Techll.htm>.

117. Ltr, Esposito to Poole, 14 May 06, 2, 16.

118. Hew Strachan, *The First World War,* vol. I: *To Arms* (Oxford: Oxford University Press, 2001), 386–387.

119. Gorn, *The TFX*, 59–60.

120. Ltr, Esposito to Poole, 14 May 06, 11, 9.

121. Gabor, *The Capitalist Philosophers*, 278–280.

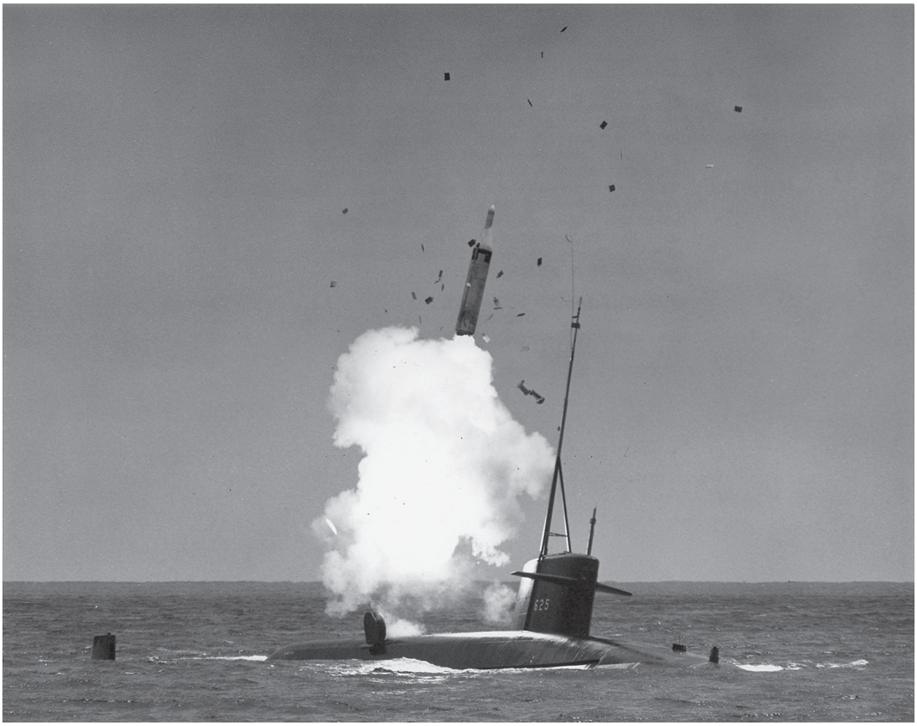
CHAPTER VIII

Managing Strategic Missile Systems

The 1960s saw the ascendance of the ballistic missile as the paramount strategic offensive weapon of both the United States and the Soviet Union. During the decade, the superpowers competed in two missile races. While Americans clearly won the first by 1962, well outstripping the Soviets in numbers of land- and sea-based launchers, the second race, in which Soviet quantity competed with American quality, proved more complex. The Soviets built larger launchers and put more megatonnage, or warhead yield, into their missiles. Americans relied on larger numbers of warheads. Their multiple independently targetable reentry vehicles could deliver warheads, with relatively small yields, accurately enough to destroy well-protected targets and in sufficient number to overwhelm defenses. But eventually, the Soviets also deployed MIRVs. Just as informed opinion in the 1930s predicted that the bomber would always get through, many U.S. analysts in the 1960s, including those with deep technical knowledge, believed that ballistic missiles equipped with MIRVs could overcome any defense.

POLARIS AND POSEIDON

If strategic offensive forces were to play a critical role in U.S. strategy, the Navy was determined to create a capability that would make it a principal participant in the mission. In developing and deploying this capability—fleet ballistic missile submarines—the Navy claimed to have created a winning formula for weapon system development that met or exceeded schedules, cost estimates, and technical performance requirements. At first glance, it seemed that the Navy had succeeded. On closer inspection, though, some claims stood up better than others. Minimizing time had top priority, and the span between the 1955 conception of a liquid-fuel missile fired from a surface ship and the 1960 availability of a solid-fuel, submarine-launched missile was remarkably short. The nuclear-powered submarine *George Washington*, with 16 Polaris A–1 IRBMs on board, began its first operational patrol in November 1960. The A–1 had performance shortfalls, none of them critical. It was accurate enough to strike urban centers, but it fell a bit below 1,200 NM in range, carried a warhead with a yield only about half the one-megaton goal, and achieved less than 50 percent reliability. Even so, the rapid fielding of a novel, highly complex system was a remarkable achievement.[1]



USS *Henry Clay* (SSBN 625) firing Polaris missile (*Naval History and Heritage Command*)

Plaudits went primarily to the Special Projects Office. Established in November 1955, SPO was unique within the Navy. Rear Adm. William F. Raborn, Jr., SPO's director, reported directly to the secretary of the Navy, from whom he received a broad grant of authority and responsibility along with orders to move fast.[2] By December 1960, SPO personnel numbered 325.[3] The SPO's Steering Task Group had supervised the initial technical studies that focused on tradeoffs between cost, schedule, and performance. Led by Capt. Levering Smith, head of SPO's Technical Division, the group included representatives from SPO, the major contractors, the Instrumentation Laboratory at MIT, the Atomic Energy Commission, the Bureau of Ships, the Naval Ordnance Laboratory, and the staff of the chief of naval operations. In bimonthly meetings, the group focused on preliminary design, performance, and technical progress. After the program gained approval, the Steering Task Group continued regular meetings. This approach to communication and coordination, later called adaptive management, fostered prompt accommodation to the project's needs.[4] SPO, together with Lockheed, bore responsibility for systems integration.

As Polaris moved forward, Raborn and Smith decided that responsibility for production should remain with the development groups but that a separate office would monitor and independently report progress and problems. Too often, in Smith's experience, "something was developed and some quantity satisfactorily produced, only to have severe problems appear when others produced it." Since production methods could vary among firms that made the same technologies, designs sometimes had to be reworked.[5]

SPO's best-known management innovation, the Program Evaluation Review Technique, offered a methodology for integrating projects and evaluating progress. Designed by a team drawn from SPO, Lockheed, and the consulting firm of Booz, Allen, and Hamilton, PERT identified events, activities, interrelationships, and time estimates that SPO had instanced in the projected development of Polaris. An "influence diagram" displayed the interconnected sequence of events or activities that had to take place on the way to completion. Engineers then prepared three time estimates for completing each—optimistic, pessimistic, and most likely. A mathematical formula combining these three estimates provided a projected completion time. Network interdependencies—that is, the parallel development of subsystems—created "paths" of various time lengths. The longest was termed the "critical" path because any delay in completing a critical activity would push back completion of the whole project. Tracking the critical path highlighted potential bottlenecks at the earliest point. Largely due to its well-publicized application in the Polaris program, PERT was in vogue throughout the Defense Department during the late 1950s and early 1960s.[6]

PERT had limitations that were not obvious to outsiders. It assumed that engineers could make reasonable time estimates for each of hundreds of development activities without knowing exactly when each activity would begin and how many workers with the requisite abilities would be available for each one. Indeed, engineers found it difficult to produce three time estimates for each activity while assuming the same level of effort, since a major factor in the differing time estimates was the availability of specific individuals to work at specific times. Also, planning work as discrete efforts with clear starts and finishes ignored the frequent overlapping of activities. Networking made sense, but computer printouts revealed so many scheduling conflicts that full compliance was simply infeasible.[7]

Some observers, such as Harvey Sapolsky, author of the classic study of the Polaris program, argued that SPO's reputation as an innovator was a bit contrived. Novel techniques, according to Sapolsky, were not widely applied until after the first submarine had been tested and put into service, or were applied but did not work, or worked but were put to a purpose wholly different from the one officially described.[8] As for PERT, Sapolsky judged that SPO often used it as a screen against outside interference, creating an image of efficiency behind which old-fashioned, hands-on management could function. Personal relationships, Sapolsky concluded, probably provided better insights than PERT. Robert Frosch, who as assistant secretary of the Navy (R&D) helped authorize Sapolsky's study, later reflected that SPO deserved credit for using "some pseudo-management techniques (along with their real ones) to flim-flam some of the pseudo-watchdogs into leaving them alone to manage the project right."[9]

How, then, did SPO and its contractors beat the time goal and fulfill most performance requirements? First, the quality of leadership and technical talent was extremely high. Polaris held the Navy's highest priority, enabling Rear Admiral Raborn to recruit needed specialists, while Congress gave strong bipartisan support and minimized the time SPO personnel spent testifying on Capitol Hill. A second key to success was a decentralized, competitive program structure that promoted rapid, synchronized advances in all of the technologies comprising the Polaris system. For example, having Hughes as an alternative to General Electric for manufacturing fire control computers improved the product and significantly reduced the price. A third element was the sense of élan and commitment that Rear Admiral Raborn, director from November 1955 until February 1962, carefully fostered. He nurtured friendships between SPO and contractor personnel, requiring his people to attend industry-sponsored parties and encouraging them to entertain contractors at their homes. Our religion is to build Polaris, Raborn preached, turning virtually his whole flock into true believers.[10]

In other branches of the Navy, some believed that Polaris turned out so well because it drained talent away from other projects. According to an officer with long service in the Polaris program and its successors, "We did attract some of the Navy's best and brightest," but "most of us . . . were inspired to excellence by outstanding leadership, the unambiguous delegation of authority and responsibility, the technical challenges, and the importance of our program to national security."[11]

The Special Projects Office prided itself on having produced accurate, realistic funding plans. The major contracts were cost-plus-fixed-fee, with statements of work covering 12-month periods. The entire program, officials said, came within 2 percent of meeting its cost estimate or target.[12] Many in the Navy, OSD, and Congress interpreted cost control as spending funds neither faster nor slower than planned during a 12-month period rather than as accomplishing defined packages of work at a cost no higher than planned. In 1961, the Navy tasked the Management Systems Corporation in Cambridge, Massachusetts, with designing a cost-control system, using the Polaris project as a model. Analysts visiting two of the major contractors found that work unfinished when the fiscal year ended would be reinserted in the work statement for the following year's contract and used again as the basis for estimating the next year's costs and fees. One firm, for example, appeared to have collected a profit for performing a work package in one contract, then profited again for performing the same work package in the follow-on contract. Some analysts construed these as equivalent to cost-plus-percentage-of-cost contracts, which were prohibited by law.[13]

In rebuttal, SPO held that Polaris's high priority, novelty, and level of technical difficulty compelled the use of annual level-of-effort contracts rather than completion contracts specifying packages of work to be accomplished. *Level of effort* meant that a contractor would employ its best efforts on the project for a certain number of hours during the period the contract covered. In return, the government would pay the contractor for its costs plus a profit, called a fee. While the contract would describe the work that SPO and the contractor hoped to accomplish during a 12-month period, it did not require the contractor to complete the work. If the contract described the scope of work in terms of levels of effort extending over several years, most of that language could stay the same from one contract to the next. The cost estimate often related to the contractor's level of effort, not the specific work to be completed. If the contractor spent more than the contract specified for 12 months, the government would reimburse the contractor for all allowable costs and the fixed fee negotiated at the contract's outset. Consequently, SPO did not construe the contract as cost-plus-percentage-of-cost, even though some of the work content used for one year's fee was carried over to the following year.[14]

In 1960, SPO started seeking ways to measure contractor performance throughout the program. The answer was PERT COST, in which "work packages" became the basis for estimating man hours and costs. A PERT COST team carried out a pilot test at Lockheed-Sunnyvale and General Electric's Ordnance Department. Fixed budgets for work packages were the basis for man-hour and cost estimating; those estimates were summarized and forwarded to higher echelons. Previously, "rubber baselines" had allowed contractors to ensure retroactively that expenditures conformed to estimates. The ability to compare estimates against the man hours and costs actually expended allowed the contractor to keep a constant check on whether work was costing more or less than originally planned.[15]

Questions about program cost, however, were much less important than deploying a system that would give the United States a decided military advantage over the Soviets. The Eisenhower administration had authorized 19 ballistic missile submarines. The Kennedy administration accelerated production to fund a larger number, 41 in total. Twelve were launched in 1963 alone, and all 41 were in commission by 1967, carrying 656 Polaris missiles and putting the United States far ahead of the Soviet Union in strategic nuclear weapons capability. Four shipyards built the submarines. Two were private firms, Electric Boat in Connecticut and Newport News Shipbuilding and Dry Dock Co. in Virginia, and two were Navy yards in Portsmouth, Maine, and Mare Island, California. SPO coordinated the activities of the yards with those of the Bureau of Ships and its Nuclear Power Directorate, which supervised design and construction of the submarines and their reactors.[16]

In designing the Polaris A–1 missile, the prime contractor, Lockheed-Sunnyvale, allowed reliability to suffer in order to meet the schedule. There was no one major failure, just an accumulation of smaller ones. In April 1958, Lockheed began developing an A–2 missile with more dependable electronics and slightly greater warhead yield. The A–2, which became operational in June 1962, had a longer range—nominally 1,500 NM—that resulted from work sponsored by SPO and performed at the Allegany Ballistics Laboratory in West Virginia, a government-owned facility operated by the Hercules Powder Company. The innovation of fiberglass casing, which had a significantly higher strength-to-weight ratio than steel, lightened the rocket's upper stage.[17]

Development of the next version, the Polaris A–3, started in October 1960. The Navy wanted much longer range and a more powerful payload. Working with the Aerojet General Corporation and Hercules, Lockheed improved propulsion enough to give the A–3 a range of 2,500 nautical miles.[18] Livermore Laboratory in California had tested a 200-kiloton design prior to the moratorium on atmospheric testing that ran from 1958 until 1961.[19] A multiple reentry vehicle (MRV) system would carry three 200-kiloton warheads; these would separate and detonate in a triangular pattern, creating enough destructive overpressure to flatten buildings across an area as large as that created by a one-megaton blast. The first A–3, with about 85 percent new hardware design, went to sea in September 1964.[20] Only two months later, in Red Square, the Soviets displayed the Galosh surface-to-air missile, which along with its associated components provided Moscow defense against ballistic missiles. In 1961, Lockheed had been awarded a contract to develop penetration aids for overcoming a missile defense system similar to the Army's Nike-Zeus, which was designed to intercept warheads within the atmosphere. Galosh missiles, however, were to intercept targets above the atmosphere and had a very high warhead yield. In response, Lockheed's kits, completed between July 1963 and July 1964, each contained six decoys, chaff (clusters of small fibers that reflect radar signals) to be released in mid-course, and electronic jammers for the early part of atmospheric reentry. Unfortunately, these kits could not counter Galosh because jammers and chaff were cut to the wrong frequencies, decoys were too small to be seen by Galosh's low-frequency radars, and MRVs were spaced improperly to accommodate the blast effects from Galosh's big warheads. The Navy reacted by starting development of a system of penetration aids for the A–3 called "Antelope."[21]

A more comprehensive answer to Galosh was in prospect. In November 1963, Harold Brown, the director of defense research and engineering, instructed SPO to define a successor to Polaris—a missile that must be able to penetrate ballistic missile defenses around urban-industrial areas. Brown also ordered the Air Force, working jointly with the Navy, to develop a new reentry vehicle, and General Electric started designing the Mark 12, which would carry a 150-kiloton warhead. Quickly, though, SPO and Lockheed turned toward what was called "mailman" technology that the Air Force was creating for its silo-based Minuteman ICBM. Essentially, a platform or "bus" would carry all the reentry vehicles for each missile and release them one at a time. Unlike a multiple reentry vehicle, which delivered warheads on only one target, warheads from one multiple *independently* targetable reentry vehicle could hit a number of widely dispersed targets. Consequently, SPO commissioned the Instrumentation Laboratory at MIT to develop what became the Poseidon missile's Mark 3 reentry vehicle.[22]

Secretary McNamara wanted Polaris's successor to possess better accuracy as well as increased yield. To that end, SPO proposed a number of technical improvements, including a new guidance system, more precise release of reentry vehicle from the bus, and navigation references for the ballistic missile submarine that would be more accurate, all-weather, and usable worldwide.

Project Transit provided one solution for supporting navigation requirements that grew ever more complex. Putting five or six Transit navigation satellites into polar orbits would make possible an accurate mapping of the Earth's shape, mass, and gravitational field. That knowledge would allow a satellite's orbit to be known precisely. Consequently, variations in a satellite's signal as it approached a listener and then departed—the Doppler effect—would give the listener an accurate fix on his own location. By 1964, the Applied Physics Laboratory of Johns Hopkins University had created a model of the Earth's gravitational field that could make navigation at sea accurate to within one-tenth of a mile. In May 1960, SPO had assumed oversight responsibility for Transit, showing how far the concept of a weapon system had broadened.[23]

In January 1965, President Johnson announced the decision to develop Poseidon, the next generation of submarine-launched ballistic missiles. The quietly competent Levering Smith, promoted to rear admiral, became director of SPO in February. Central to the development of a Poseidon missile was a decision about its purpose. Should it be a counter-city weapon, like Polaris, or a counterforce weapon, accurate and powerful enough to destroy or neutralize hardened missile silos and command and control centers? OSD wanted a counterforce capability, but Rear Admiral Smith was wary. Among other things, he wanted to keep Poseidon's mission and identity distinct from the Air Force's programs and objectives that emphasized counterforce capabilities. Ultimately, Smith succeeded in having OSD's aim of 50 percent improvement over the A–3's accuracy listed as a "development goal" rather than a "development requirement." The Special Projects Office, Smith reasoned, could determine a missile's accuracy in test firings but could not be sure why shortcomings occurred because it did not fully control testing procedures.[24]

Rear Admiral Levering Smith (*Naval History and Heritage Command*)

Vice Admiral Levering Smith (1910–1993)

From 1957 through 1977, Levering Smith was either the technical head or program director for the Navy's submarine-launched ballistic missiles—Polaris, Poseidon, and Trident. Indeed, the Naval Submarine League, in naming an annual award in his memory, said that he, "more than any other individual, was responsible for the successful marriage of the ballistic missile with the nuclear submarine."

For much of his early career, Smith served on surface warships, often as the gunnery officer. During World War II, he participated in 11 Pacific campaigns and engagements, surviving the sinking of both the aircraft carrier *Hornet* in the battle of Santa Cruz in October 1942 and the heavy cruiser *Northampton* in the battle of Lunga Point only five weeks later.

Before the war broke out, Smith completed the Naval Postgraduate School course in ordnance, which was followed by a one-year tour at the Bureau of Ordnance. After more than two years in action in the Pacific, he returned to the bureau in late 1944 and spent the next three decades in rocket- and missile-related work. From 1947 to 1954, he was assigned to the Naval Ordnance Test Station in California where he was, successively, deputy head and head of the Rockets and Explosives Department, specializing in solid propellants and high explosives, and then the facility's associate technical director. Captain Smith next assumed command of the Naval Ordnance Rocket Test Facility at White Sands Proving Ground in New Mexico. In the spring of 1956, Rear Adm. William F. Raborn, Jr., head of the Navy's effort to develop a fleet ballistic missile system, tapped him for duty in the Special Projects Office.

While serving as the SPO's technical director, in June 1957 Smith was promoted to rear admiral, and in 1965 became the ballistic missile program's director, occupying that post until retiring from the Navy in November 1977 as a vice admiral. In a tribute to Smith, Willis M. Hawkins, a former vice president of Lockheed, summed up the views of those who knew him well: "He was what he appeared to be: a highly intelligent, rational, practical engineer with immense respect for those around him, particularly those with good ideas and a reasonable approach to developing them."[1]

Counterforce versus counter-city targeting played out in a debate over the best method of missile guidance. An OSD study concluded that small MIRVs were preferable to large single warheads with sophisticated decoys. That finding helped Rear Adm. Smith eliminate Mark 12s from consideration. But counterforce advocates wanted Poseidon to carry the Avco Corporation's Mark 17 reentry vehicle, designed for the Air Force and able to deliver a multimegaton warhead that could take out even the most hardened targets. Engineers at the Kearfott Division of the General Precision Corporation, working apart from specialists in Smith's organization and the Instrumentation Laboratory, argued for a new guidance system. All-inertial had been preferred to stellar-inertial guidance because the latter required sightings on two stars. Kearfott claimed that one optimum star sighting would reduce drastically the sources of error that had made submarine-based missiles less accurate than land-based missiles. Lockheed responded in 1966 with a finding that a Mark 3 carrying stellar-inertial guidance could destroy or neutralize hard targets and thereby make the Mark 17 unnecessary. SPO agreed to drop the Mark 17. Improving accuracy enough to make Poseidon a counterforce weapon provoked congressional opposition. In 1969, following the test flight of a stellar-aided Poseidon, Sen. Edward W. Brooke III (R–MA) led an effort to withhold funds for stellar guidance. So much accuracy, he argued, could upset the delicate balance of mutual deterrence. The president yielded, and Poseidons carried all-inertial guidance.[25]

Poseidon C–3 had a range of 2,500 nautical miles, the same as the Polaris A–3, but its Mark 3 reentry vehicle system could carry 14 warheads per missile. Because the Soviets were improving their antisubmarine as well as their antimissile capabilities, the C–3 was designed to counter either threat by varying the number of warheads placed in a missile before it was loaded on board a submarine. Fewer warheads increased the C–3's range, thereby improving a submarine's survivability by allowing it to stay farther out at sea. More warheads enhanced the C–3's ability to penetrate missile defenses.[26] A yield of only 40 kilotons per warhead led Air Force officers to joke about the Navy's puny "firecrackers." Still, the C–3 was sufficiently accurate to destroy not only cities but also targets such as nonstrategic military installations, research and development centers, and industrial facilities outside urban areas.[27]

Between 1961 and 1968, SPO's management techniques stayed essentially the same.[28] However, it had to cope with two changes that OSD imposed: first, the shift from cost-plus-fixed-fee to fixed-price-incentive contracting; and second, the promulgation of DoD Directive 3200.9 spelling out steps within the phases of concept formulation and contract definition. In March 1968, the Navy awarded Lockheed a $456.1 million cost-plus-incentive-fee contract, one of the first awards that covered both development and production of the missile system.[29] Initially, SPO engineers worried that incentives would cast the boundaries between development and production in concrete, cost more, involve more paperwork, and give the contractor more profits. Most of their fears proved to be unfounded. As much as half of the design work on some subsystems reached completion before letter contracts and prices were set. Because the government bore the burden of proof to show why it would not accept incurred costs, letter contracts gave contractors an incentive to spend as much as possible before contract definitization occurred, with the incentive applying only to the reduced amount of work that remained. SPO only opened the propulsion contract, involving little innovation, to competition. All other subsystem contracts were sole-source awards. Also, assigning weights to each of the multiple incentives gave SPO a good deal of leverage in shaping the program. With Polaris, SPO accepted performance shortfalls to beat the time deadline. With Poseidon, SPO imposed different priorities. Rewards for technical performance weighed most, those for meeting the schedule next, and those for staying within cost targets least.[30]

Compared with the Polaris A–3, weighing 36,000 pounds and with a 54-inch diameter, the Poseidon C–3 weighed 64,000 pounds and had a 74-inch diameter.[31] Of the 41 Polaris boats, 31 were slated for modification to carry C–3s. Converting the earliest 10 boats was deemed too costly and difficult.[32] The administration in 1968 wanted to authorize six conversions during FY 1969. But Sen. Richard Russell (D–GA), aware of the Navy's troubles with the Tartar, Terrier, and Talos shipboard antiaircraft missiles, opposed rushing ahead with missiles that had yet to be proven. Despite pleas from Rear Admiral Smith and senior OSD officials, Russell succeeded in cutting FY 1969 conversions to two. The first submarine to be refitted, *James Madison*, entered the Electric Boat shipyard in February 1969; it returned to sea in March 1971.[33] Since the Soviets had not yet flight-tested a MIRV, the American lead remained substantial.

MINUTEMAN I, II, AND III

The Air Force's Minuteman ICBMs, protected in hardened underground silos, rivaled the Navy's acquisition achievement with Polaris. Program definition and hiring of contractors took place during 1958. Minuteman's first full flight test, on 1 February 1961, was a complete success. In December 1962, 20 Minuteman ICBMs reached operational status. By 1967, the force peaked at 1,000 launchers.[34]

Brigadier General Schriever's Western Development Division (WDD), created in 1954, directed the Air Force's ICBM and IRBM programs. Located in Inglewood, California, WDD was an element of the Air Research and Development Command. As the Air Force's ICBM effort began to take shape, Schriever and his superiors concluded that no private firm had the capacity to act as a missile prime contractor. Since the Air Force likewise lacked personnel qualified to oversee missile development, it recruited talent for a technical management organization to handle Atlas, Titan, and the intermediate-range Thor.[35]

Poseidon missile launched from USS *James Madison* (SSBN 627) (*Naval History and Heritage Command*)

The Air Force chose a private corporation headed by Simon Ramo and Dean Wooldridge, who had earned reputations working on electronics and missiles for Hughes Aircraft. In WDD, Ramo-Wooldridge acted as deputy responsible for systems engineering and technical direction, with Schriever and Ramo meeting almost daily. To its nucleus of highly capable personnel, Ramo-Wooldridge added university engineers and physicists who were granted leaves of absence from their academic positions. In December 1957, the element of Ramo-

Wooldridge at Inglewood became the private Space Technology Laboratories (STL), tasked with integrating the designs and directing the development of ballistic missile systems and space programs. Schriever's WDD was renamed the Ballistic Missile Division (BMD).[36]

A breakthrough with solid fuels brought the second generation of ICBMs into service swiftly. By 1955, experts anticipated that gains in metallurgy, chemistry, and high-temperature materials would permit rapid advances in solid-propellant technology. Atlas and Titan used a highly unstable liquid-fuel mixture that had to be loaded in exactly the right proportions just before launch. Solid fuels, on the other hand, had virtues that included ease of handling, immediate availability because the propellant could be stored on board indefinitely, and a good thrust, range, and payload ratio. In the Ballistic Missile Division, Col. Edward N. Hall was a persistent advocate of solids. A Ramo-Wooldridge study, begun in 1955 and circulated in July 1957, concluded that solid-fuel engines could be created by 1960 without radical improvements in the state of the art.[37] Another group, led by Colonel Hall, judged that by 1964 a solid-fuel, three-stage rocket could deliver a one-half to one-megaton warhead within one nautical mile of a target 5,500 to 6,500 nautical miles distant.[38]

By February 1958, OSD and the Air Force Ballistic Missiles Committee,[39] convinced that Minuteman had matured sufficiently, felt confident that simplified, relatively inexpensive weapons could be fielded in 1962–1963. Predictions that the first R&D version of Minuteman would be delivered in October 1960, followed by the first operational missile in June 1962,[40] proved to be extremely close to the mark.

Praising the work of the Ballistic Missile Division and STL on Atlas and Titan, the Air Force Scientific Advisory Committee urged extending this same collaboration to Minuteman. Joined by other Air Force officers and contractors, Hall argued that widespread expertise now made STL's role redundant. Nonetheless, in April 1958, STL was made responsible for Minuteman's systems engineering and technical direction. Later that year, STL's parent, Ramo-Wooldridge, completed a merger with Thompson Products, its main financial backer, and became Thompson Ramo Wooldridge (TRW), Inc.[41]

Since the engines constituted the airframe in a solid-propellant rocket, the outcome of engine development would go far to determine Minuteman's success. The Ballistic Missile Division and STL prepared work statements for R&D contracts. During April and May 1958, selection boards drawn from BMD, Air Materiel Command, and SAC recommended the firms that appeared best qualified to be subcontractors. Another board chaired by BMD evaluated contractors' proposals, submitting its findings for review by higher echelons, up through Air Force headquarters.[42]

Colonel Edward N. Hall (1914–2006)

Colonel Edward N. Hall (*Air Force Space Command*)

Edward Hall, the key figure in developing Air Force solid-propellant rocket technology in the 1950s, was born in New York City on 4 August 1914. After earning degrees in chemical engineering from the City College of New York in 1935 and 1936, he enlisted in the Air Corps in September 1939. Commissioned a second lieutenant following Pearl Harbor, Hall spent the war years in England supervising teams that repaired damaged B–17s. His introduction to missiles occurred at war's end as a member of an Army Air Forces intelligence unit that acquired information on Germany's wartime aerial propulsion work.

After the war, Hall served for a year at the Air Force's Wright Air Development Center in Dayton, Ohio; received a master's degree in aeronautical engineering from Caltech in 1948; and was sent back to England for work on British-developed jet engines.

Returning to Dayton in 1950, Hall was involved in developing both liquid and solid power plants for Air Force missile systems. By then recognized as the service's expert on rocket propulsion, he was recruited by Brig. Gen. Bernard Schriever in the summer of 1954 to be the chief of propulsion for the Air Force's high-priority ballistic missile program. At Schriever's Western Development Division in Inglewood, California, Hall developed engines for the Atlas and Titan ICBMs and the Thor IRBM. In 1957, he became the Thor program's first director.

While initially concerned with liquid-fuel systems, his most significant contribution came in the development of a solid-propellant ballistic missile. His persuasive advocacy of the advantages of solid fuel was instrumental in the Air Force decision in February 1958 to authorize the development of a solid-propellant ballistic missile, known as the Minuteman. But Hall, who possessed an abrasive personality, did not fare well as that program's director, and Schriever replaced him in late 1958. After retiring from the Air Force in 1959, Colonel Hall worked for United Aircraft Corporation for 14 years.[II]

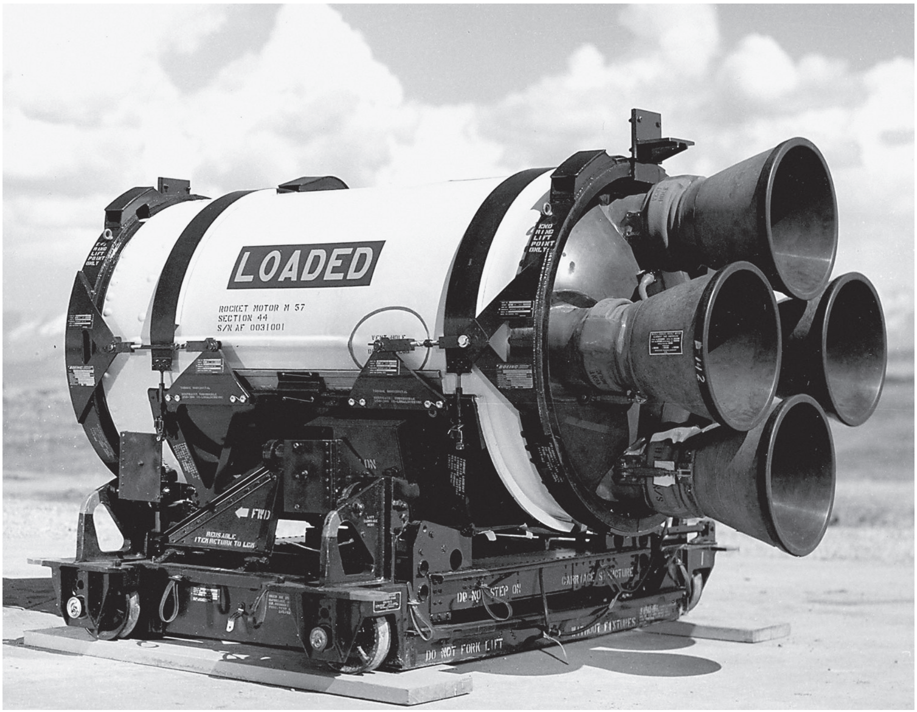
Engine contracts went to Thiokol Chemical Corporation for the first stage, Aerojet General for the second, and Aerojet with Hercules Powder Company for the third. The Autonetics Division of North American Aviation started developing the guidance and control system, while Avco designed a reentry vehicle. In October 1958, Boeing contracted to undertake "planning, studies, design, fabrication, component and subsystem tests, integration and coordination, system tests, evaluation redesign, documentation and services as required to deliver complete missiles." Although not a prime contractor in the normal sense, Boeing filled the most crucial role in Minuteman development. But STL's activities expanded to include "experimental effort on certain supporting research and development programs, more direct participation in the design, assembly, and test of the missile system, and more detailed technical direction of the subsystem developments."[43]

Thompson Ramo Wooldridge, Inc. (TRW)

While working for Hughes Aircraft, physicists Simon Ramo and Dean Wooldridge led a team of scientists and engineers that developed fire control systems and air-to-air missiles. In 1953, the two founded their own company in Los Angeles specializing in military electronics and systems engineering. Thompson Products, a Cleveland-based precision manufacturer of parts for the automotive and aircraft industries, provided $20 million in return for options to purchase more than 80 percent of Ramo-Wooldridge's common stock. R-W's practice of giving top responsibilities to its scientists and engineers, with professional managers and administrators working under them, helped the firm attract more than its share of talent.

In November 1957, just after Sputnik, Ramo turned R-W's Guided Missile Research Center into an autonomous Space Technology Laboratories. By 1958, 90 percent of R-W's business came from Air Force guided missile programs. Ramo, in effect, became science advisor to Major General Schriever, who directed the Air Force's ICBM and IRBM programs. Thompson Products, flush with cash but faced by a sudden decline in the turbojet engine business, pressed for a merger that was consummated in September 1958. Chairman J. David Wright from Thompson worked in Cleveland; President Wooldridge stayed in Los Angeles. At that point TRW, Inc., had 23,000 employees and nearly $340 million in revenues.

TRW diversified and grew rapidly, with spacecraft and satellites as notable achievements. By the late 1960s, at STL's Space Park complex in California, no single product or program accounted for more than 10 percent of revenues. In 1970, TRW's group general managers supervised 55 separate divisions. By the mid-1980s, though, diversification and decentralized management worked less well. TRW restructured and shed units to focus upon core competencies—space and defense, automotive supply, and information systems and services. A decade later, with rack-and-pinion steering a great success, automotive supplies comprised two-thirds of TRW's business.[III]



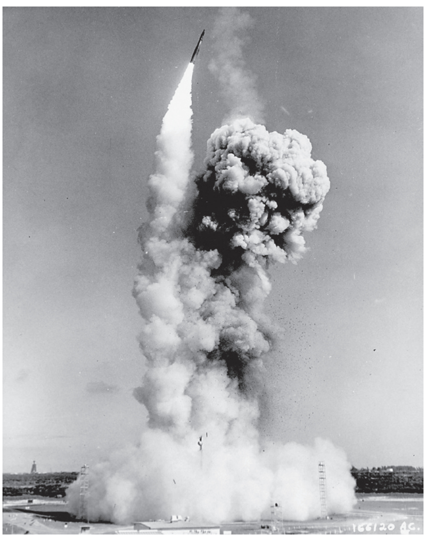
Each Minuteman solid-fuel engine stage contained four steerable rocket nozzles.This Minuteman I third-stage engine was made by Hercules Powder Company. (*National Museum of the U.S. Air Force*)

In October 1958, STL and a panel of the President's Science Advisory Committee recommended more basic research on solid fuels. When Colonel Hall objected vehemently, Schriever replaced him with Col. Otto Glasser.[44] Progress, nevertheless, continued on a remarkably quick and smooth path. During April and May 1959, all three engine stages test-fired successfully. By mid-year, planning for the operational system, launcher configuration, a squadron size of 50, and details of the communication and launch control systems had been worked out.

On 4 September 1959, Minuteman received a DX rating, which meant that the program had been assigned the highest national industrial priority. In March 1960, OSD approved production of 150 missiles by mid-1963. Five months later, alterations to the system were limited to essential changes that did not delay scheduled deployments. On 23 February 1961, after a spectacularly successful test flight, the Air Force chief of staff designated Minuteman a crash program with overriding priority. The production target doubled to 60 missiles per month.[45]

STL's growing involvement with space programs, combined with its role in ballistic missile development, seemed to offer TRW an unfair advantage in competitive bidding. Some in Congress sharply criticized what struck them as STL's intimate and privileged position with the Air Force. Hearings brought out charges that STL's sole-source status led to flagrant profiteering and that STL appropriated competitors' proprietary information for its own use. The solution lay in creating, in June 1960, a nonprofit Aerospace Corporation headed by Ivan A. Getting, a member of the Air Force's Scientific Advisory Board and a former vice president of Raytheon. At Schriever's insistence, STL continued to provide systems engineering and technical direction for ICBM programs. With all other functions transferred to the Aerospace Corporation, STL's role was expected to diminish as Minuteman squadrons became operational. Its record of experience and accomplishment, however, preserved STL as the Air Force's preferred supplier.[46]

In March 1961, the new Air Force Systems Command, headed by Schriever, replaced the Air Research and Development Command and became the single manager for Minuteman. In AFSC, Maj. Gen. Osmond J. Ritland's Ballistic Systems Division assumed the responsibilities formerly shared by the Air Materiel Command's Ballistic Missile Center and Air Research and Development Command's Ballistic Missile Division. Within Ritland's division, Col. Samuel C. Phillips served as director of the Minuteman program office.[47]



Successful test launch of Minuteman I on 17 November 1961, Cape Canaveral, Florida (*National Museum of the U.S. Air Force*)

Between 1960 and 1965, the Minuteman program went through three shifts in emphasis. During 1960–1961, meeting a tight deployment schedule had top priority. Consequently, like the Polaris A–1, Wing I of 150 Minuteman missiles entered service with less accuracy and range as well as less hardness in the launch facilities than originally specified. Then, beginning in 1961, concern over the possibility of an inadvertent launch and a push for targeting flexibility led to major changes in the command and control systems.[48] As a compromise, Wings II through V incorporated whatever improvements would not cause schedule delays, while Wing VI would be able to incorporate significant technical advances. By 1965, financial concerns gained priority, and cost emerged as the central consideration in all major program decisions.[49]

Minuteman's achievements did not come cheap. In May 1959, OSD approved program acceleration, which required concurrent action in all system areas. Concurrency was unavoidably expensive. Acceleration raised the original budget proposal of $260 million for FY 1960 to $342 million. The actual expenditure reached $380.9 million. However, since the Ballistic Missile Division had submitted a figure of $382.5 million in January 1960, it could claim that Minuteman was staying within budget.[50]

In November 1962, the Air Force recognized that Minuteman's costs would exceed programmed funds by $419 million. Measures to improve targeting flexibility, protect against blast effects, and prevent unauthorized launches were largely responsible. Inadequate procedures for estimating costs aggravated the problem. Reassigning funds made available from cancellations and deferrals elsewhere somewhat reduced this overrun.[51]

In 1958, the cost per Minuteman was estimated at $350,000 per missile for 4,000 missiles; about five years later, estimates rose to $1,450,000 per missile for 800. An Air Force analyst argued that learning curve adjustments for the much smaller production run should change the 1958 figure to $700,000 per missile, so the 1963 figure was merely two times rather than five times higher.[52]

Starting in 1962, Minuteman's managers emphasized fixed-price and cost-type incentive contracts. One fixed-price contract, balanced by performance incentives, covered engineering development and production. These types of contracts required a more exacting style of management. Often, however, reducing TRW's technical staff and replacing senior with less experienced Air Force personnel undermined managerial control.[53]

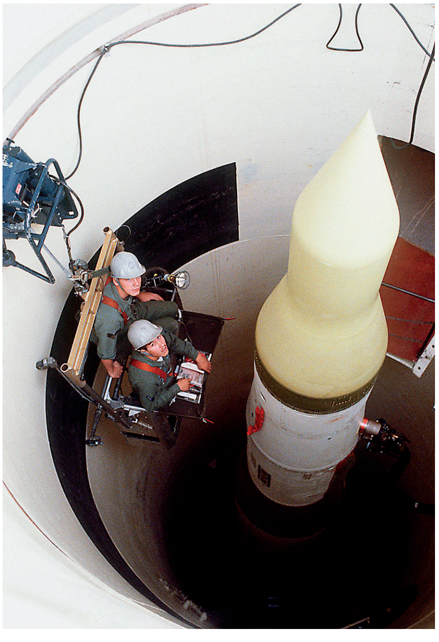
The Minuteman program office collaborated with the Performance Technology Corporation, a private management firm, to design a system for measuring contractor performance. Building on lessons learned from the Polaris PERT COST group, an Earned Value approach that focused on improving contractors' internal reporting methods emerged. During 1964–1965, Air Force Systems Command and the consulting firm of McKinsey and Company tested a Specification Approach to contractors' cost planning and control. The outcome was a manual incorporating the most effective points of PERT COST and Earned Value.[54]

In one important respect, Minuteman's requirements were more demanding than those of Polaris. The Air Force emphasized counterforce capability, which required considerably more accuracy than Polaris's counter-city targeting. The floated gyroscopes in first-generation Atlas and Titan ICBMs needed as much as an hour to heat up, erect (orient correctly in the direction of gravity), and align (position properly in the horizontal plane). Autonetics won the Minuteman I contract by claiming that it had found a way to keep an all-inertial, or self-contained, guidance system in continuous operation. Replacing the ball bearing with a self-activating gas bearing could allow a gyroscope to run for years without wear and tear.[55]

Unlike Atlas and Titan, Minuteman I would carry an onboard computer. With solid-state transistors replacing vacuum tubes, Autonetics promised to produce a general purpose onboard digital computer, superior to the special-purpose calculator used in Polaris. The inertial measurement unit and digital computer would record components of acceleration and reduce them to flight signals. Then an automatic flight control system would translate those signals into nozzle movements that provided directional control of the missile. Thus, in-flight stabilization would combine with inertial guidance to create an integrated system.[56]

In July 1958, at the outset, Autonetics calculated that its guidance system would cost $37 million, while the Ballistic Missile Division estimated $132 million. By mid-1960, unexpected and increasing technical difficulties increased funding requirements to $260 million. An Air Force management survey team identified several problems: an average of two months' slippage across the program, failure by Autonetics to control costs, and a lack of influence of those involved in production on the engineering effort as emphasis shifted to manufacturing.[57]

Autonetics instituted reforms, but problems persisted. Initially, Minuteman I's guidance system met its functional performance goals but achieved a mean time between failures (MTBF) of only 600 hours, falling far short of the capabilities required, which included 8,700 hours of operation annually in a constant state of readiness for immediate launch. Thus, the inertial guidance system had to be removed every 25 days and replaced and a new one warmed up and calibrated. To increase reliability, Autonetics began a second development cycle, awarding $1 million to $2 million subcontracts to more than a dozen companies. The modifications resulted in a greatly improved MTBF, as measured by a fifteen-fold reduction in the removal rate. Such an improvement was well worth the cost and delay.[58]



Minuteman II in silo near Whiteman Air Force Base, Missouri (*National Museum of the U.S. Air Force*)

If the Soviets deployed ICBMs underground in hardened silos beginning in the late 1960s, as intelligence analysts expected, Minuteman I would no longer be an effective counterforce weapon. Accordingly, in 1962, the Air Force issued specifications for an improved Minuteman II that included longer range, higher yield and accuracy, and greater retargeting capability.

Again, Autonetics won the guidance contract. Its engineers decided that, for Minuteman II's onboard computer, integrated circuits would replace transistors. In fact, this technology was so new that the military bought all integrated circuits produced in 1962 and 70 percent 3 years later. By making maximum use of the highly reliable parts in Minuteman I's guidance and substituting new components for others, Autonetics engineers hoped to give Minuteman II's guidance system an initial service life equal to that of the improved Minuteman I. Then evolutionary refinements would further improve the mean time between failures of Minuteman II, just as had occurred with Minuteman I. Since spare sets had to be available for quick replacement of failures, a longer MTBF meant that fewer spares would be needed, saving substantial sums.[59]

By 1964, the Guidance Panel of General Schriever's Project Forecast predicted dramatic advances in accuracy, leading to a zero CEP (exactly on target) by 1975.[60] Minuteman II's first test flight took place in September 1964, and by April 1967, 550 Minuteman I and 450 Minuteman II launchers were operational. But again, the initial guidance system fell well short of performance requirements. Integrated circuits failed frequently, sometimes when they were brand new. About 40 percent of the online Minuteman IIs were out of service at any time.[61]

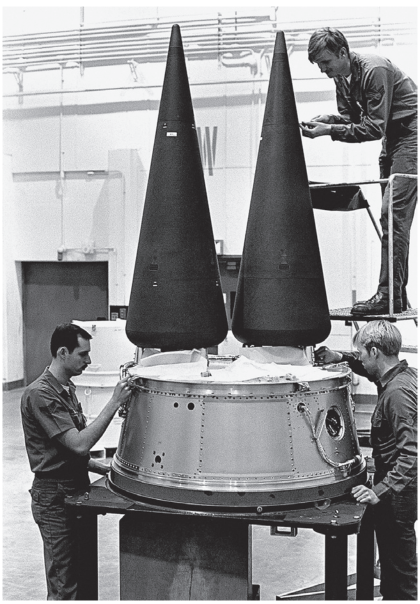
In mid-1966, Brig. Gen. Arthur W. Cruikshank, Jr., became the system program director for Minuteman. Early in 1967, at a meeting chaired by Assistant Secretary of the Air Force (Financial Management) Leonard Marks, Jr., Cruikshank gave a blunt assessment of the guidance system: "It's sick, and it's been sick for a long time." In Autonetics's contract, he pointed out, the MTBF figure had been a "goal" but not a firm specification. Mark's deputy, A. Ernest Fitzgerald, observed that repeatedly replacing these guidance sets actually allowed Autonetics to profit from its own shortcomings.[62]

In June 1967, an exasperated Secretary of the Air Force Harold Brown ordered a 90-day study of the guidance problem. The commander of AFSC's Electronic Systems Division, Maj. Gen. John W. O'Neill, led the study group, which included both government and private-sector personnel.[63] The group's TRW members cited poor quality control and sloppy workmanship as major causes of system failures. The program manager in the Ballistic Systems Division held that Autonetics had been overly bold in pushing the limits of miniaturized electronics. A more conservative course, he believed, would have resulted in fewer corrections and modifications.[64]

In July, Air Force Systems Command combined its Ballistic and Space Systems Divisions into a new Space and Missile Systems Organization (SAMSO) headed by O'Neill, who received his third star.[65] Within SAMSO, Brig. Gen. Kenneth W. Schultz became deputy for Minuteman.[66] Learning that Autonetics had not assigned any of its two dozen vice presidents to handle the Minuteman II guidance contract, Schultz told the company's top executives that they must either fix the problem or face cancellation. At his urging, Autonetics put Milton Margolis, a well-regarded executive, in charge. Margolis spoke with Schultz every day. TRW also contributed some of its best guidance engineers.[67] According to an AFSC history, the contractors achieved acceptable reliability five months ahead of schedule at a cost of $64 million (the original estimate was $13.7 million). Mean time between failures jumped from 1,400 hours in March 1967 up to 2,950 in July 1968.[68]

Overcoming another technological hurdle significantly increased costs. After the AC Spark Plug Division of General Motors failed to produce a reliable accelerometer based on a new MIT Instrumentation Laboratory design, the Bendix and Honeywell corporations stepped in and solved the problem, but the extra cost, when added to the guidance fix described above, reached $300 million to $400 million.[69]

Were recurring cost increases exorbitant or simply inevitable, given the technological leaps involved? Ernest Fitzgerald attributed the overruns to contractors' incompetence and dishonest reporting, which he believed Air Force leaders tolerated and even abetted.[70] Alexander Flax, assistant secretary of the Air Force (R&D), traced excessively optimistic reporting to a can-do attitude created by "riding the crest of the computer revolution. . . . Everything was being microminiaturized and people were waxing eloquent about all the wonderful things they could do with a shoebox computer." Instead of maintaining a separate computer in the silo, it was thought that a computer in the missile itself could handle all functions. But improving command and control as well as widening retargeting capability left the computer's capacity "very badly strapped."[71]



Airmen work on a Minuteman III's MIRV system (*National Museum of the U.S. Air Force*)

With improved accuracy and a 1.2-megaton warhead, Minuteman II qualified as a counterforce weapon, able to destroy or neutralize hardened silos. It could be launched against any of eight previously programmed targets.[72] Yet work on what became Minuteman III already had started in 1962. The Ballistic Systems Division's advisory group, drawn from industry and academia, believed that Soviet missile defenses were bound to appear and recommended using multiple reentry vehicles to thwart them. Additionally, a consensus emerged in DoD that relying on decoys would be dangerous because the Soviets might unexpectedly improve their techniques for discriminating warheads from decoys. Finally, as the weight of decoys compared to reentry vehicles increased, cost-effectiveness also argued for multiple RVs.[73]

Several RV systems were under consideration: the Mark 12, capable of directing as many as three warheads at different targets; the Mark 18, small enough to be employed in clusters; and the Mark 17, designed for precise delivery of a high-yield warhead. In 1964, intelligence indicated that almost two-thirds of the time-urgent Soviet targets were still "soft." Consequently, Minuteman III need not improve accuracy beyond what was expected from Minuteman II. Hence, the warhead planned for the Mark 12 would be adequate; its yield, in fact, was sacrificed to meet weight specifications.[74]

Minuteman III's novel features included an improved third stage and a post-boost vehicle with a liquid-fuel control system, enabling it to maneuver for releasing its reentry vehicles.[75] Experts in the Aerospace Corporation and the Office of the Director of Defense Research and Engineering envisioned a maneuvering platform or "bus" as the best means of deploying warheads and decoys. Keeping RVs and decoys indistinguishable meant that they had to be positioned accurately on specified flat or level planes. The bus would maneuver within those planes to keep the arrival times of RVs sufficiently separated. It required only a small modification to enable the bus to maneuver out of the plane so that it could deliver multiple warheads. The Autonetics and Rocketdyne Divisions of North American Aviation, joined by the Aeronutronic Division of Ford-Philco, paid for their own feasibility studies. In August 1963, on its own initiative, Autonetics submitted a bus proposal. Two months later, General Electric received a contract to develop a Mark 12 reentry vehicle that would be carried by the bus.[76]

In October 1964, General Electric's contract was amended to include a mechanism for deploying MIRVs. Three months later, Autonetics received authority to draft specifications, select subcontractors, and prepare plans for full-scale development of a MIRV bus, formally termed the Post-Boost Control System. A contract followed in July 1965. Space Technology Laboratories took responsibility for technical support of the bus. Aerospace Corporation was similarly responsible for the Mark 12 until November 1967, when that task was transferred to STL.[77]

An OSD study completed in mid-1965 identified small multiple warheads as the best means of defeating terminal missile defenses and thereby helped clinch the case for MIRVs. In March 1966, the administration authorized development of Minuteman III with a new stage carrying three Mark 12s. The Air Force recommended and OSD approved waiving contract definition so that production of an improved third stage could begin as quickly as possible. In June 1968, Autonetics signed a production contract for 76 post-boost control systems. The following month, General Electric received a separate contract for 68 Mark 12s. Meanwhile, between 1963 and 1967, the total value of Mark 12 contracts jumped from $148 million to $306 million. Negotiated changes were behind much of the increase.[78]

During 1967–1968, the Minuteman program ran short of skilled system managers as many officers, especially pilots and navigators, were assigned to support operations in Southeast Asia. That shortage may have contributed to a gradual blurring in the lines of managerial responsibility. In the belief that the Aerospace Corporation was encroaching on the rightful preserve of the Minuteman program office, the Air Force reorganized the Minuteman program office to provide more centralized control, while Aerospace began to concentrate exclusively on reentry systems.[79]

In 1967, when difficulties over a liquid-fuel, post-boost control system combined with other problems to create an R&D deficit of $112 million, the Air Force decided to postpone Minuteman III's initial operational capability by 5 months, putting it back to December 1969. OSD budget-trimming compelled a further postponement to June 1970. Making a bad situation worse, Aerojet General more than doubled the estimated cost of each third-stage motor. General James Ferguson, who headed Air Force Systems Command, believed Aerojet had "bought in" with an unrealistically low bid and now hoped to recoup its R&D as well as its projected production losses. Since the existing contract covered only 343 engines, the Air Force solicited bids to manufacture the remaining 392 from Aerojet's design. A new contract, signed in October 1968, went to Thiokol.[80]

On 16 August 1968, a Minuteman III and a Poseidon C–3 launched successfully from Cape Kennedy, Florida. Each of the three reentry vehicles on board Minuteman hit its target. The first Minuteman III squadron reached operational status in December 1970. Carrying three Mark 12 170-kiloton warheads, compared to the 40-kiloton warheads on a Poseidon, Minuteman III was deemed capable of destroying or neutralizing hard targets. Thus, Poseidon and Minuteman III could be considered complementary rather than competitive. Designed to penetrate missile defenses, both had the capability to achieve assured destruction.

MISSILE DEFENSE MEETS INSUPERABLE OBSTACLES

While the Navy and Air Force concentrated on SLBMs and ICBMs, the Army looked to defense against ballistic missiles as a logical extension of its role in antiaircraft defense. The Army's surface-to-air missiles (SAMs) could destroy bombers, but how could they stop ballistic missiles traveling 24,000 feet per second at altitudes far above 100,000 feet? Bell Laboratories was the prime contractor for the Army's Nike-Ajax and improved Nike-Hercules SAMs deployed during the 1950s. In February 1955, the Army Ballistic Missile Agency awarded Bell Laboratories and Western Electric Company contracts to appraise air defense requirements for the 1960s, when intercontinental ballistic missiles would enter both the U.S. and Soviet arsenals.

Minuteman III test launch from Vandenberg Air Force Base, California (*National Museum of the U.S. Air Force*)

Experts likened missile defense to hitting a bullet with a bullet. Bell quickly identified the basic difficulties to be overcome: determining the best interception point; distinguishing warheads from decoys; and developing a long-range target acquisition radar able to process data at a high rate. In March 1956, after running 50,000 intercept simulations, Bell advised that these problems appeared solvable. Eleven months later, the Army selected Bell/Western Electric as the prime contractor for the Nike-Zeus ballistic missile defense system. By 1960, Bell supervised 24 major and 89 lesser subcontractors. Western Electric manufactured and tested Bell-designed R&D models of system elements. Carrying a nuclear warhead, the Zeus missile was to destroy an incoming warhead when it was about 100 miles above the Earth's surface. Douglas Aircraft designed and developed Zeus (less Bell's guidance unit), the launcher, and associated ground equipment. Goodyear Aircraft worked on the antenna structure for the target acquisition radar.[81]

At this time, the Air Force was studying a satellite-based interceptor system called Wizard. Fearing that it would become expensive and undercut Nike-Zeus, Secretary of Defense Neil McElroy assigned all ballistic missile defense work at the OSD level to the recently created Advanced Research Projects Agency. Supporters intended the new agency to serve as an honest broker in determining the agenda for scientific and technical programs of interest to more than one military service. ARPA's first director later cited reentry physics, which revealed the characteristics of reentry bodies as they came back into the atmosphere, as an example of why brokering was necessary:

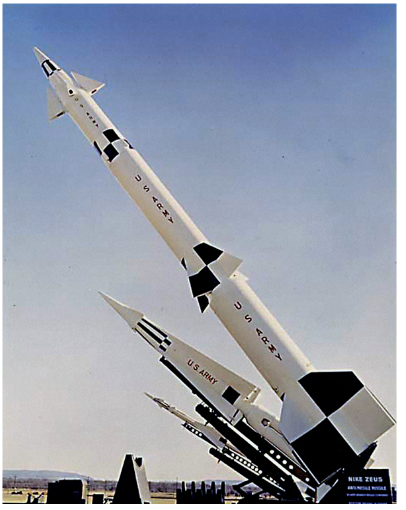
> [T]he Air Force is interested in re-entry physics because of the design of its decoys. . . . [T]he Army is interested in it for the opposite reason, trying to find out how one can discriminate against decoys. So the Army would design a program to try to find the weaknesses in re-entry vehicles and the Air Force would try to design a program to find the strengths . . . and both of them are clearly based on the same physics. It is therefore simpler for all concerned . . . to have one agency with no particular operational point of view in mind looking into that problem.

As ARPA saw matters, the Army wanted a system that could move into production while the Air Force "picked up the most exotic, most outlandish, most remote, most Buck Rogers programs." An example of the latter was Ballistic Missile Boost Intercept, in which a scanning satellite would detect missile launches. Separate tracking satellites would then relay flight data back to Earth, guiding Minuteman-like missiles to intercept the attackers over the North Pole. ARPA's criticisms would help end the project in 1963.[82]

Since Nike-Zeus appeared to be well ahead of Wizard, McElroy awarded primary responsibility for ballistic missile defense to the Army. The Army Ordnance Missile Command, established in March 1958 at Redstone Arsenal, Alabama, reported to the chief of ordnance. Its subordinate elements included the Army Ballistic Missile Agency and the new Army Rocket and Guided Missile Agency, which assumed responsibility for the Nike-Zeus project.[83]

During 1958, in collaboration with MIT's Lincoln Laboratory, ARPA launched Project Defender to explore unsolved problems in ballistic missile defense, seeking answers that might either improve Nike-Zeus or move it in a different direction. Engineers began by assuming that radar could detect and track incoming missiles. Soon, however, they recognized that more sophisticated warheads accompanied by even the crudest decoys would outstrip the most advanced radar's capabilities by several orders of magnitude.[84]

The radars for a Nike-Zeus system lacked the ability to discriminate between warheads and decoys because they could not measure enough details about the signatures of vehicles reentering the atmosphere. Experts in OSD and ARPA rated lack of knowledge about the physical and chemical phenomena involved in warhead reentry as a major obstacle. In response, ARPA initiated the Pacific Range Electromagnetic Signature Study. Lincoln Laboratory managed the effort, which became the core program of Project Defender. ARPA piggy-backed on Nike-Zeus tests, using the firings as target vehicles for its own purposes while providing feedback to the Army's development program. The Army was cool to the signature study because highlighting the difficulties in discriminating warheads from decoys made a case against moving Nike-Zeus forward. Those same difficulties convinced President Eisenhower to reject Army recommendations for taking the first steps toward deployment.[85]



Nike family of surface-to-air missiles (*top to bottom*): Nike-Zeus, Nike-Hercules, Nike-Ajax (*U.S. Army Aviation and Missile and Life Cycle Management Command*)

In November 1960, a full-scale Electronically Steerable Array Radar reached completion. The radar, inherited from the Air Force and completed under ARPA's supervision, marked a major advance. Steered electronically rather than mechanically, this phased-array radar could change its aim as fast as electricity could course through the computers and the radar itself. With such an agile beam, many targets could be observed almost simultaneously. Bell shifted to phased-array work, and Western Electric received the prime contract. Sylvania, as the major subcontractor, handled the detailed design of a phased-array prototype; Sperry Rand Univac took responsibility for developing a digital computer and radar programming. Advances in solid-state electronics promised reliable computers that could process the huge amounts of data needed to track large numbers of incoming vehicles.[86]

In autumn 1961, Secretary McNamara approved funding for limited production of Nike-Zeus, so that by 1967, 12 batteries would protect 6 cities. In July 1962, a Zeus missile fired from Kwajalein Atoll in the mid-Pacific was deemed to have intercepted an Atlas ICBM launched from California. But ARPA's work showed that the Nike-Zeus system still could not discriminate between warheads and decoys. Accordingly, McNamara deferred a deployment decision; in January 1963, he reoriented research to focus on a multilayered project labeled Nike-X.

Relying on phased-array radars, Zeus missiles would strike warheads and decoys at altitudes of 70 to 100 miles above the Earth's surface. Then, after atmospheric pressure had separated the surviving decoys, short-range high-acceleration Sprint missiles would hit the remaining warheads at altitudes of 20 to 30 miles. In March, Martin Marietta won a development contract for Sprint. In September 1964, Army Materiel Command awarded Western Electric what was then the largest single contract in Army history, $309.6 million, to fund all other elements of Nike-X research, development, and testing through September 1965.[87]

Sprint missile on transporter at White Sands Missile Range (*U.S. Army Space and Missile Defense Command, Historical Office*)

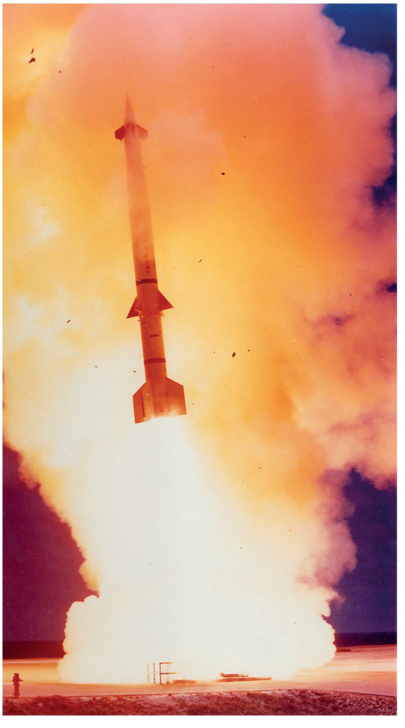
Radar work lagged because, among other problems, power requirements far outstripped what existing technology could provide. Also, rising costs forced the Nike-X project office to redefine system capabilities, changing from a very high to an ultra-high frequency that would reduce the effects from atmospheric nuclear blast. After extensive design modifications, the radar that emerged was much cheaper and still able to provide adequate tracking.[88]

Even so, Nike-X faced growing skepticism from the scientific community. In October 1964, Herbert York, formerly director of defense research and engineering, and Jerome B. Wiesner, formerly the president's special assistant for science and technology, publicly criticized Project Defender for keeping alive "the forlorn hope of developing an active antimissile defense." They delivered a "considered professional judgment that this dilemma has no technical solution."[89]

Concurrently, John Foster, the DDR&E, had broadened ARPA's charter to cover the physical properties of reentry vehicles. The scientists serving on ARPA's Ballistic Missile Defense Advisory Committee initiated "Pen-X," a detailed study of the penetration aids that would accompany offensive missiles. Completed in July 1965, the Pen-X study accentuated the advantages of offense over defense. Consequently, in setting R&D priorities, McNamara ranked development of penetration aids ahead of working on ballistic missile defenses.[90]

In October 1964, China's explosion of a nuclear device gave new life to Nike-X. Chinese missiles looked much easier to stop than Soviet systems. Early in 1965, the Army tasked Bell with preparing a defense against an unsophisticated attack, which was termed the "Nth country" threat. Countering such a threat lowered the cost of a multifunction array radar, conceived as the centerpiece of city defense. In July 1965, the Army requested $188 million in preproduction funding for Nike-X, aiming at an initial operational capability by 1970. Simultaneously, the secretary of the Army established a Nike-X system manager to exercise operational control over the project office and oversee all elements of R&D, testing, production, training, and deployment. One year later, the Army chief of staff identified Nike-X for exceptional management because of its scope and importance to national defense. He assigned Lt. Gen. Austin W. Betts, chief of R&D on the Army staff, the added duty of Nike-X system manager.[91]

Late in 1965, a panel of the President's Science Advisory Committee reviewed the Army-Bell proposal and recommended against deployment. Area defense against first-generation Chinese ICBMs with limited penetration aids could be quite effective, but decoys likely would appear soon and change the equation. Instead, the panel recommended, and McNamara approved, design of a simplified area defense system. The DDR&E tasked ARPA, the Air Force, and the Nike-X project with studying how to defend Minuteman silos. Bell's work for Nike-X focused on exploratory development that emphasized phased-array performance, the phenomena of atmosphere reentry, and late terminal intercepts. Bell contracted with General Electric to develop a perimeter acquisition radar to perform the initial target detection, discrimination, and tracking for long-range intercepts. In January 1966, Bell authorized McDonnell Douglas to start work on a modified Zeus missile that would



Launch of Spartan antiballistic missile, 3 April 1975 (*U.S. Army Space and Missile Defense Command, Historical Office*) complement the new radar. Soon named the Spartan, it was armed with a nuclear warhead whose blast and X-rays would knock out incoming enemy warheads, boosters, and decoys well above the atmosphere.[92]

At the time, ARPA was supervising the development of the High-G Boost Experiment (HIBEX), an experimental missile that would intercept maneuvering reentry vehicles. HIBEX advanced rapidly into testing because ARPA focused exclusively on the technical problems relating to performance and maneuverability. Sprint and Spartan made slower progress and incurred higher costs because they were "weaponized"—that is, designed from the start to incorporate warheads, avoid operator error, and stay in silos for long periods without experiencing particulate contamination or suffering mechanical failure.[93]

Late in 1966, the JCS recommended deploying Nike-X to provide a "light" area defense of the continental United States and a "local" defense of 25 cities. Congress appropriated $168 million for preproduction funding. McNamara, however, advised the president that he saw no point in trying to defend cities against a Soviet attack:

> It is the virtual certainty that the Soviets will act to maintain their deterrent which casts such grave doubt on the advisability of our deploying the Nike-X system. . . . In all probability, all we would accomplish would be to increase greatly both their defensive expenditures and ours without any gain in real security to either side.

The Soviets were building ballistic missile defenses around Moscow, but U.S. intelligence rated that system as highly vulnerable to a well-planned, large-scale attack. Therefore, McNamara supported only a "light" deployment, mainly to protect cities against Chinese missiles and Minuteman fields against a Soviet strike.[94]

In December 1966, McNamara met with executives of the firms involved in developing Nike-X. Without qualification, he told President Johnson, they opposed building defenses against a heavy Soviet attack but fully supported his "thin" system. On 4 January 1967, the president reviewed courses of action with senior officials and prominent scientists. York spoke for the science advisers: do nothing now, except continue a vigorous R&D effort. McNamara did not solicit an opinion from Foster, the DDR&E, who believed ballistic missile defense to be feasible. The science advisers evidently interpreted Foster's silence as agreement with them.[95]

In December 1966, OSD, Army Materiel Command, and the Nike-X project office had directed Bell and Western Electric to prepare a model for "thin" deployment. For this designated "Plan I–67 Area/Hardsite Defense," McNamara and Foster specified that investment costs not exceed $5 billion and initial operational capability occur within 54 months of a decision to deploy. Reporting on 5 July 1967, Bell outlined a Nike-X system containing 6 perimeter acquisition radars, 17 missile site radars, 480 long-range Spartans, and 455 short-range Sprints, of which 355 would defend Minuteman sites.[96]

Meantime, McNamara's rationale for delaying a deployment decision eroded. China tested a thermonuclear device in June 1967, and the Soviets rejected an offer to start talks about restricting defensive systems. On 5 July, after receiving Bell's report, McNamara ordered a 30-day study of the evolving Chinese threat and I–67's ability to cope with it. The study found that I–67 constituted an adequate basis for proceeding. Accordingly, on 18 September 1967, McNamara publicly announced the administration's decision to deploy a "light" system capable of defending urban/industrial areas and Minuteman fields against Chinese missiles. By going this far, McNamara hoped to forestall a "heavy" anti-Soviet deployment. What, he asked, was the point of spending $40 billion for defenses that could be penetrated by $5 billion to $10 billion worth of MIRVs, decoys, and penetration aids?[97]

The light Nike-X, promptly renamed Sentinel, received the Army's highest priority. Lt. Gen. Alfred D. Starbird took the post of Sentinel system manager, working within the Office of the Chief of Staff. Starbird headed an organization consisting of the Sentinel System Office in Washington, DC, a new Sentinel System Command in Huntsville, Alabama, and a System Evaluation Agency at the White Sands Missile Range, New Mexico. The Advanced Ballistic Missile Defense Agency, collocated and coordinated with the command in Huntsville and Washington, continued R&D work.[98]

In March 1968, at Foster's initiative, Project Defender transferred from ARPA to the Army. The time looked right for shifting advanced research into the Army program, so ARPA's separate role no longer appeared necessary. Also, Foster believed that the Army had not put enough talented people into Sentinel; adding experts from Project Defender could remedy that shortcoming.[99]

The Army had won a foothold, but once again it led nowhere. Early in 1969, Sentinel, renamed Safeguard, was limited to protecting 12 Minuteman fields. Congressional support for ballistic missile defense dwindled, however, and U.S.-Soviet strategic arms limitation talks ended in agreement. The 1972 Anti-Ballistic Missile Treaty allowed each country to have one site shielding its capital and one protecting a missile field. Although a Safeguard complex defending 150 Minuteman ICBMs in North Dakota became operational in 1975, the program reached a dead end.[100]

Bell claimed to have dealt satisfactorily with every technical problem put before it.[101] While narrowly correct, Bell's claim was misleading. According to Major General Ritland, who had served a tour as Minuteman's program director, the antimissile launching system was quite simple, but the integration of detection, identification, tracking, launch, interception, and detonation of a nuclear warhead to kill an incoming nuclear warhead was well-nigh impossible. Even under preplanned conditions—"knowing where to look for it and what time it's going to arrive"—interception was difficult enough. Taking account of electronic deficiencies or failures in the checkout system of the phased-array radar, Ritland concluded that 24-hour readiness year after year was beyond reach.[102]

* * * * *

The technical reasons why a particular system faltered or went forward are relatively straightforward. Whether those results came about because one service provided better or worse management than another is less clear. The main difference between Navy and Air Force programs was that the Navy had nothing equivalent to TRW. Instead, the Special Projects Office provided systems engineering and technical direction over the life cycles of Polaris and Poseidon. Rear Adm. Levering Smith stands out as an astute manager who made choices that fulfilled strategic objectives while avoiding technological overreach. Poseidon enjoyed unique survivability as well as penetration and some counterforce capability, complementing rather than directly competing with Minuteman III. From the Navy's perspective, SPO interacted directly with contractors, while the Air Force's Ballistic Systems Division and then its Space and Missile Systems Organization were several levels removed from the contract firms.[103]

For Minuteman, the Air Force remained satisfied with the organizational arrangements created during 1960–1961, many of which traced to Schriever's Western Development Division. TRW's Space Technology Laboratories and later the autonomous Aerospace Corporation oversaw systems engineering and provided technical direction. STL and Aerospace, though, had only recommending authority. Air Force officers in the Ballistic Missile Division and its successors possessed decisionmaking or line authority.[104] Difficulties with Minuteman II's guidance system could be traced to a variety of failures by Autonetics and lax oversight by the Air Force. Solutions to these difficulties included assigning better managers and engineers as well as exercising tighter control at every level.

The Army stood alone in using private firms—Bell Laboratories and Western Electric—as prime contractors. OSD added the Advanced Research Projects Agency, which enlisted Lincoln Laboratory. The Army Rocket and Guided Missile Agency at first, and then, starting in 1962, the Army Missile Command, exercised oversight of missile programs for the Army. In 1965, the chief of R&D on the Army staff assumed the added duty of Nike-X system manager. Two years later, the Army created the Sentinel System Command and appointed a three-star officer as system manager in the Office of the Chief of Staff. These changes reflected the Army's mounting frustration. ARPA could detect where the blind alleys were but not where the clear path lay. John Foster worried that the Army had insufficient expertise, yet the problem had become insurmountable. By adding MIRVs to the offensive arsenal, Poseidon and Minuteman III made ballistic missile defense more difficult in 1968 than it was 10 years earlier.

Endnotes

1. Robert A. Fuhrman, "Fleet Ballistic Missile System: Polaris to Trident," lecture,

February 1978, 4; copy provided to the author by Dennis H. Trosch. See also the related published article, Robert A. Fuhrman, "The Fleet Ballistic Missile System: Polaris to Trident," *Journal of Spacecraft* 5, no. 5 (September-October 1978): 265–286. Spinardi, *From Polaris to Trident*, 36–37, 58, 63–64. The A–1's range reduction resulted from sacrificing a bit of performance to stay on schedule. A propellant able to reach 1,500 miles, the range initially called for by the chief of naval operations in 1957, required a very high specific impulse, which meant that nozzles had to withstand high temperatures. The nozzle solution was a ring or "jetevator" that deflected the jet stream enough to provide some directional control. When the Navy advanced initial operational capability from 1963 to 1960, meeting that deadline required using a propellant of somewhat lower specific impulse and therefore of shorter range. Brig. Gen. Austin W. Betts, USA, "Research and Development in the Armed Forces," lecture to the Industrial College of the Armed Forces, Fort Lesley J. McNair, Washington, DC, 19 Dec 58, 14–15, NDU Library.

2. Starting in 1963, after Raborn departed, the director reported to the chief of naval material.

3. Sapolsky, *The Polaris System Development*, 200, 88 fn 47, 90; Fuhrman, "Fleet Ballistic Missile System," 2–3; interview, Vice Adm. Levering Smith, USN (Ret.), by Leroy Doig and Elizabeth Babcock, 15 Jun 89, 50, Oral History Collection, Naval Historical Center; email, Rear Adm. Robert H. Wertheim, USN (Ret.), to W.S. Poole, 18 Apr 06.

4. Gary E. Weir, *Forged in War* (Washington, DC: Naval Historical Center, 1993), 249; Sapolsky, *Polaris System Development*, 73, 206, 219; email, Robert A. Frosch to W.S. Poole, 14 Mar 07.

5. Smith interview, 50–51; email, Frosch to Poole, 14 Mar 07.

6. Email, Fox to Poole, 16 Sep 05, 17 Sep 06; Sapolsky, *Polaris System Development*, 116–117; Weir, *Forged in War*, 250.

7. Email, Fox to Poole, 16 Sep 05, 17 Sep 06, 3; Sapolsky, *Polaris System Development*, 116–117; Weir, *Forged in War*, 250. Later, an SPO official joked that PERT stood for "Progressive Erosion of Rational Thought." Less expensive and less complicated "Line of Balance" (LOB) reports gave schedule durations rather than the times themselves. SPO kept using PERT to track overall program planning, but some subsystem managers introduced LOB. However, PERT was designed to manage developmental, nonrepetitive tasks; LOB was a technique for controlling repetitive production tasks. Susan Scott, "Planning and Control in Project Management: The Navy's Strategic Systems Project Office," unpublished paper, American University, fall 1979, copy provided by Rear Admiral Wertheim. Email, Wertheim to Poole, 13 May 06; email, Fox to Poole, 17 Sep 06, 3.

8. Sapolsky, *Polaris System Development*, 95.

9. Ibid., 106, 120–122, 246; memo of telcon, W.S. Poole with Rear Admiral Wertheim, 18 Apr 06; email, Frosch to Poole, 14 Mar 07.

10. Sapolsky, *Polaris System Development*, 177, 131–132, 150, 158–159. By avoiding competitive bidding and fly-before-buy, SPO established close working relationships with contractors and claimed to have saved much money. Memo, Poole-Wertheim telcon, 18 Apr 06. This remains a debatable issue. While sole-sourcing allows program managers to keep working with proven performers, introducing competition often has resulted in major price reductions. Email, Fox to Poole, 17 Sep 06, 4.

11. Email, Wertheim to Poole, 13 Apr 06.

12. Sapolsky, *Polaris System Development*, 179; email, Fox to Poole, 17 Sep 06. New obligational authority for the Polaris program rose from $1.009 billion in FY 1960 to $1.978 billion in FY 1962 and $1.764 billion in FY 1963, the peak years of submarine construction, then fell to $1.291 billion in FY 1964 and $564 million in FY 1965. Sapolsky, *Polaris System Development*, 169.

13. Email, J. Ronald Fox to Walter S. Poole, 23 and 28 Mar 05.

14. Interview, Dennis H. Trosch by Walter S. Poole, 5 Apr 05, McLean, VA, 4, 7, 8, 9.

From 1962 until 1974, Trosch was a lawyer in the Office of Counsel for the SPO. Email, Fox to Poole, 17 Sep 06.

15. Fox, *Arming America*, 403–413 ("rubber baseline" quotation, 413). A good many of those involved in the Polaris program, both in government and the private sector, resisted the introduction of cost control. They considered their performance vis-à-vis annual funding to be the only relevant financial measure and viewed cost control as imposing an entirely new standard of performance. Email, Fox to Poole, 17 Sep 06, 1–2.

16. Spinardi, *From Polaris to Trident*, 76–79, 63–65; *FRUS 1961–1963*, vol. 8, 138–140; Fuhrman, "Fleet Ballistic Missile Systems," 16.

17. Spinardi, *From Polaris to Trident*, 76–79, 63–65; *FRUS 1961–1963*, vol. 8, 138–140; Fuhrman, "Fleet Ballistic Missile Systems," 16.

18. An A–1 traveling 1,200 NM could reach a great many targets if launched within 100 miles of the Norwegian coast. Intelligence considered that an acceptable risk through 1962–1963 but believed that Soviet ASW capabilities would improve so much by 1964–1965 that missile range would have to be 2,500 NM. Harvard Business School Weapons Acquisition Project, *A Case Study of Polaris*, V–12a; copy provided by Frederic M. Scherer.

19. When U.S. testing resumed in 1962, a Polaris missile carrying a nuclear warhead was launched over water. A treaty banning atmospheric, outer space and underwater testing took effect in October 1963.

20. Spinardi, *From Polaris to Trident*, 66–67, 72; Fuhrman, "Fleet Ballistic Missile Systems," 17–18.

21. Spinardi, *From Polaris to Trident*, 72, 66; email, Wertheim to Poole, 13 Apr 06.

22. Spinardi, *From Polaris to Trident*, 88–89; MacKenzie, *Inventing Accuracy*, 263.

23. Spinardi, *From Polaris to Trident*, 92, 74–76. Transit's limitation stemmed from the small number of satellites being used, so that only a few position determinations could be made each day. Later, using more satellites, the Global Positioning System was able to provide accurate fixes anywhere on Earth.

24. Ibid., 91–94; MacKenzie, *Inventing Accuracy*, 283.

25. Spinardi, *From Polaris to Trident*, 95–100; MacKenzie, *Inventing Accuracy*, 223–224, 268–270. In the 1980s, though, stellar-inertial guidance was incorporated quite successfully into the Trident missile system.

26. Levering Smith interview, 48. Usually, a C–3 carried no more than ten RVs. With Poseidon's very large number of hardened reentry bodies and the flexibility of spacing them to meet changes in defensive systems, there was no need for decoys. The "Antelope" penetration aid for A–3 was cancelled, but the British, who had bought Polaris missiles (less warheads), developed a "Chevaline" similar to "Antelope" and chose not to buy Poseidons. Both "Antelope" and "Chevaline" were rated as effective against Galosh. Email, Wertheim to Poole, 13 Apr 06.

27. Spinardi, *From Polaris to Trident*, 110–112.

28. Sapolsky, *Polaris System Development*, 97.

29. Strategic Systems Project Office, *FBM Facts* (Washington, DC: Navy Department, 1982), 31. On 29 July 1968, the SPO's name changed to Strategic Systems Project Office.

30. Sapolsky, *Polaris System Development*, 206–212 (quoted words, 209); Spinardi, *From Polaris to Trident*, 105.

31. Fuhrman, "Fleet Ballistic Missile Systems," 20.

32. Each of the first five submarines was 380 feet in length and displaced 6,700 tons. Each of the next five was 410 feet in length and displaced 7,900 tons. Each of the 31 due for conversion was 426 feet in length and displaced 8,250 tons. Ibid., 10.

33. Ted Greenwood, *Making the MIRV* (Cambridge, MA: Ballinger Publishing Co., 1975), 122; *FBM Facts*, 32, 35.

34. Nalty, *USAF Ballistic Missile Programs 1962–1964,* 7, 23–24; Neufeld, *Development of the Ballistic Missiles in the United States Air Force, 1945–1960*, 237.

35. Neil Sheehan, *A Fiery Peace in a Cold War: Bernard Schriever and the Ultimate*

Weapon (New York: Random House, 2009), 201–210, 234–235; Davis Dyer, *TRW: Pioneering Technology and Innovation since 1900* (Boston: Harvard Business School Press, 1998), 179–184, 189–190, 199–201.

36. Sheehan, *A Fiery Peace*, 201–210, 234–235; Dyer, *TRW*, 179–184, 189–190, 199–201. Under the 1955 contract, Ramo-Wooldridge's duties included research studies and experimental investigations, maintenance of a development plan, preparation of systems specifications, technical direction of associated contractors, direction of the flight test program, investigation of alternative approaches, and general technical support to the Western Development Division. Ramo-Wooldridge agreed not to develop or manufacture any equipment for those programs. As a further shield against gaining unfair competitive advantage, the company created a Guided Missile Research Division that was segregated from other operating divisions. Partly in compensation, Ramo-Wooldridge received a fixed fee of 14.2 percent, which was about twice the customary level for R&D contracts. Dyer, *TRW*, 183–184.

37. Robert F. Piper, *The Development of the SM–80 Minuteman* (Washington, DC: Historical Office, Deputy Commander for Aerospace Systems, Air Force Systems Command, 1962), 7–8, 14–15.

38. Ibid., 17–20.

39. The Ballistic Missiles Committee membership consisted of the secretary of the Air Force, three assistant secretaries, and an assistant chief of staff.

40. Ibid., 33.

41. Ibid., 30; Dyer, *TRW*, 210.

42. Piper, *Minuteman*, 34–35.

43. Ibid., 35–38 (quotation, 37); Dyer, *TRW*, 210.

44. Dyer, *TRW*, 210. In 1959, Glasser was succeeded by Col. Samuel C. Phillips. Hall retired as a colonel and worked for United Aircraft Corporation. Glasser reached three-star and Phillips four-star rank. Hall saw his concept of a simple, reliable, survivable, and affordable ICBM deployed in large numbers (4,000 proposed at one point) being compromised. Administration pessimism about solid-propellant development, reflected in spending restrictions, and proposals to harden the silos and launch control centers threatened his vision of Minuteman. See chap IV in David N. Spires, *On Alert: An Operational History of the United States Air Force Intercontinental Ballistic Missile Program, 1945–2011* (Colorado Springs, CO: Air Force Space Command, 2012).

45. Piper, *Minuteman*, xvi, xvii, 53, 57, 78, 90, 75.

46. Dyer, *TRW*, 230–232.

47. Sapolsky, *Polaris System Development*, 84–85; *History of Air Force Systems Command: 1 July–31 December 1961*, vol. II, 51, 52, 55, microfilm roll 2848, AFHSO.

48. A 50-missile squadron could launch either in salvo, all leaving their silos practically simultaneously, or by a ripple launch, with a preset interval between missiles. The problem in a ripple launch was how to interrupt, if necessary, after the launch command had been transmitted to the silos. John H. Rubel, *Doomsday Delayed* (New York: Hamilton Books, 2008), 9–16.

49. "Abstract of Minuteman History," September 1967, fldr 3, box 12, Phillips Papers, LC.

50. Piper, *Minuteman*, 52–53, 56, 62.

51. Nalty, *USAF Ballistic Missile Programs 1962–1964*, 30–31.

52. Email, Fox to Poole, 14 Sep 06; Maj. Charles Eger, "Minuteman Financial History, 1955–1963," chap VI, fldr 1, box 11, Phillips Papers, LC.

53. "Abstract of Minuteman History," Phillips Papers, LC.

54. Fox, *Arming America*, 405–406. In April 1969, the program director assured congressmen that for FY 1968 and as of the close of FY 1969, the Minuteman program would have expended exactly the amount appropriated while achieving all its developmental and acquisition goals. House, Cte on Govt Ops, *Government Contracting and Procurement*, 91 Cong, 1 sess, pt 4, 1248. The extent to which this rosy picture represented funds control in the guise of

cost control is impossible to discern.

55. MacKenzie, *Inventing Accuracy*, 155–157. A gyroscope provided guidance by virtue of its inertia. By changing orientation in a predictable way, it signaled to the computer when a missile was deviating from its predetermined course. J.D. Hunley, "Minuteman and the Development of Solid Rocket Launch Technology," in Roger D. Launius and Dennis R. Jenkins, eds., *To Reach the High Frontier: A History of U.S. Launch Vehicles* (Lexington: University of Kentucky Press, 2002), 252 fn 52.

56. Interview, Dr. Alexander H. Flax by J.C. Hasdorff and Jacob Neufeld, 27–29 Nov 73, 137, microfilm 00904822-00904827, roll no. 24667, AFHSO. Piper, *Minuteman*, 183; MacKenzie, *Inventing Accuracy*, 159–160.

57. Piper, *Minuteman*, 61, 184–186.

58. Ibid., 186–187; Michael Rich and Edmund Dews with C.L. Batten, Jr., *Improving the Military Acquisition Process*, RAND Report R–3373–AF/RC (Santa Monica, CA: RAND, February 1986), 38; MacKenzie, *Inventing Accuracy*, 159–161.

59. MacKenzie, *Inventing Accuracy*, 204–207; Fitzgerald, *High Priests of Waste*, 111–112.

60. Project Forecast is described in chapter VI.

61. MacKenzie, *Inventing Accuracy*, 207.

62. Quoted in Fitzgerald, *High Priests of Waste*, 116–117.

63. Ibid., 126–127. Concurrently, as chapter IV relates, Autonetics reported a large overrun on its Mark II avionics system.

64. Bernard C. Nalty, *USAF Ballistic Missile Programs 1967–1968* (Washington, DC: USAF Historical Division Liaison Office, September 1969), 15–16.

65. *History of Air Force Systems Command: Fiscal Year 1968*, vol. I, 27, 29. The reason for consolidating these divisions was that most missile sites had been activated, while space systems were pared below what Air Force officers had envisioned. David N. Spires, *Beyond Horizons: A Half-Century of Air Force Space Leadership* (Maxwell AFB, AL: Air Force Space Command in association with Air University Press, 1998), 135.

66. The guidance fracas derailed careers, with two major generals being relieved in six months. Oral history interview, Lt. Gen. Kenneth W. Schultz, USAF (Ret.), by Lt. Col. Maurice Maryanow, 27–31 Oct 86, 127, K239.0512–1728, AFHSO; MacKenzie, *Inventing Accuracy*, 223; Fitzgerald, *High Priests of Waste*, 129–130.

67. Schultz interview, 129–132. Systems engineering and technical direction of Minuteman, which had been split between Space Technology Laboratories and the Aerospace Corporation, was given completely to STL in November 1967. Aerospace handled the reentry system and all space work. Ibid., 175, 177, 214–217.

68. *History of Air Force Systems Command: Fiscal Year 1968*, vol. I, atchmt 1, "Management of Major Systems," microfilm K 243.01, AFHSO; Nalty, *USAF Ballistic Missile Programs 1967–1968*, 16, 15.

69. MacKenzie, *Inventing Accuracy*, 206–211.

70. This is the recurring theme of his *High Priests of Waste*.

71. Flax interview, 206.

72. Nalty, *USAF Ballistic Missile Programs 1967–1968*, 2.

73. Greenwood, *Making the MIRV*, 163, 21.

74. Bernard C. Nalty, *USAF Ballistic Missile Programs 1964–1966* (Washington, DC: USAF Historical Division Liaison Office, March 1967), 34–35. In fact, Minuteman III, with a CEP of 0.12, turned out to be more accurate than Minuteman II with its 0.26 CEP. See MacKenzie, *Inventing Accuracy*, 167.

75. Nalty, *USAF Ballistic Missile Programs 1967–1968*, 53.

76. Greenwood, *Making the MIRV*, 29–30.

77. Ibid., 40, 6, 8, 10, 20; Nalty, *USAF Ballistic Missile Programs 1964–1966*, 44, and *USAF Ballistic Missile Programs 1967–1968*, 47.

78. Greenwood, 40, 6, 8, 10, 20; Nalty, *USAF Ballistic Missile Programs 1964–1966*, 44,

and *USAF Ballistic Missile Programs 1967–1968*, 47.

79. Nalty, *USAF Ballistic Missile Programs 1967–1968*, 8–9.

80. Ibid., 9–12, 54.

81. James Walker, Lewis Bernstein, and Sharon Lang, *Seize the High Ground: The U.S. Army in Space and Missile Defense* (Washington, DC: Historical Office, U.S. Army Space and Missile Defense Command, 2003), 25; *ABM Research and Development at Bell Laboratories: Project History*, pt. I, October 1975, 5, 11, 15, 33, 34. Bell's main facility was located in Whippany, New Jersey. Donald R. Baucom, *The Origins of SDI* (Lawrence: University Press of Kansas, 1992), 7. For acquisition of the Nike-Ajax, see Converse, *Rearming for the Cold War,* chap XI.

82. Baucom, *Origins of SDI*, 11, 16; Richard C. Barber and Associates, *The Advanced Research Projects Agency, 1958–1975*, chap III, 49–50, chap V, 19, 23 (quotation, chap VIII, 75–76). Fred Koether of the Defense Advanced Research Projects Agency made a copy available to the author. DoD Directive 5105.15, 7 February 1958, establishing ARPA is printed in ibid., fig. II–2, after chap II, 18. In 1959, ARPA was brought under the supervision of the new director of defense research and engineering.

83. In December 1961, both the Army Rocket and Guided Missile Agency and the Army Ballistic Missile Agency were abolished and their functions merged with Army Ordnance Missile Command. In August 1962, AOMC became Missile Command, which reported to the new Army Materiel Command.

84. Barber, *ARPA*, chap III, 54, 56. Project Defender's budget ran about $100 million to $125 million annually.

85. Ibid., chap IV, 22, 24, 25, chap V, 21.

86. Ibid., 26; Bell, *ABM Project History*, pt. I, 33; Barry Bruce-Briggs, *The Shield of Faith: A Chronicle of Strategic Defense from Zeppelins to Star Wars* (New York: Simon & Schuster, 1988), 228.

87. *FRUS 1961–1963*, vol. 8, 154, 164, 392–395, 416; Baucom, *Origins of SDI*, 17, 19; Bell, *ABM Project History*, pt. I, 36–37; Walker, Bernstein, and Lang, *Seize the High Ground*, 56.

88. James A. Walker, Frances Martin, and Sharon S. Watkins, *Strategic Defense: Four Decades of Progress* (Washington, DC: Historical Office, U.S. Army Space and Strategic Defense Command, 1995), 26.

89. Baucom, *Origins of SDI*, 22.

90. Barber, *ARPA*, chap V, 23, 24, chap VI, 15; Baucom, *Origins of SDI*, 22–24.

91. In August 1962, Brig. Gen. Ivey O. Drewry, USA, was appointed to head the Nike-Zeus project office; he continued in that role for Nike-X. Originally placed under Missile Command (successor to the Army Ordnance Missile Command), his office and personnel were transferred to Headquarters, Army Materiel Command in February 1963. Bell, *ABM Project History*, pt. I, 41, 37; *FRUS 1964–1968*, vol. 10, 322; Walker, Bernstein, and Lang, *Seize the High Ground*, 49, B–12, 13.

92. *FRUS 1964–1968*, vol. 10, 273–274, 282; Bell, *ABM Project History*, pt. I, I-43–44, pt. II, 8–1.

93. *FRUS 1964–1968*, vol. 10, 284, 303–308, 318–319; Bell, *ABM Project History*, pt. I, 43–44; Baucom, *Origins of SDI*, 92; Barber, *ARPA*, chap VII, 11–14.

94. *FRUS 1964–1968*, vol. 10, 402–403, 480, 483–484, 503, 508, 526–532 (quoted paragraph, 503); Baucom, *Origins of SDI*, 32.

95. *FRUS 1964–1968*, vol. 10, 402–403, 480, 483–484, 503, 508, 526–532.

96. Bell, *ABM Project History*, pt. I, 44–45; Walker, Bernstein, and Lang, *Seize the High Ground*, 53–54; Baucom, *Origins of SDI*, 35–37.

97. Bell, *ABM Project History*, pt. I, 44–45; Walker, Bernstein, and Lang, *Seize the High Ground*, 53–54; Baucom, *Origins of SDI*, 35–37.

98. Walker, Bernstein, and Lang, *Seize the High Ground*, 54, B–14. Previously, Starbird headed a task force charged with creating an anti-infiltration barrier in Southeast Asia.

99. Barber, *ARPA*, chap VII, 38, chap VIII, 29, 30.

100. Nicholas Wade, "Safeguard: Disputed Weapon Nears Readiness on Plains of North Dakota," *Science* 185, no. 4157 (27 September 1974): 1137–1140; Alexander Flax, "Ballistic Missile Defense: Concepts and History," *Daedalus* 114, no. 2 (Spring 1985): 33–52, esp. 36–37.

101. This is the gist of Bell's *ABM Project History*.

102. Ritland interview, 242.

103. The last sentence derived from email, Frosch to Poole, 14 Mar 07.

104. Ritland interview, 261–262.

I. Official biography, Rear Admiral Levering Smith, 26 May 1972, box 758, Officer Bios File, Naval Historical Center; Willis M. Hawkins et al., "Levering Smith," *Memorial Tributes: National Academy of Engineering*, vol. 7 (Washington, DC: National Academy Press, 1994), 218, available at <http://www.nap.edu/openbook/0309051460/html/215.html> (accessed 16 June 2012); Levering Smith Award, Naval Submarine League Web site, <http://www.navalsubleague.com/NSL/award.aspx?pagelet_name=award_levering&award. nnn> (accessed 4 April 2012).

II. Stephen B. Johnson, *The United States Air Force and the Culture of Innovation* (Washington, DC: Air Force History and Museum Programs, 2002), 92, 98; J.D. Hunley, *The Development of Propulsion Technology for U.S. Space-Launch Vehicles, 1926–1991* (College Station: Texas A&M University Press, 2007), 42, 246–247; Neil Sheehan, *A Fiery Peace in the Cold War: Bernard Schriever and the Ultimate Weapon* (New York: Random House, 2009), 235–249, 261, 316, 333, 352, 356–357, 409–417; J.D. Hunley, "The History of Solid-Propellant Rocketry: What We Do and Do Not Know," American Institute of Aeronautics and Astronautics, 1999; "Colonel Edward Hall Induction Biography," available at <http://www.afspc.af.mil/shared/media/document/AFD-100405-065.pdf> (accessed 1 June 2012); Thomas H. Maugh II, "Edward Hall, 91, A Giant of Missile Defense Program," *Los Angeles Times*, 21 January 2006; "Edward N. Hall," *Gale Biography and Context* (Detroit: Gale, 2006); "Edward Hall Developer of Missile Program Dies at 91," *New York Times*, 18 January 2006.

III. Davis Dyer, *TRW: Pioneering Technology and Innovation Since 1900* (Boston: Harvard University Business School Press, 1998).

CHAPTER IX

Warships and Their Weapons

According to leading naval scholar Nicholas A.M. Rodger, the most important lessons to be drawn from studying warships and their weapons are that "the only useful measure of quality is fitness for purpose" and that the strategic judgment about what functions a navy should fulfill is more important than the technical skill of the designer.[1] During the 1960s, U.S. Navy planners and designers often found "fitness for purpose" hard to define and evaluate. Much of their difficulty stemmed from changes in the threat that necessitated changes in purpose. Soviet naval strategy was switching from an antishipping campaign (such as that carried out by German U-boats during World War II) to sending cruise missile submarines and then ballistic missile submarines into the North Atlantic and directing attack submarines to destroy U.S. aircraft carriers and Polaris submarines.[2] American strategy involved deploying nuclear attack submarines in barriers, particularly along the Greenland–Iceland–United Kingdom gap, to kill Soviet submarines as they moved into the North Atlantic or returned to base for replenishment. Attack submarines' fitness for that purpose depended on their speed, operating depth, and "quietness" in avoiding detection, factors that changed in relative importance as new classes of Soviet submarines appeared. The shift in balance from convoy escort to protecting aircraft carriers affected the requirements for surface combatants.[3]As the range of threats facing carrier task forces broadened to include missiles fired from surface ships and long-range aircraft, new classes of surface combatants required antiair as much as antisubmarine warfare capability. Yet throughout the 1960s, the Navy's ability to protect against aircraft and missiles remained less than desired.

FROM BUREAUS TO SYSTEMS COMMANDS

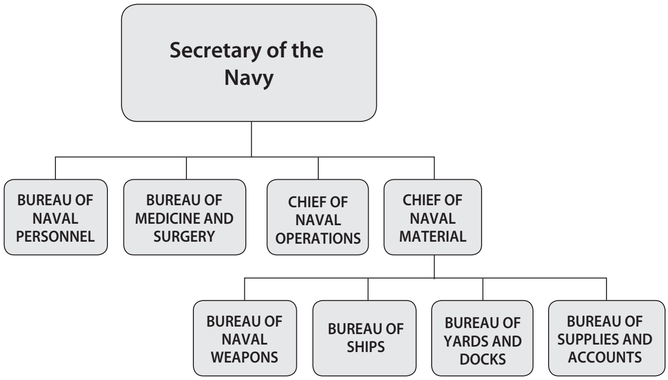
In the mid-1950s, the Navy filled its material requirements through organizations that followed "bilinear" tracks, one through the CNO, and the other through the secretary of the Navy. The CNO controlled the "consumer logistics" track, forecasting needs of the fleet and evaluating progress toward meeting them. Responsibility for the other, the "producer logistics" track—research, development, procurement, production, supply, maintenance, distribution of materials, and facilities—was spread among seven bureaus: Aeronautics, Medicine and Surgery, Ordnance, Personnel, Ships, Supplies and Accounts, and Yards and Docks. The bureau chiefs, all of whom "enjoyed virtual autonomy in technical and business management matters," reported directly to the secretary of the Navy.[4] With respect to the acquisition of major weapon systems, Aeronautics, Ordnance, and Ships were the most important bureaus.

The Bureau of Ships dated from 1939, when the Navy combined the Bureau of Engineering and the Bureau of Construction and Repair. For the next two decades, the acquisition process began when the Ship Characteristics Board, working in the Office of the CNO (OPNAV), determined the purpose and capabilities desired in a new ship class. After the Bureau of Ships worked up concept and preliminary designs, a naval architectural firm would be selected to complete the contract design. Next, after circulating complete sets of plans and specifications to shipbuilders, the bureau often would fund three contractors for six months to prepare comprehensive proposals. Finally, a source selection board would evaluate competing proposals and recommend a winner.[5]

The Department of Defense Reorganization Act of 1958 prompted two changes that impinged on the bureau chiefs' autonomy. First, the Navy established the position of assistant secretary of the Navy for R&D and granted it general management responsibility and approving authority over the Navy's RDT&E budget—an authority unique among assistant secretaries in the Defense Department. Second, a vice admiral designated deputy CNO (development) gained authority to coordinate and integrate the Navy's RDT&E program. Another change created a potentially more powerful bureau. Aeronautics and Ordnance merged into the new Bureau of Naval Weapons, controlling about two-thirds of the Navy's development programs. The merger reflected advances in technology that had blurred the line between Aeronautics and Ordnance, concerning responsibility for development of both air-to-air and ship-launched surface-to-air missiles.[6]

In 1962, a board headed by John C. Dillon, administrative assistant to the secretary of the Navy, criticized the practice of designating a "lead" bureau to assume responsibility for technical execution of projects involving more than one bureau. The board recommended creating a chief of naval support who would have authority over the bureau chiefs, serving as an intermediary between the chiefs and the secretary of the Navy. The secretary of the Navy decided, instead, to work through the chief of naval material, a position created in 1948, giving that office authority over the new Naval Material Support Establishment as well as the four material bureaus: Naval Weapons, Ships, Supplies and Accounts, and Yards and Docks (see figure 9–1).[7]

Figure 9-1: NAVY ORGANIZATION, 1963



Source: Stuart J. Evans, Harold J. Margulis, and Harry B. Yoshpe, *Procurement* (Washington, DC: Industrial College of the Armed Forces, 1968), 47.

A longstanding concern about fragmentation of Navy research and development also drove change. Late in 1961, OSD created six categories for R&D projects: research having no clear military application; exploratory development directed toward the solution of specific military problems; advanced development, moving projects into experimental or operational testing; engineering development; management and support; and operational systems development.[8] The Dillon Board concluded that funds appropriated for exploratory development often were diverted to systems that had advanced beyond that stage. Worried that R&D might focus on short-term payoffs, the board wanted to protect funding for exploratory development. While the bureaus controlled new starts in exploratory development, OPNAV had to approve moving them into advanced development. In 1964, the deputy chief of naval material was dual-hatted as chief of naval development (roughly paralleling the post of deputy CNO for development in OPNAV in the "consumer logistics" track) and gained responsibility for coordinating exploratory development programs but did not acquire control over the transition from exploratory to advanced development.

On 1 July 1965, DoD Directive 3200.9 injected into R&D management "concept formulation," defined as the opening phase of the acquisition cycle, including "comprehensive system studies and experimental hardware efforts under Exploratory and Advanced Development." This meant that preliminary design and trade-off studies for new ships came under the RDT&E program.[9] Yet Robert Frosch, assistant secretary of the Navy (R&D) during 1966–1967, recalled that he found it impossible to set clear boundaries for each of the six categories OSD created. What Frosch called "polite bureaucratic bickering" occurred daily, particularly over budget decisions in the first three categories. Sometimes it was convenient to place funds in the wrong category if doing so would advance the whole program.[10]

After changes prompted by the Dillon Board were put in place, the vice CNO predicted that the chief of naval material would either confine himself to coordinating and processing papers or amass sufficient staff and authority to render the bureaus redundant. For the most part, Vice Adm. William A. Schoech, the chief of naval material during 1963–1965, leaned toward the former course. Early in 1965, however, after Schoech told subordinates that he had “no intention” of following guidance from Secretary of the Navy Paul Nitze, the secretary replaced him with Vice Adm. Ignatius J. (“Pete”) Galantin.[11]

Galantin, who had just finished a tour as director of the Polaris/Poseidon program, believed that concentrating resources and responsibilities in the Bureaus of Naval Weapons and Ships hampered his ability to manage technology.[12] His goal was greater command authority over the bureau chiefs. In August 1965, on short notice, he invited them to a three-day conference at the Farmington Country Club in Charlottesville, Virginia. The scheme that emerged from Farmington, which Secretary McNamara approved, took effect on 1 May 1966. It replaced the four material bureaus with six systems commands, all under Galantin and the Naval Material Command he headed.[13] Because merging Aeronautics with Ordnance had downgraded the ordnance function, the Navy replaced the Bureau of Naval Weapons with two commands: Naval Air Systems and Naval Ordnance Systems. Electronics technology, increasingly important in weapons development, needed an organization of its own, if only because the Bureau of Ships was oriented toward naval architecture. Accordingly, the Bureau of Ships split into the Naval Ship Systems Command and the Naval Electronic Systems Command. The reorganization also turned the Bureau of Yards and Docks into the Naval Facilities Engineering Command and changed the Bureau of Supplies and Accounts into the Naval Supply Systems Command (see table 9–1). Thus, the Navy’s bilinear organization disappeared, with medical and personnel as well as material functions coming under control of the CNO, to whom the chief of naval material now reported.[14]

Vice Admiral Galantin’s role resembled that of General Besson in Army Materiel Command—running a decentralized headquarters that supervised project or program managers—more than it did that of General Schriever, who directed the centralized Air Force Systems Command. In fact, criticisms of the new setup resembled those leveled against AMC. According to Rear Adm. Ralph K. James, a former chief of the Bureau of Ships, “The dismembering of the bureau system . . . forced most of the basic research and development and design effort of the technical bureaus into the hands of industry. . . . [T]he desire to have many companies or groups participating on a competitive basis means each has to have its own engineering and design and research capability. So we see a proliferation of engineering talent that used to be concentrated under . . . a single technical bureau.”[15] As OSD wished, industry assumed a much larger role in ship design. Whether private shipbuilding firms could master the challenge remained to be seen.

Table 9–1: Systems Commands of the Naval Material Command

Naval Ship Systems Command	Naval Air Systems Command	Naval Ordnance Systems Command	Naval Electronic Systems Command	Naval Facilities Engineering Command	Naval Supply Systems Command
Ships and craft acquisition, conversion, modernization, overhaul	Aircraft acquisition, modernization, overhaul	Shipboard weapon systems acquisition, modernization, overhaul	Communications systems, ship, shore, satellite	Military construction	Supply management
Ship system integration and life cycle management	Aircraft equipment	Ordnance system integration	Fixed surveillance systems	Real property acquisition, disposal, inventory, management	Printing and publications
Ship equipment, hull, machinery, electrical, others	Aircraft system integration	Mines, torpedoes, guns, ammunition, ship-launched missiles, acquisition, storage, loading, assembly, etc.	Navigation aids, air traffic control equipment	Navy housing management	Exchanges, commissaries, ship stores, food service
Salvage and diving	Air-launched weapons and expendables	Explosives technology safety, disposal	Command control systems	Facility planning and programming	Field purchasing management
Sonars and surveillance radars	Shipboard catapults, arresting gear, visual landing aids	Small arms, swimmer weapons, demolition charges, etc.	General test and telemetry equipment	Facility maintenance guidance	Transportation management
Inactive reserve fleet ship management	Photographic equipment and technology		Electronic warfare equipment, ship, shore	Nuclear shore power	Movement of household goods
	Meteorologic equipment and technology		Electronic technology, compatibility, etc.	Automotive railway construction, weight-handling equipment	Material handling, food service
				Natural resources	Navy stock fund management
				Pollution control	
				Navy Seabee support	

Source: Booz, Allen & Hamilton, Inc., *Review of Navy R&D Management*, 1946–1973 vol. I, June 1976, 89.

THE SHIPBUILDING INDUSTRY

As Japanese, West German, and Swedish firms won an ever greater share of the world market for commercial ships, private U.S. shipbuilders grew increasingly dependent on military orders. In 1961, Navy yards employed 96,000 civilians compared to 122,000 by private firms. Assessments of whether Navy or private yards operated more efficiently appeared to depend on who conducted the study. Politically, though, private companies held a key advantage. The Navy operated 11 facilities in 9 states, but the 155 private facilities were spread among 24 states, giving the shipbuilding industry more clout in Congress. In 1961, 14 percent of the Navy's ship conversion and repair budget went to private yards. The next year, over Navy objections, Congress required that 35 percent go to private firms. In 1964, Secretary McNamara ordered an appraisal of Navy facilities, but the result was hardly a compromise. The Navy had to close its New York shipyard and San Diego fleet repair facility and allocate about 80 percent of new construction to industry. In 1968, the Navy assigned all of its new construction to private yards.[16]

The administration hoped that multiyear contracts would introduce economies of scale, allowing companies to modernize their yards and retain skilled workers. Until 1965, the Navy retained responsibility for design; bids were not solicited from shipbuilders until designs and specifications had been developed. With the Fast Deployment Logistics ship, however, industry participated in concept formulation and contract definition, allowing the Navy to choose among competing designs. The successful bidder also had to propose a highly automated facility capable of turning out 12 ships in 12 months. The Navy hoped to replicate a Swedish shipyard where "modules" were welded together sequentially to form a completed hull.[17]

McNamara and his subordinates believed that technological obsolescence was the primary source of problems in the American shipbuilding industry. After touring a number of shipyards in northern Europe, Vice Admiral Galantin and Assistant Secretary of the Navy (Installations and Logistics) Graeme Bannerman praised the European integrated control and production processes. Computers described hull dimensions, ship contours, power requirements, and optimum compartmentation, while remotely controlled machines run by a small number of highly trained technicians automatically cut, shaped, and welded the steel.[18]

Systems Analysis in OSD asked the Institute for Defense Analyses (IDA), a civilian, nonprofit, federally funded research organization, to analyze the costs of shipbuilding. Completed in December 1966, IDA's report noted how modern foreign yards, in Sweden and Japan particularly, were moving from a concept of "constructing" ships to one of "manufacturing" them. Changing shipyards into mechanized assembly facilities, the report noted, "not only permits a much more productive use of labor but [also] establishes a flow of material which permits the use of recently developed managerial skills as well." But no private U.S. yard had won an order of more than four warships until 1964. Unable to pursue production efficiencies, these firms tended to be undercapitalized and lacked modern management techniques. The IDA study noted that prior to the FDL program, U.S. shipyards had not become involved until they received invitations to bid on prepared plans that were "rather abstract with respect to the production process." The Navy did have standardized ship designs, and purchases often were made on a fixed-price, negotiated basis. According to IDA, however, "as a result of frequent and numerous design change orders, virtually every ship within a class is completed in a significantly altered configuration from the design initially presented to the builder." Each ship, ultimately, was slightly different from its sisters. Moreover, each shipyard was buying from its suppliers on the basis of only one or two ships, reducing opportunities to economize through volume production of the components and making materials scheduling much more complex. Obviously, IDA concluded, the key to efficient production lay in standardizing the product.[19]

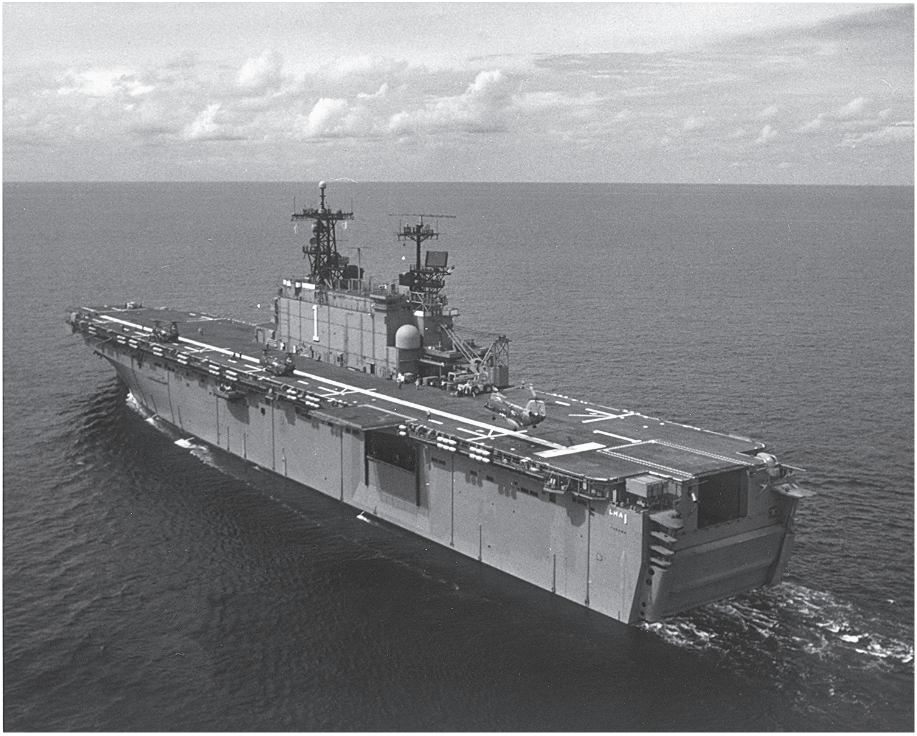
Early in 1967, Galantin asked U.S. shipbuilding executives to submit views on two issues. First, should DoD confine itself to setting general operational requirements? Second, should builders of warships adopt total package procurement? Most of the answers were negative. According to the president of Friede and Goldman, a naval architectural and marine engineering firm in New Orleans, foreign yards could turn out ships more economically because they had "more and better people" who created "superior management and engineering." Since private U.S. yards had done little basic concept and design work, "[i]t would take many years to develop ordinary talent of this type, much less brilliant capability." The president of John J. McMullen Associates, another naval architectural company, ascribed U.S. lack of competitiveness largely to significantly higher American wage rates. Since "our foreign friends will introduce economies and streamlining of construction methods just as rapidly as we will . . . some significant differential in shipbuilding costs will always be maintained, as long as we here in the United States enjoy a higher wage rate." He warned, further, that total packaging would lead to a complete "sopping up" of marine technical personnel, leading to a "tremendous" increase in wages. From his experience, European and Japanese productivity was no greater than that of first-class U.S. yards. A major reason why Japanese yards looked so good at modernization and mass production, he argued, was that they could count on government-backed financing. The executive vice president of National Steel and Shipbuilding, whose firm had won a multiyear LST (landing ship, tank) contract, claimed that "the system of isolating professional design engineering from the risks involved in fixed price construction has been proved through many years as a sound technique." Anticipating negative outcomes for systems developed using TPP, National declined to bid on the Fast Deployment Logistics ship.[20]

Nonetheless, McNamara accepted IDA's arguments. A Draft Presidential Memorandum dated 10 March 1967 charted the course. Single-year contracts, fixed delivery schedules, and geographical distribution of orders previously had forced the Navy to buy in small, uneconomical quantities. Contracts that reflected short-term direct costs prevented companies from raising funds for modernization. McNamara hoped that integrating designers with producers, as Europeans had done, would bring forth creative solutions. For instance, current U.S. practice treated weapon and sensor systems as integral parts of a ship, which minimized ship size but proved costly in other ways. Why not instead design the weapon and sensor systems "as standardized modular units for installation on the basic hull, with necessary services (e.g., power) supplied through plug-in connections"? Summing up, McNamara said that "[w]e must deal in fewer, but larger standardized classes of ships using the modern techniques of series production. We must achieve a much better economic balance between manning and equipment, and we must improve our analytical, planning, and management capabilities."[21]

Although Congress cut off FDL funding in 1968, the desired reforms were applied to the Amphibious Assault Ship. Designated LHA, the ship was intended to combine the characteristics of a troop and helicopter carrier and to carry landing craft for across-the-beach assaults. In October 1966, Naval Ship Systems Command sponsored an LHA briefing attended by representatives of more than 75 companies. The Navy specified performance requirements, allowing industry to craft the designs. Its RFPs ran to 1,500 pages. Litton Industries, which had acquired Ingalls Shipbuilding Corporation in 1962, replied with an "Executive Volume" plus 25,000 pages in 68 notebooks; about 5,000 graphs, tables, drawings, and other illustrations accompanied the full text. The Navy chose Avondale Shipyards, Inc., General Dynamics, Litton Industries, and Newport News Shipbuilding to proceed beyond the concept formulation phase.[22]

Litton won the competition and was awarded the LHA contract. Its top management had no expertise in this area, but the company often had demonstrated its ability to master the most advanced technology.[23] For example, Litton originated and then dominated the military market for inertial navigation systems. At its facility in Pascagoula, Mississippi, Litton began what would become the world's most automated production yard.[24]

Pascagoula proved to be something of a wonder, producing about 70 percent of the Navy's surface warships. Initially, though, there were serious problems. The Navy imposed total package procurement on the LHA, and Litton incurred severe financial losses. When schedules slipped and costs escalated, the Navy cut its order from nine to five vessels, so Litton did not benefit from the usual "learning curve." Some blamed these troubles on management mistakes, aggravated by shortcomings in the education and job skills of the local workforce. As elsewhere, advanced technology and untried techniques proved costly. Litton had taken a high-risk venture, employing new techniques like modular construction on a scale never before attempted.[25]



General Purpose Amphibious Assault Ship USS *Tarawa* (LHA–1), Gulf of Mexico, 8 July 1976 (*Naval History and Heritage Command*)

In addition, the emphasis on adopting advanced methods from abroad was probably overdone. Swedish and Japanese yards appeared to be more efficient, in part, because their tankers and cargo ships were simple vessels compared to U.S. warships, which were loaded with electronic subsystems. As McNamara observed, electronics kept changing faster than hulls and machinery. By the early 1970s, it looked as though the attempt to revive private yards and transform shipbuilding techniques was falling short.

NUCLEAR ATTACK SUBMARINES

The Navy commissioned the world's first nuclear-powered vessel, the submarine USS *Nautilus*, in September 1954. With a nuclear power plant, submarines could remain below the surface almost indefinitely, the duration of a voyage limited only by the crew's human needs. Six nuclear attack submarines of the *Skipjack* class, laid down between May 1956 and January 1959, followed *Nautilus*. The Soviets did not send a nuclear submarine to sea until July 1958.[26] A *Skipjack*-class boat served as the basis for USS *George Washington*, the first of 41 fleet ballistic missile submarines commissioned during the 1960s.[27]

Accolades for achieving nuclear propulsion went principally to Hyman G. Rickover, who in 1958 reached the rank of vice admiral and became an admiral in 1973. Rickover enjoyed a unique status in the Navy: he was both assistant chief of bureau for nuclear propulsion in the Bureau of Ships as well as chief of the Naval Reactors Branch in the Atomic Energy Commission's (AEC's) Division of Reactor Development. Although dual-hatted, he ran a single staff. Like Rear Admiral Raborn, who headed the Polaris program, Rickover reported directly to the secretary of the Navy. On problems of nuclear propulsion, he could deal directly with anyone in the Navy. Yet when Rickover failed to gain what he wanted from his service, he would lobby Congress in his capacity as an AEC official, testifying frequently before the Joint Committee on Atomic Energy and the House and Senate Armed Services Committees, whose members accorded him great respect.[28]

Many who dealt with Admiral Rickover considered him a genius, albeit a difficult one to deal with. His technical knowledge probably was unrivaled, and the propulsion plants created under his direction were unfailingly excellent. An adept bureaucrat, he kept abreast of everything that could affect his programs. As an example, Assistant Secretary of the Navy Charles A. Bowsher once returned to his office after testifying to a congressional committee about cost overruns on nuclear-powered carriers to find Rickover waiting there. The admiral told Bowsher, "You gave a correct answer, but not the full answer. Here's some additional language that I'd like you to be sure to insert for the record."[29] Such behavior contributed to Rickover's reputation for having a prickly personality. Another assistant secretary characterized him as "an example of 'the power of positive rudeness'; he would ask, wheedle, bluster, threaten, blackmail to get his way."[30]

The AEC bore responsibility for the design, development, and safe operation of nuclear reactors. It owned two nuclear power laboratories: Bettis in Pennsylvania, operated by Westinghouse, and Knolls in New York, operated by General Electric. Near both sites, Rickover established procurement organizations that tied these laboratories to shipyards. In 1958, seven shipyards were building ships with nuclear power plants. Five were private (Electric Boat in Groton, Connecticut; Newport News in Virginia; Ingalls in Pascagoula, Mississippi; New York Shipbuilding in Camden, New Jersey; and Bethlehem Steel in Quincy, Massachusetts), and two were Navy yards (Portsmouth, Maine, and Mare Island, California). Initially, at the Navy yards, a nuclear power superintendent trained by Rickover reported to the yard commander. As the nuclear fleet grew, though, Rickover installed his own representatives at those yards who reported directly to him.[31]

Rear Admiral Hyman G. Rickover, circa mid-1955 (*Naval History and Heritage Command*)

Admiral Hyman G. Rickover (1900–1986)

For more than three decades, Admiral Hyman Rickover directed the Navy's nuclear propulsion program, earning a reputation as a demanding leader who relentlessly pursued the development of a nuclear Navy.

Born in Poland, Rickover emigrated in 1906 with his mother and sister to join his father in the United States.

After graduating from the Naval Academy in 1922, Rickover was assigned to the destroyer *La Vallette* and then to the battleship *Nevada* from 1925 until 1927. He next attended the Naval Postgraduate School at Annapolis, Maryland, followed by a year at Columbia University, earning an M.S. in electrical engineering in 1929. The 1930s saw Rickover return to sea, including four years on submarines. For most of World War II, he headed the Electrical Section in the Bureau of Ships.

While the Navy was intrigued by the possibilities of nuclear propulsion following the war, its initial focus did not extend beyond research. Assigned to the Manhattan Project's Clinton Engineer Works in Oak Ridge, Tennessee, in 1946, Rickover quickly became a strong advocate of nuclear propulsion. Gaining solid support from Navy leadership, beginning in 1949, he simultaneously held positions with the Division of Reactor Development in the U.S. Atomic Energy Commission and as director of the Naval Reactors Branch in the Bureau of Ships.

Rickover's initial and iconic achievement in nuclear propulsion was development of the world's first nuclear-powered vessel, the submarine *Nautilus*, which joined the fleet in January 1955. Thereafter, he promoted nuclear propulsion for fleet ballistic missile and high-speed attack submarines (the *Los Angeles* class), a deep-submergence research vehicle, and surface combatants, especially aircraft carriers. He also advised in the development of the nation's first commercial nuclear power plant, constructed in Shippingport, Pennsylvania, which went into operation in 1957. In 1982, after 64 years of service—more than any other officer in the history of the Navy—Rickover retired.[1]

The *Skipjack* class of attack submarines combined a newly designed reactor with a teardrop hull already tested in a diesel submarine. Created by Westinghouse's Bettis Laboratory under Rickover's supervision, its S5W pressurized-water reactor became the mainstay of the underwater fleet during the 1960s.[32] For the plates of its pressure hull and frames, *Skipjack* used HY–80, a low-carbon steel developed after World War II. In July 1957, the Ship Characteristics Board drew up tentative specifications for the next class of attack submarines. Thicker HY–80 plates and better welding methods indicated that this class could operate at greater depth. The keel-laying of *Thresher*, first of the new class, designed to reach a depth of 1,300 feet and run near 30 knots, took place at Portsmouth in May 1958. Electric Boat had been the lead yard, but the chief of the Bureau of Ships wanted to broaden the nuclear power shipbuilding base. Consequently, Portsmouth handled not only the construction but also the contract and detail designs.[33]

Admiral Arleigh A. Burke, the CNO, wanted assurance that the *Thresher* class was sound technically. In January 1959, at his direction, the Ship Characteristics Board convened a meeting of representatives from the fleet, shipyards, and bureaus. Conferees agreed that HY–80 could be welded safely under careful procedures and that the number of new, unproven features was not excessive. Late in 1959, however, one yard after another complained of troubles welding HY–80. Cracks were common; some welds had to be reworked six times. In response, the Bureau of Ships issued more complicated, demanding procedures for welding and fabrication.[34]

Hull construction was not the only problem. A submarine's piping systems, which carried seawater to cool the propulsion components, needed to withstand the same pressure as the HY–80 steel hull. The joints that linked pipes, valves, and pumps could be either welded or silver-brazed. All the yards experienced difficulties with silver brazing. Welding was stronger but costlier and more complicated and could not join some types of different materials.[35]

Because advances like HY–80 could be incorporated into Polaris ballistic missile submarines, Admiral Burke in April 1960 gave *Thresher* the highest priority in the submarine construction program. Worried by continuing difficulties and differences over how to solve them, Burke bypassed the Bureau of Ships and asked for an appraisal from Rear Adm. Francis D. McCorkle, president of the Navy's Board of Inspection and Survey. McCorkle determined that HY–80 steel had to be used, but he wanted better data about it. To acquire that data, the date for *Thresher*'s sea trials was pushed forward, and Portsmouth went on a six-day week. But calling for acceleration was easier than achieving it. In mid-1960, a civilian engineer from the Bureau of Ships reviewed the procedures that Electric Boat and Portsmouth were using to inspect HY–80 welds. At Electric Boat, where two Polaris submarines were under construction, he judged the weld radiology good and procedures sound but did not find the same at Portsmouth, where *Thresher* was being built.[36]

Nonetheless, *Thresher*'s sea trials began in April 1961. Test dives revealed some failures of silver-brazed joints; welds replaced many of them. Electric Boat and Mare Island developed a technique for the ultrasonic testing of brazed joints. Portsmouth reluctantly agreed to such tests on *Thresher* but, finding them difficult and time-consuming, stopped performing them in December 1962 without informing the Bureau of Ships.[37]

USS *Thresher* under way, 30 April 1961 (*J.L. Snell/ Naval History and Heritage Command*)

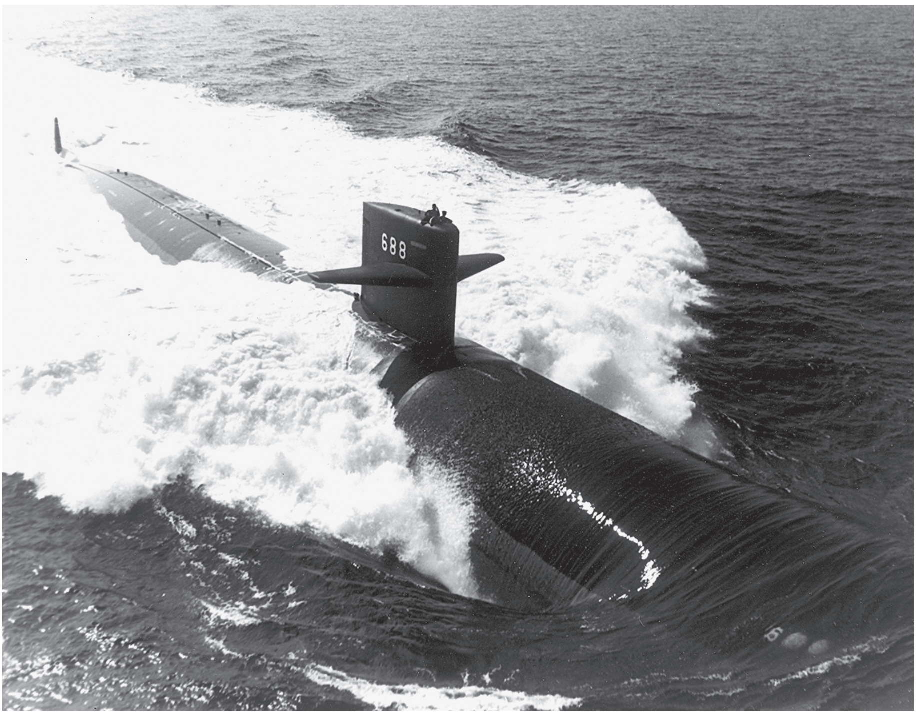
On 9 April 1963, *Thresher* broke apart during a deep test dive; all 129 on board died. A Navy court of inquiry speculated that an engine-room leak, possibly caused by failure of a silver-brazed joint, had short-circuited the electrical equipment and shut down the reactor. The court cited as an underlying cause of the tragedy the rapid changes in material requirements resulting from the accelerated pace of technical development. Subsequently, critical piping systems were welded and radiographed; the silver-brazed joints were tested ultrasonically. The Navy commissioned 13 *Thresher*-type submarines, renamed the *Permit* class, between 1962 and 1968. All operated without major incident, as did 37 of the follow-on *Sturgeon* class, which were similar to *Permit*s in design but less noisy and slightly larger, therefore a bit slower.[38]

In April 1964, Vice Admiral Rickover asked Electric Boat to design a high-speed attack submarine. Three months later, the Ship Characteristics Board urged the Bureau of Ships to study an electric-drive boat. In October, the board contracted with Electric Boat for preliminary designs of two types of nuclear propulsion plants: first, a reactor with an electric-drive system; second, a reactor with steam turbines and mechanical reduction gears.[39] In August 1966, the CNO sent the chief of naval material a development objective for a new class able to carry advanced sonar yet be fast enough to escort surface warships. Concept formulation, under a project manager, began on a submarine design labeled CONFORM.[40]

Secretary McNamara saw no need for either electric drive or a new class of submarines. Late in 1967, OSD systems analysts concluded that in a war at sea, "our losses would be small and that we could destroy the enemy submarine force in a few months."[41] McNamara fixed the strength of the attack submarine fleet at 105, of which 69 were to be nuclear and 36 diesel-electric. Since 65 nuclear submarines were authorized, under construction, or in commission, he concluded that the force already was near full strength. Accordingly, McNamara opposed building a new class of high-speed attack submarines.[42]

An incident on 5 January 1968 startled the Navy. As a Soviet *November*-class attack submarine (13 of which had entered service between 1959 and 1964) trailed the nuclear-powered *Enterprise* in the eastern Pacific, the carrier gradually increased its speed above 30 knots, but the trailer kept pace. Evidently, the oldest Soviet boats were faster than the U.S. nuclear attack submarines, which ran close to, but not over, 30 knots.[43]

Matching the Soviets' speed now became an overriding concern. Vice Admiral Rickover advocated a new reactor plant that would deliver about twice as much horsepower as the S5W to boost speed. Adapted from a plant used in surface warships, the S6G could be evaluated in SSN 688, a high-speed design Rickover promoted. Admiral Thomas H. Moorer, the newly appointed CNO, favored that approach and appointed a panel of submariners to determine a proper configuration. On 30 April 1968, the panel recommended placing SSN 688 in the FY 1970 program. Driven by the S6G plant with turbines and reduction gears, the SSN 688 sacrificed some operating depth to gain speed. The CONFORM effort, which had produced 36 design concepts and looked more daring technologically, ended. With McNamara gone and key members of Congress backing Rickover's solution, funding for SSN 688 won quick approval. Launched in April 1974, USS *Los Angeles* was the first in a class of nuclear submarines that would become the most numerous in the world.[44]



USS *Los Angeles* (SSN 688), no date (*Naval History and Heritage Command*)

TRAVAILS OF THE MARK 48 TORPEDO

Torpedoes were the key weapon system of attack submarines, and World War II had marked a breakthrough in torpedo capabilities. Homing torpedoes with on-board controls provided a dramatic advance over gyro-controlled, set-depth torpedoes. Acoustic homing torpedoes acquired targets passively, listening until they detected ship noise, and then employing their sonar systems actively, sending out signals to bounce off the target and help guide them to it. For an acoustic homing torpedo to work, its own noise had to be low enough to not drown out the target's signal. During World War II, the Harvard Underwater Sound Laboratory and Bell Laboratories created a passive homing system. When the Harvard laboratory disbanded after the war, many of its engineers and scientists went to the Ordnance Research Laboratory (ORL) at Pennsylvania State University, and to the Defense Research Laboratory at the University of Texas. After the Navy issued an operational requirement, these laboratories would formulate a conceptual system and test a prototype. Ultimately, after a bid and contract award process, industry would carry out engineering development under the supervision of Navy laboratories.

In the 1950s, because of the increasing threat from cruise and ballistic missiles, developing an antisubmarine torpedo gained priority, leaving a better capability for destroying surface ships largely neglected. The Mark 37 antisubmarine torpedo, which entered the fleet in 1959, was the first to contain active as well as passive homing. However, it was rated as having little chance of killing the newest nuclear-powered submarines. The Mark 46, an antisubmarine torpedo that entered service in 1965, could be launched from fixed-wing aircraft and helicopters as well as from surface ships. Meantime, the advent of transistors and other solid-state devices made possible more complex logic circuits and on-board computers, which greatly improved detection and homing capabilities.[45]

What the Navy needed was a submarine-launched torpedo that would be effective against fast, evasive, deep-diving nuclear submarines. An operational requirement issued in November 1960 called for a torpedo with four times the range of the Mark 37, twice the speed, and 150 percent more diving depth.[46] The ORL drafted design and performance specifications. In mid-1963, parallel study contracts went to Westinghouse's Undersea Division and to the small firm of Clevite, Inc. In June 1964, Westinghouse received a fixed-price incentive contract for what became the Mark 48 Mod 0. While ORL provided technical direction and assessment, Westinghouse retained control over the design.

In January 1965, Clevite received a small contract to make an acoustic homing system that was to be interchangeable with Westinghouse's product and fit into the torpedo's nose. Clevite insisted that its contract be cost-plus and not fixed-price. Attracted by Clevite's comb filter, which promised to reject surface reverberation and discriminate against countermeasures, the Navy wanted to ensure that the company survived as a second source. Since ORL was busy with Westinghouse, the Naval Ordnance Laboratory at White Oak, Maryland, became Clevite's technical director.[47]

In theory, Westinghouse's fixed-price contract should have controlled costs, and the incentives should have minimized the need for government oversight. In practice, these benefits did not materialize. Robert Blouin, a Navy deputy project manager, identified three reasons for the failure. First, Westinghouse underestimated the size and complexity of its task, despite two years of access to government data, hardware, and research personnel. Second, the firm started with a weak management and technical staff. Consequently, early reviews and assessments were inadequate for preventing poor design approaches from becoming hardware realities. Third, the Navy's technical monitoring support activity did not contain enough experts in detail design to spot the contractor's errors early enough, taking almost 20 months to recognize Westinghouse's difficulties. Compounding the problem, Westinghouse was reluctant to provide design details and its rationale for selecting particular approaches.[48]

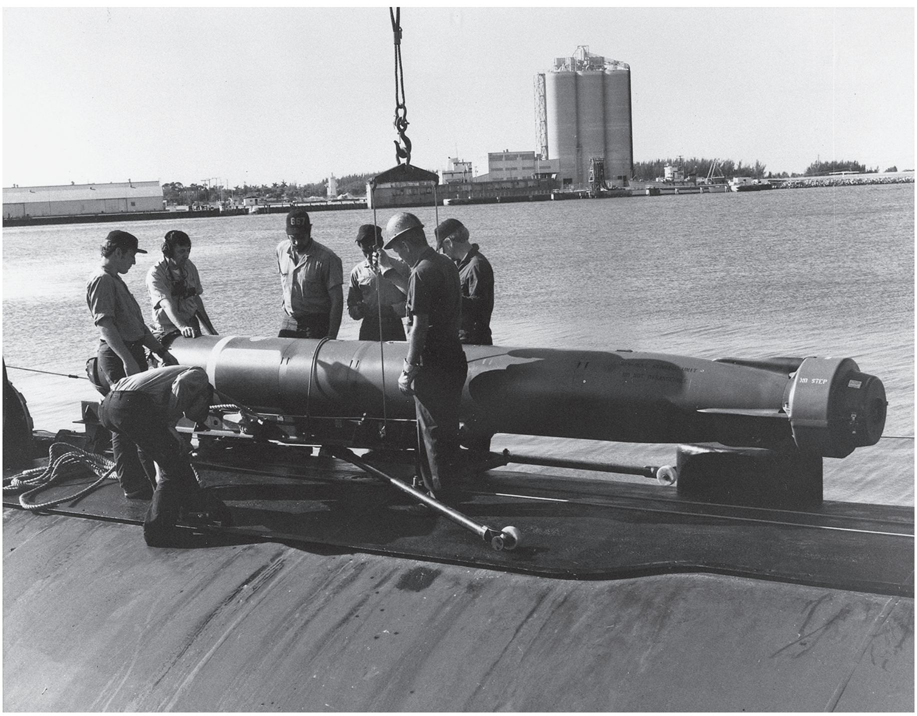
Finally, in 1967, the Navy assembled its best experts to review Westinghouse's Mod 0. Over 12 months, they developed detailed data pertaining to design deficiencies that finally smoothed the way toward technical solutions. Concurrently, Westinghouse completely changed its technical and management staff. But this was not enough. The contract specified the first major delivery milestone about three years after the execution date. From a legal, contractual standpoint, that was a dangerously long time for determining whether the contractor had made satisfactory progress. Robert Blouin believed that, as troubles grew, the pressure of the ceiling price drove Westinghouse to take risky shortcuts. By letting its legal, financial, and contract administration personnel help to shape decisions, Westinghouse worsened an already bad situation.[49]

Westinghouse's contract called for an advanced development prototype, to be followed by a production prototype. But even after Westinghouse exceeded the contract's fixed-price ceiling, the development prototype still had problems. Nonetheless, perhaps hoping to take advantage of the contract's elaborate incentives, Westinghouse started building 65 production prototypes. The Navy bought 12 and gave them to ORL, which carried out modifications under a separate contract.[50]

Clevite now had an unexpected opportunity. Westinghouse had developed a small warhead, suitable only for attacking submarines. OSD vetoed separate funding of an antiship torpedo in 1963–1964 but reversed itself in 1966. Clevite had designed a more compact swashplate torpedo engine, providing space for a considerably larger warhead without a significant sacrifice of range. Awarded a contract in January 1967 to make a propulsion system for testing its acoustic homing device, Clevite worked on a variation of the Mark 48 called Mod 1, with a warhead large enough to be an anti–surface ship torpedo. Instructed to conform exactly to Westinghouse's exterior design, Clevite changed the entire internal hydraulic system and found other suppliers. Gould Inc., which took over Clevite, persuaded IBM to become its subcontractor and torpedo producer.[51]

Gould/Clevite maintained that, compared to Westinghouse's Mod 0, its Mod 1 was simpler and had interchangeable components. Meantime, though, the Navy had tasked Westinghouse's Aerospace Division with developing a Mod 2 that would be antiship as well as antisubmarine. Thus, Gould/Clevite's Mod 1 and Westinghouse's Mod 2 became fully competitive.[52]

In extensive firing tests conducted during 1970–1971, Mod 1 was judged the winner, so Gould/Clevite received the production contract in July 1971. The program manager for the losing Mod 2, Capt. Jeffrey C. Metzel, complained that the Mod 1 project office never allowed its torpedo to be tested under marginal conditions, while improvements made to Mod 2 during the trials were not given enough weight. Gould/Clevite personnel responded that they always had looked on specifications as minimum requirements and sought to exceed them. Westinghouse, they maintained, became the victim of its earlier corner-cutting.[53]



Technical personnel of the Naval Underwater Systems Center, Complex Thirty Detachment, load a Mark 48 Mod One torpedo aboard a nuclear-powered submarine at Port Canaveral, Florida, 27 February 1972 (*Naval History and Heritage Command*)

Between 1964 and 1971, estimates for the Mark 48's total cost jumped from $642 million to $2.23 billion. Several factors contributed to the quadrupling. Even after undergoing the equivalent of contract definition, both the Navy and Westinghouse underestimated complexity and cost. The fixed-price contract discouraged the incorporation of expensive but necessary design corrections. Then, a single-purpose torpedo turned into a dual-purpose weapon. The Navy had not anticipated a competition between contractors, so Gould/Clevite's costs were not included in the original estimate.[54]

In October 1970, the Navy ordered from Gould/Clevite a pilot run of 50 torpedoes; another order for 480 accompanied the award in July 1971. However, when deliveries from the pilot run began in August, proof testing and technical evaluation revealed serious troubles. The torpedo's 30 percent success rate, discounting material failures, fell well below the system's 53 percent during the selection tests described above.

Proof tests had to be suspended while the procedures for preparing the torpedo's fuel control system were improved. Gould/Clevite had hired production engineers, put them into design and development, then returned them to production when it won the contract. Evidently, the expected carryover of expertise did not take place. Early in December 1971, project manager Rear Adm. George G. Halvorson met with Gould/Clevite executives and emphasized that top-quality production managers should be brought on board.[55]

Soon, in renewed proof runs, the overall mission success rate climbed to 67 percent. Gould delivered its first operational or "warshot" torpedo to the fleet in February 1972.[56] Still, the biggest challenge lay in hastening Gould's transition from an R&D, small-quantity builder to a large-output, high-quality producer. Gould hired Ray Tieger from the electronics industry. He had worked on several highly classified projects and understood the techniques of quality production. As the new vice president, Tieger took complete charge of the Mark 48 program. The fixed-price incentive production contract achieved a modest cost underrun. During 120 fleet firings in 1973, the torpedo met or exceeded all performance requirements except one for radiated noise.[57]

A cautionary lesson from Mark 48 development is that competitive prototyping and the equivalent of fly-before-buy did not yield many of the expected benefits. During operational testing and evaluation, some tests may have been designed to facilitate particular outcomes. Whether Clevite/Gould's Mod 1 truly bested Westinghouse's Mod 2 can be debated, but Gould's "warshot" torpedo did not match the performance of its lightweight test model.

NUCLEAR-POWERED SURFACE SHIPS

Nuclear propulsion for surface warships promised important advantages: unlimited cruising endurance with freedom from refueling at sea, hulls designed to maximize top speed, more power for complex electronics systems, and less corrosion from stack gases.[58] A nuclear-powered aircraft carrier could carry much more aviation fuel and air-delivered munitions than a conventional vessel.[59]

Admiral Burke commissioned a three-year study of nuclear power for the fleet. Completed in 1958, it proposed deploying six all-nuclear task forces by 1970, each consisting of one attack carrier, two guided-missile cruisers, and three frigates. The keel of cruiser *Long Beach*, the Navy's first nuclear-powered surface ship, was laid down in 1957. Construction of *Enterprise*, the first nuclear-powered carrier, started the next year. In 1959, work began on *Bainbridge*, the first nuclear-powered frigate.[60]

Aircraft carrier USS *Enterprise*, cruiser USS *Long Beach*, and frigate USS *Bainbridge*, the first nuclear-powered task force, under way, 18 June 1964 (*Naval History and Heritage Command*)

Rising costs forced reconsiderations. *Enterprise*, displacing 85,000 tons and powered by eight nuclear reactors, cost at least one-third more than would oil-fired carriers of nearly comparable size. By the time *Long Beach* neared completion, displacing 17,000 tons, its original cost estimate had more than tripled. To investigate the situation, Vice Admiral Rickover sent four of his engineers to the Bethlehem yard at Quincy, Massachusetts, where *Long Beach* was under construction. Bethlehem's management ascribed the trouble to the unique demands of nuclear propulsion. Rickover's men, however, cited problems at the yard, such as poor welding and brazing aggravated by inadequate planning.

In January 1960, Admiral Burke created an investigating committee under Rear Adm. Miles S. Hubbard, formerly chief of the Bureau of Ordnance. One team went to Newport News Shipbuilding in Virginia to appraise progress on *Enterprise*, the other to Quincy. The committee's report, dated 25 February, rated the work at Newport News superior to that at Quincy. But, the report continued, both yards suffered from working for two masters: a supervisor of shipbuilding who represented the Navy, and a representative of Vice Admiral Rickover. Because Rickover's representative bypassed the supervisor of shipbuilding during technical discussions, informing him only after decisions had been made, the latter could not coordinate government direction. Moreover, according to the committee, the gap between the Navy Department's supervisors and Rickover's representatives mirrored problems within the Bureau of Ships where "the same schism . . . bears bitter fruit at all levels." Hubbard's committee opposed starting more nuclear-powered surface ships until the three under construction had been tested at sea. Pressurized-water reactors, it concluded, could not be cost competitive with oil-fired plants. Therefore, as long as costs mattered, ships with better antiair and ASW weapons should take priority over nuclear propulsion.[61]

Vice Admiral Rickover remained committed to nuclear power, but Admiral Burke and civilian leaders backed away from starting more nuclear-powered ships. In 1960, the Eisenhower administration proposed and Congress appropriated funds for an oil-burning carrier, *America*. Early in 1961, a treatise by Rear Adm. Robert H. Speck, who was assigned to OPNAV and had worked closely with nuclear propulsion engineers in the Naval Reactors Branch, concluded that nuclear propulsion by itself would not allow a reduction in numbers of ships.[62]

Initially, the Kennedy administration showed little enthusiasm for nuclear-powered surface ships. In August 1961, Kennedy signed legislation authorizing a second nuclear frigate, *Truxtun*, along with six oil-fired ships. The next month, Secretary McNamara proposed that the next three carriers—slated to start in FYs 1963, 1965, and 1967—all be oil-fired. He also recommended, but later canceled, a third nuclear frigate. Thus, the Navy would have only one nuclear-powered carrier task force.[63]

Deciding that nuclear propulsion could not be applied to any ship smaller than *Bainbridge*, an 8,500-ton frigate, Rickover stopped work on a single-reactor plant intended for a destroyer. He allied with Rep. Carl Vinson, chairman of the House Armed Services Committee, to seek legislation mandating nuclear power for ships exceeding 8,000 tons; they did not succeed. *Enterprise* entered service in 1961 and seemed to showcase the advantages of nuclear power. During the Cuban missile crisis of October 1962, Vice Adm. John W. ("Chick") Hayward commanded a task force that included the oil-fired *Independence* and the nuclear-powered *Enterprise*. Subsequently, Hayward reported that *Enterprise* had outperformed every carrier in the fleet, adding that "[t]he margin between victory and defeat in future naval engagements may well depend on the availability of nuclear-powered ships."[64]

At the time, Newport News Shipbuilding had not yet laid the keel for the next carrier, CVA 67; Rickover still hoped to make it nuclear powered. Westinghouse's Bettis Laboratory was designing a four-reactor plant that could fit into the space allocated for propulsion machinery. The Bureau of Ships reported that a redesigned, nuclear-powered CVA 67 would cost $113 million more than the oil-fired version.[65]

Long Beach was now serving with the fleet, and *Bainbridge* had passed her sea trials. The Naval Research Advisory Committee, which was composed of civilian scientists and advised the CNO and the secretary of the Navy, urged that all future major combatant ships have nuclear power plants. Early in January 1963, the chairman of the Atomic Energy Commission, Glenn T. Seaborg, advised McNamara that propulsion plants in all three ships were reliable, met the Navy's design objectives, and showed a state of maturity and promise that justified building more. Supported by Secretary of the Navy Fred Korth, Seaborg asked McNamara to reconsider his decision that CVA 67 be oil-fired.[66]

On 2 February 1963, McNamara directed the Navy to prepare a comprehensive, quantitative study of nuclear power for surface ships. He sought the most efficient force attainable, which meant a military with the ability to achieve positive results at a given level of spending. Two months later, Secretary Korth and Admiral George Anderson, the CNO, supplied supporting information along with their recommendation for making all surface ships larger than 8,000 tons nuclear powered. Unsatisfied, McNamara demanded more detailed data, explaining that he believed that nuclear-powered ships were superior to conventional ships, but that the costs of nuclear power drained funds from elsewhere and, therefore, such decisions needed to be weighed carefully.[67]

The Navy's second study, submitted in September 1963, claimed that the operational advantages of a nuclear task force, such as greater opportunities to use evasive tactics while in transit and the ability to extend an attack along a greater perimeter, more than offset the slightly lower cost of its conventional equivalent. Again, McNamara disagreed, being "absolutely certain" that six oil-fired task forces were superior to five with nuclear power. On 25 October, he ordered that construction of the oil-fired CVA 67 go forward. Displacing 87,000 tons when fully loaded, *John F. Kennedy* would be commissioned late in 1968.[68]

The following year, technological advances led McNamara to reconsider his position. The propulsion plants of *Bainbridge* and *Truxtun* each had two reactors. Bettis Laboratory was designing a two-reactor plant for a carrier smaller than the 76,000-ton *Forrestal*, an oil-fired carrier that had been commissioned in 1955. McNamara was impressed with what he saw when he visited Bettis in April 1964. In September, after a seven-month study, the federally funded Center for Naval Analyses reported that a two-reactor *Enterprise* would cost about the same as *John F. Kennedy* plus two replenishment ships and would have greater operational capabilities. The Defense Department and the AEC agreed to develop a two-reactor plant having about the same power rating as the eight in *Enterprise* and the four that had been proposed for CVA 67. Lengthening the lives of reactor fuel cores also made nuclear power more cost-effective. The Navy recommended starting a two-reactor carrier, and in late 1965, McNamara approved a nuclear-powered carrier.[69]

From 1965 onward, all new carriers would be nuclear powered. McNamara opposed building more nuclear frigates, however, unless their costs could be reduced. Thus, in February 1966 he asked Congress to fund two oil-fired frigates along with the second nuclear carrier. Secretary of the Navy Nitze recommended providing two nuclear and two oil-burning escorts for each nuclear carrier. McNamara believed that one nuclear escort was enough, but politics intervened. The House Armed Services Committee, now chaired by Rep. Mendel Rivers (D–SC), strongly supported Rickover's argument for all-nuclear task forces. President Johnson signed legislation in July 1966 providing funding for three nuclear-powered ships: the carrier *Nimitz*, the frigate *California*, and long lead-time items for the frigate *South Carolina*.[70]

A battle between McNamara and Rivers ensued. Seeing no need for *South Carolina*, McNamara refused to release funds for starting the ship. What the Navy needed, in his judgment, was new conventional types. Relying on modular construction to cut costs, McNamara directed feasibility studies for a destroyer (DX) and a guided-missile destroyer (DXG) with many common elements. One new nonnuclear option, a gas turbine propulsion plant that was nearing fruition, would allow quicker response times, ease maintenance, and reduce personnel requirements. For FY 1968, therefore, McNamara sought funds to build two gas turbine destroyers, study DX and DXG designs, and appraise steam, gas turbine, and nuclear propulsion plants.[71]

Rear Adm. Elmo R. Zumwalt, Jr., then director of the Office of Systems Analysis in OPNAV, carried out a study of the requirements for major fleet escorts. To Zumwalt, the main issue was whether the Navy's mission could be best performed by many smaller, rather austere ships or by a relatively few big, sophisticated vessels. Zumwalt believed that numbers mattered more, given the Navy's far-flung responsibilities, but he also realized the danger of antagonizing Rickover. The study, completed in August 1967, proposed building 135 DXs and 107 DXGs. A supplement written mainly to mollify Rickover, matched conventional against nuclear escorts operating with nuclear carriers. Comparing quantifiable factors, it found the cost differential to be marginal, meaning that the choice should depend upon nonquantifiable factors. Under those assumptions, which Zumwalt privately thought unprovable and bent in Rickover's favor, between 14 and 18 more nuclear frigates could be justified. Rickover and the new CNO, Admiral Moorer, set a goal of 16. Including ships already authorized, each of the 4 nuclear carriers would have 5 escorts.[72]

In November 1967, McNamara proposed building 5 nuclear frigates, based on the DXG's characteristics. *South Carolina* would be the first. Before any ships were ordered, though, a satisfactory design using the procedures of contract definition in DoD Directive 3200.9 had to be completed. The Navy would determine the mission and work with contractors to draw up general characteristics; then preliminary design and engineering studies would be verified and contracts let. Rickover, however, saw danger in the plan. Systems analysts in OSD might delay agreement about a design long enough that the ships would never be built. In December, Rickover's ally, Representative Rivers, threatened to have Congress withhold authorization for all major items unless the contracts for *South Carolina* and *Virginia*, the second of the five nuclear frigates, were awarded promptly.[73]

On 20 January 1968, McNamara urged President Johnson to sign a determination that building *South Carolina* and *Virginia* was not in the national interest. But McNamara left office one month later and his successor, Clark Clifford, opted quickly for a compromise. Already under sharp criticism after *Pueblo*'s seizure and the Tet offensive, the administration shied away from another fight with Congress. Clifford released procurement funds for *South Carolina* during May and June; Congress then authorized money for *Virginia* and *Texas*, the third nuclear frigate.[74]

Nuclear-powered guided missile cruiser USS *South Carolina* (CGN–37) departs Norfolk, Virginia, September 1975 (*Naval History and Heritage Command*)

To all appearances, Rickover and Rivers were winning their fight for enough escorts to form all-nuclear-powered task forces. Yet the story would play out differently. During the 1970s, a troubled economy and a changed political climate compelled stretch-outs and cancellations. In 1980, the Navy had three nuclear-powered carriers and nine nuclear-powered guided-missile "cruisers," as the escort frigates had been reclassified. By the early 1990s, the Navy was operating seven nuclear-powered carriers but still had only nine nuclear-powered cruisers—a result that bore no relation to proposals made in the 1960s.

DESTROYERS AND ESCORTS: DECISIONS DELAYED

Having built the bulk of its surface warships between 1942 and 1945, the Navy faced a danger of "block obsolescence" during the 1960s. From FY 1957 onward, rapid growth in the cost of high-technology ships needed for fast carrier task forces sharply limited how many the Navy could build. But by 1963, if building rates of the late 1950s continued, almost half the Navy's warships would be serving beyond their normal 20-year life spans. Late in 1958, a committee comprised of the president of Newport News Shipbuilding, the operating manager of States Marine Corporation, and the technical director of the Applied Physics Laboratory at Johns Hopkins University recommended complete rehabilitation of ships that had reached middle age. A two-part program of Fleet Rehabilitation and Modernization (FRAM) began in 1959. FRAM I conversions would extend useful life by eight years and more modest FRAM II refits by five. From 1959 to 1963, FRAM I provided 79 destroyers with unmanned drone antisubmarine helicopters (DASH), antisubmarine rockets (ASROC) that could be armed with nuclear depth charges, and improved SQS–23 sonars. Putting 52 ships through the cheaper FRAM II was less successful because DASH failed and, lacking ASROC, the ships were left without any long-range ASW weapons.[75]

In December 1963, as FRAM ended, Secretary McNamara challenged the concept of "block obsolescence." Age alone was not a good measure, he concluded. A better measure was how technological change affected design efficiency, which had to be evaluated class by class. For destroyers, mostly displacing around 2,200 tons, upgrades were limited because the most advanced sonar could not be installed in their hulls. Moreover, it appeared doubtful that those destroyers could be re-equipped for antiair warfare (AAW) in addition to their ASW modernization. Only the larger and costlier guided missile destroyers, frigates, and cruisers could accommodate both antisubmarine and antiair systems. At that point, however, the administration's five-year shipbuilding program did not include ships of those types.[76]

Efforts to design a new class of destroyers met with many detours and some dead ends. In 1959, OPNAV's Long-Range Objectives Group suggested changing emphasis from antiair to antisubmarine warfare. The Ship Characteristics Board also stressed the need for a guided-missile destroyer possessing maximum ASW, but limited AAW and gunfire, capabilities. What resulted were hybrids, classified as escorts but really halfway between destroyers and escorts. Ten *Garcia*-class ships, each armed with two 5-inch guns and one ASROC launcher, were commissioned between 1964 and 1968. Their novel pressure-fired boilers supplied 70 percent more power than previous steam plants of the same size and weight. Commissioned during 1966 and 1967, each of six *Brooke*-class escorts carried a Tartar antiair missile system in place of the second 5-inch gun.[77]

The Navy projected a large program of building guided-missile destroyers, but the ongoing troubles of the Talos, Tartar, and Terrier surface-to-air missiles (the "3 Ts") led McNamara to hold back approval. What emerged instead was the largest group of U.S. surface warships built to the same design since World War II, the austere *Knox* class of ocean escorts, redesignated frigates in 1975. Bethlehem Steel had designed the *Garcia* and *Brooke* classes, but in December 1963 the Gibbs and Cox naval architectural firm won the *Knox* design contract. Although the original plan called for placing a pair of pressure-fired boilers amidships, side-by-side, Francis Gibbs, one of the two brothers who founded the company, persuaded the chief of the Bureau of Ships to use conventional boilers instead. Bidding on construction stopped in January 1964. Redesign consumed 12 months. Ten ships were authorized in FY 1964, 16 in FY 1965, 10 in FY 1966, and 10 in FY 1967. Todd Shipyards in Seattle, Lockheed in California, and Avondale in Louisiana built the first units. To promote cost efficiency, all orders after the first 27 went to Avondale, which built the last half of its run using serial production techniques.[78]

The *Knox* class had a standard displacement of 3,011 tons, carrying one ASROC launcher and one 5-inch gun. *Knox*es had been intended to carry Sea Mauler antiair missiles, adapted from the Army's Mauler, but cancellation of that system also terminated the Sea Mauler program. Soon, the *Knox* class came under criticism for being ASW ships lacking general purpose capabilities. The 1971 prize-winning essay in the U.S. Naval Institute *Proceedings*, the Navy's professional journal, characterized this class as "the greatest mistake in ship procurement the U.S. Navy has known." Between 1971 and 1975, however, Sea Sparrow antiair launchers were installed on 31 of the 46 ships in the class.[79]

USS *Patterson* (DE–1061), a *Knox*-class escort, under way in Narragansett Bay, Rhode Island, August 1970 (*Naval History and Heritage Command*)

Ocean escorts were not destroyer equivalents, of course, and most of the FRAMs would have to be retired by 1970. In September 1961, the Long-Range Objectives Group urged the design of a new destroyer. Project Seahawk began in April 1962, when the Ship Characteristics Board formed a steering group that envisioned a fast destroyer carrying a wide range of advanced ASW weapons and sensors. A prototype would be funded in FY 1965 and delivered in mid-1969. The CNO, Admiral Anderson, considered Seahawk so important that he made the board's chairman personally responsible for its success.[80]

The vice president of Bethlehem Steel told Admiral Anderson that his firm could design a ship able to reach a burst speed of 40 knots. The CNO consequently changed Seahawk's emphasis from ASW systems to propulsion. Ultimately, that change proved fatal. Director of Defense Research and Engineering Harold Brown pointed out that early Seahawks would be little more than advanced destroyer escorts without new sensors. By 1964, the new CNO, Admiral David McDonald, rated an upgraded *Knox* as nearly equivalent to Seahawk and directed studies of alternatives.[81]

In January 1965, with Seahawk dead, the Ship Characteristics Board started working on a guided-missile destroyer. A major innovation involved using gas turbines instead of high-pressure, high-temperature steam. The advantages over conventional steam included much lower weight that allowed more fuel to be stored aboard, faster starting and acceleration, lower noise levels for sonar operation, and much smaller crews. The CNO opposed installing gas turbines until they had been tested at sea, but in April 1966, McNamara rated the potential gain great enough to make that risk acceptable. Probably, McNamara saw gas turbines as a suitable, less expensive alternative to nuclear power plants for smaller surface combatants.[82]

By that time, the Navy badly wanted new missile ships since none had been authorized since FY 1962. Systems analysts in OSD suggested combining the capabilities of a missile ship with the characteristics of a general-purpose destroyer, holding down costs by enforcing standardization and confining large-scale production to a single yard. In a Draft Presidential Memorandum of November 1966, McNamara proposed building 75 antisubmarine DXs and 18 guided-missile DXGs during FYs 1969–1974. They were to be designed to facilitate modernization about once every 10 years—a unique requirement—and also have a potential for conversion, in case antisubmarine DXs had to mutate into DXGs armed for antiair area defense. The ASROC launcher on a DX, for example, might be replaced by a combined ASROC/Tartar launcher. McNamara also wanted to apply total package procurement, with one contractor creating the design and then building all the ships.[83]

A rear admiral was appointed to coordinate the DX/DXG program. He reported directly to the CNO and the secretary of the Navy, just as Rear Admiral Raborn had for Polaris. In October 1967, the Navy completed a development plan that endorsed the single contractor idea and analyzed speed, gun, and range requirements. Three months later, performance capabilities for the new ships were incorporated into a DPM that specified 30-knot speed in rough seas so that the ship could screen attack carriers, operating presumably in the North Atlantic; 6,000-mile endurance at 20 knots; two 5-inch guns; and a basic hull capable of accepting modules like antiair or ASW systems.

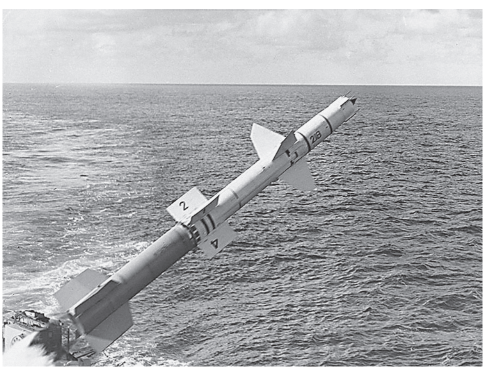
Requests for proposals went out on 15 February 1968. The companies selected for contract definition were Todd, Avondale, General Dynamics at Quincy, Ingalls, and Bath Iron Works. In June 1970, Litton's Ingalls Shipbuilding won the contract to build 30 destroyers. No DXGs were ordered, partly because nuclear-powered frigates appeared more efficient. USS *Spruance* (DD 963) was built at the Pascagoula yard and commissioned in September 1975. It had four gas turbine engines and displaced 7,810 tons when fully loaded, just below the 8,000 tons at which Rickover was arguing for nuclear power. *Spruance* began its life as primarily an ASW ship, carrying one ASROC launcher with a large reload magazine, two helicopters, one Sea Sparrow Basic Point Defense Missile System, and two 5-inch guns. Compared to their Soviet counterparts, *Spruance*-class ships looked underarmed. As one officer remarked, "You had to walk a mile in those ships before you ever stumbled over a weapon." But they were designed to facilitate the major upgrades that occurred later.[84]

USS *Spruance* (DD–963), lead ship of its class of destroyers, under way during builders' trials in the Gulf of Mexico, February 1975 (*Naval History and Heritage Command*)

Vietnam spending compelled cuts in the Navy's shipbuilding budget, which kept FRAMs in service beyond their five- and eight-year extensions. Also, as noted earlier, the importance of ASW surface ships was diminishing. Even more important were the difficulties in creating effective antiair defense. The "Get Well" teams, composed of individuals with specialized expertise brought together to solve difficult problems, effected improvements for Talos, Tartar, and Terrier, but shortcomings persisted. Why build new classes of guided-missile destroyers or frigates with no truly reliable missile system available? Repeated and probably unavoidable delays would force Navy leaders to make wrenching choices during the early 1970s about the size and capabilities of the surface fleet.

TROUBLES OF THE "3 Ts"

Even before World War II ended, the Navy foresaw a day when task forces could be attacked by missiles launched from bombers flying far beyond the range of naval antiaircraft guns. Project Bumblebee, initiated during 1944 by the Applied Physics Laboratory at Johns Hopkins, began developing countermeasures. Talos, a long-range ramjet missile originally envisaged by Bumblebee, entered service in 1957, but it proved to be too large for installation on anything smaller than a cruiser. Terrier, rocket-propelled and compact enough for destroyers and frigates, had reached operational status one year earlier. It was designed to deal with high speed, low-flying "pop-up" aircraft. Conceived as a shorter range equivalent of Terrier and sharing many of its components, Tarter entered service in 1961. Unlike Terrier, Tarter had a fully automated loader that cut reload time from 30 seconds to 7. Tartar featured semi-active guidance, homing on radar energy generated by the firing ship and then reflected by the target. The less sophisticated Terrier rode a radar beam that sometimes reflected off the ocean's surface instead of the target. Tartar also had some antiship capability.[85]



Talos missile just after launch from USS *Galveston* (CLG–3) in the Caribbean Sea, 1961 (*Naval History and Heritage Command*)

None of the 3 Ts, however, performed close to expectations. Among other problems, reliability remained low because testing procedures had failed to identify precise problem areas. In 1959, the Navy initiated a Terrier/Tartar Reliability Improvement Program that did little good, partly because evaluators discounted failures that might reflect poorly on their organizations. Capt. Eli T. Reich, commanding the cruiser *Canberra*, recorded a November 1960 test in which six of the eight Terriers fired were aborted or unsatisfactory.

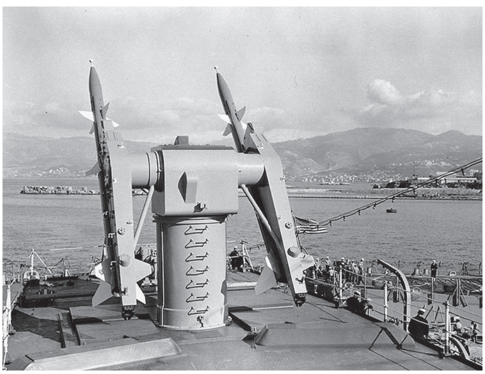
Telemetry experts from Sperry Rand and the Applied Physics Laboratory witnessed an Atlantic Fleet exercise in the early spring of 1961 that yielded spotty successes, indicating serious defects in the system.[86]

Assistant Secretary of the Navy (R&D) James H. Wakelin, Jr., commissioned Milton C. Shaw, a civilian engineer who had worked under Rickover, to appraise the 3 Ts. In January 1962, Shaw reported that none of the systems on board the 28 missile ships in commission and the 38 under construction could be classified as operational. Of the six Talos cruisers that would be in the fleet by January 1963, only the systems on *Galveston* would be truly operational. Shaw's findings threatened the careers of some officers. Senior civilians, however, insisted on strong remedial action.[87]

USS *Columbus* (CG–12) fires a Tartar missile. Talos missile is visible on launcher, aft portion of ship (*Naval History and Heritage Command*)

On 4 July 1962, Reich, now a rear admiral, was appointed head of a Special Navy Task Force for Surface Missile Systems, making monthly reports directly to the secretary of the Navy.[88] Reich concluded that the Bureaus of Ships and Naval Weapons were focused more on future systems and had failed to treat shortcomings of the 3 Ts as a high priority. Methods of supporting the missile ships struck Reich as deeply flawed.[89] Failure to appreciate and examine the complex interplay of each system's elements meant that design defects were not being readily identified. Reich detected parochialism between the bureaus and even within the Bureau of Ships, between its radar and switchboard groups. Consequently, he saw no possibility of duplicating the kind of vertical management structure that had been used for Polaris. Instead, Reich established a Contractor Steering Group of senior members from such firms as Bendix for Talos, General Dynamics-Pomona for Terrier and Tartar, Sperry for fire control, Northern Ordnance, Inc., for missile launchers, Vitro for service engineering support, and Bath Iron Works for shipbuilding. Also, in September 1962, Bell Laboratories and Western Electric took on the task of systems engineering.[90]

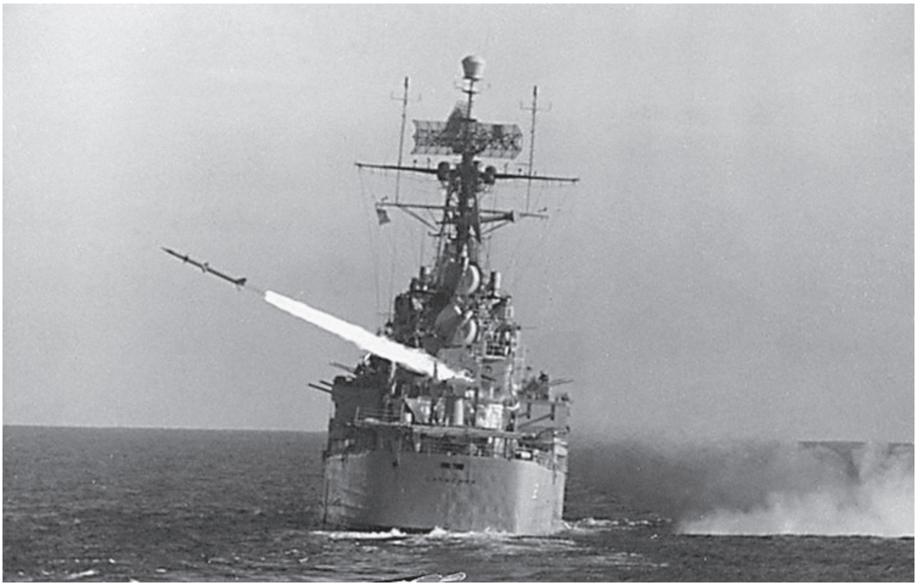
Rear Admiral Reich's "Get Well" team began work in the wake of a spectacular failure. With President Kennedy watching, the new missile frigate *Dewey* fired three Terriers at a propeller drone, one after another—and all missed. Subsequently the team outlined, in broad terms, remedial steps for the 3 Ts: First, redesign components and provide ample spare parts to increase missile reliability. Second, concentrate on the accumulation of data and thorough training of missile crews to improve operating procedures. Third, make missiles perform better after launch. Evaluators found that battery alignment and transmission checks often were perfunctory because crews wrongly assumed that missiles would guide themselves to their targets.[91]



Terrier missiles on launchers, USS *Boston* (CAG–1), while the ship was moored in Beirut, Lebanon (*Naval History and Heritage Command*)

Gains came slowly. In October 1963, for example, cruiser *Albany* conducted 15 Talos firings; 5 were successful. Because Talos had been designed 8 to 12 years earlier, the "Get Well" team limited improvements to component replacement and minor system modifications. Tartar's testing record showed satisfactory operation at the outset but a deterioration in reliability as operations continued. For Terrier, flight reliability had improved enough so that the requirements for FY 1964 rose to 72 percent for older and 85 percent for newer versions.[92]

By late 1966, $2 billion had been spent deploying and producing the 3 Ts, plus $350 million to correct the faults of those already installed; another $550 million had been programmed for their modernization. During FY 1966, slightly more than half the Tartars and Terriers fired during FY 1966 hit their targets, while the success rate for Talos stood at only 35 percent. Technicians provided Talos with a feature that made the enemy's electronic jammers act instead as magnets for U.S. missiles. Off North Vietnam, the record was good but not perfect. During 1968, Talos missiles launched by *Long Beach* twice downed MiGs about 60 miles away. But, in separate episodes, a MiG escaped two Terriers launched from the frigate *Jouett*, while *Long Beach* apparently fired five Talos missiles in vain.[93] In 1972, the missile frigates *Biddle* and *Sterret* claimed kills by their Terriers.[94]



USS *Canberra* fires a Terrier missile during First Fleet demonstrations for Secretary of the Navy Paul H. Nitze off the West Coast, December 1963 (*Naval History and Heritage Command*)

Effective detection and tracking were crucial. In 1957, the Applied Physics Laboratory had begun developing a Typhon system able to track hundreds of targets and guide as many as 30 missiles against 30 different targets simultaneously. In July 1962, Rear Admiral Reich calculated that letting a contract for a Typhon-carrying frigate during FY 1963 meant that the system would have to be ready for installation about two years later—a deadline that was impossible to meet. Reich found, for example, that Westinghouse faced significant difficulties putting together even a prototype. As late as 1964, only a very small model of Typhon was available at the Applied Physics Laboratory. Accordingly, McNamara terminated all parts of the program save one. The radar, Typhon's most advanced component with electronically steered beams that could guide as well as search, was put aboard the converted seaplane tender *Norton Sound* and tested for several years.[95]

One portion of the "Get Well" program involved creation of a Standard missile, replacing Tartar and Terrier with a common airframe. Late in 1963, the Navy also began to define an Advanced Surface Missile System (ASMS). Rear Admiral Reich awarded six-month ASMS study contracts to seven organizations; prime contractors joined with other firms to create teams. Boeing teamed with Bendix, while Sperry Rand teamed with General Dynamics and Northern Ordnance. From his experience with the 3 Ts, Reich drew the lesson that those tasked with developing a tactical missile system needed a thorough understanding of ship architecture and shipbuilding. Thus, the design firm of Gibbs and Cox teamed with Space Technology Laboratories, Northern Ordnance, ITT, Westinghouse, and RCA.[96]

Early in 1965, Reich organized an assessment group to appraise the seven studies of ASMS. Rear Adm. Frederic S. Withington, a former chief of the Bureau of Ordnance, was recalled from retirement to head the group. The president of Operations Research, Inc., in Maryland, J. Emory Cook, served as technical director. Other members included approximately a dozen Navy officers and 20 senior civil servants, 5 or 6 officers and civilians from Army Missile Command, and about 60 specialists from industry and private laboratories. The group recommended developing ASMS in an evolutionary manner, at first using the Standard's airframe and launcher. In March 1967, the Navy awarded General Dynamics a five-year production contract for Standard, which featured solid-state electronics and an improved inertial guidance system. In December 1969, RCA won a multiyear contract for what was now called the Aegis air defense system, which included Standard but would incorporate new radar and fire control systems.[97]

The need for better antiair defense was grimly highlighted on 25 October 1967, when four Soviet-made Styx missiles fired from Egyptian torpedo boats sank the Israeli destroyer *Eilat*. The Soviets were installing even more advanced missiles on their own warships. A Navy study completed in July 1968 concluded that one hit from a cruise missile might cause as much as $50 million in damage. An effective defense would need to be airtight.[98]

Could blame be assigned to the low priority given surface combatants during the 1960s for the 3 Ts' long-running troubles? Some, like Admiral Moorer, said Polaris and Poseidon moved ahead so quickly because the Navy poured its top talent into those efforts and starved other programs. But Polaris's technical challenges were quite different from those posed by the 3 Ts. In every sphere, reliable defensive missile systems proved to be harder to create than their offensive counterparts. The equivalent of Rear Admiral Raborn's hand-picked officers might not have improved the 3 Ts any faster than had Rear Admiral Reich and his "Get Well" team.

* * * * *

The Navy contained what have been called three separate unions: aviators, surface warriors, and submariners. Their missions and weapons were quite different, as were their approaches to acquisition. The managerial solutions found by one "union" were not, and very likely could not be, applied to another. Thus, while the Special Projects Office's handling of Polaris and Poseidon was exemplary, Rear Admiral Reich did not believe that its methods could be used to develop the Standard antiair missile.

Programmatically, the record appears mixed. *Permit* and *Sturgeon* submarines ran slower than Soviet *Victor*s and *November*s, but the *Los Angeles* class regained the lead in overall performance. For torpedo development, the Mark 48's long delay and substantial cost overrun attracted congressional attention, but the ADCAP Mod 3 version was a fine weapon. As to the management of ASW programs, a panel of the President's Science Advisory Committee was severely critical, reporting in April 1966 that it saw "little evidence of *effective* testing, analysis, evaluation or decision-making." It gained the impression that, instead of responding to current and projected realities, "our ASW posture is largely a residue of tradition, of history, and of considerations of 'balanced forces'." Therefore, it "is very poor in relation to what we should expect from a program which costs the nation approximately $3 billion per year." Emphasis on quantity, according to the panel, resulted in neglect of quality.[99] OSD and the Navy appraised the ASW effort much more favorably, judging that the Soviet submarine threat could be defeated within a few months and without major U.S. losses.[100]

The sophistication of naval technology increased considerably during the first two decades of the Cold War. Although the overall record of Navy acquisition in the 1960s was impressive, building new systems and incorporating advances in electronics and nuclear technologies into existing systems was not easy. Development and production difficulties, cost overruns, and performance shortfalls were frequent, yet they were seen as problems to overcome, rather than reasons to temper the effort to maintain a qualitative lead over the Soviet Union in warships and weapons.

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2. Norman Polmar and Kenneth J. Moore, *Cold War Submarines* (Washington, DC: Brassey's, 2004), 164, 172.
3. Norman Friedman, *U.S. Destroyers* (Annapolis, MD: Naval Institute Press, 1982), 363–364.
4. Booz, Allen & Hamilton, Inc., *Review of Navy R&D Management 1946–1973*, vol. I, 1 Jun 76, 5, 48; Weir, *Forged in War*, 48, 102.
5. John H. Rubel, *Memoirs III: Time and Chance, 1959–1976* (Santa Fe, NM: Key Say Publications, 2006), 283–284.
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7. Booz, Allen & Hamilton, *Navy R&D Management*, vol. I, 105, 46, 77–80, 85.
8. Ibid., 210–211.
9. Ibid., 235, 83, 104, 236–237.
10. Email, Frosch to Poole, 24 Feb 07.
11. Paul H. Nitze, "Running the Navy," U.S. Naval Institute *Proceedings* 115, no. 9 (September 1989): 72.
12. Booz, Allen & Hamilton, *Navy R&D Management*, vol. I, 78–80, 85–86.

13. The new command replaced the Naval Material Shore Establishment. Galantin was promoted to four-star rank in 1967 and served as chief of naval material until his retirement in 1970.

14. An exception was the chief of naval research, a rear admiral who reported to the secretary of the Navy—in practice, to the assistant secretary (R&D). Ibid., 86–89; email, Frosch to Poole, 24 Feb 07; Scott McDonald, "How the Decisions Were Made: Exclusive, Inside Story of Navy Reorganization," *Armed Forces Management* 12, no. 8 (May 1966): 74–79. In 1974, Ship Systems Command changed to Sea Systems Command.

15. Interviews, John T. Mason with Rear Adm. Ralph K. James, 1971–1972, 373, Naval Historical Center; Booz, Allen & Hamilton, *Navy R&D Management*, vol. I, 90–91.

16. Friedberg, *In the Shadow of the Garrison State*, 260–264; John D. Alden, "The Case for Navy Shipyards," *Armed Forces Management* (February 1965): 40–43. According to Rear Admiral James, who was chief of the Bureau of Ships during 1959–1963, the Navy yards' machinery and equipment had become badly outdated. A 10-year, $200 million modernization program was begun but then cut back. James interview, 313, 318.

17. Rubel, *Time and Chance*, 285.

18. House Armed Svcs Cte, *Hearings on Military Posture*, 90 Cong, 2 sess, 1968, 909–910.

19. Institute for Defense Analyses Report R–120, "An Economic Analysis of U.S. Naval Shipbuilding Costs," December 1966, 31, 37, 48, 42, 69, 77, 68, 30, fldr Shipbuilding/Merchant Marine, box 110, Glass Papers, RG330, OSD/HO; Rubel, *Time and Chance*, 297, 300–305.

20. House Armed Svcs Cte, *Hearings on Military Posture*, 90 Cong, 1 sess, 1967, 645–660 (quotations, 646–647, 657, 660).

21. "Final Draft Memo for the President on FY 68–72 Shipbuilding Practices," 10 Mar 67, OSD/HO.

22. Rubel, *Time and Chance*, 297–305.

23. Among the competitors, probably only Newport News, because of its record in building aircraft carriers, had expertise in carrying a completed design from the concept stage through production. Ltr, John Rubel to W.S. Poole, 24 Oct 08.

24. Rubel, *Time and Chance*, 286–287, 315. Rubel was a vice president at Litton, overseeing the Pascagoula project.

25. Ltr, Rubel to Poole, 24 Oct 08. According to the business journalist William S. Rukeyser, in "Litton Down to Earth," *Fortune* (April 1968): 140, Litton's core concept was that "talented general managers, applying general management techniques, can effectively oversee diverse businesses in which they have no specific experience." Email, Frosch to Poole, 24 Feb 07. On the work force, see interview, W.S. Poole with Charles A. Bowsher, 3 May 04, 15–20, CMH. Norman Friedman, *U.S. Amphibious Ships* (Annapolis, MD: Naval Institute Press, 2002), 370–378, gives a detailed description of LHA design.

26. Polmar and Moore, *Cold War Submarines*, 58, 76; *Jane's Fighting Ships, 1969–1970*, 443.

27. *George Washington* was created from a *Skipjack* hull; a 130-foot missile section was inserted amidships. Electric Boat sent 15 engineers to Washington, where they collaborated with the Bureau of Ships in preparing contract designs. Weir, *Forged in War*, 251. Beginning with *Ethan Allen*, the sixth fleet ballistic missile submarine laid down, all such vessels were designed from the keel up to carry Polaris missiles.

28. Francis Duncan, *Rickover and the Nuclear Navy* (Annapolis, MD: Naval Institute Press, 1990), 7; email, Frosch to Poole, 24 Feb 07.

29. Interview, Poole with Bowsher, 3 May 04, 10.

30. Email, Frosch to Poole, 29 Sep 05. Paul Ignatius, secretary of the Navy during 1967–1969, "detested" Rickover's methods but believed that "the nation was in his debt." Ignatius, *On Board*, 164. Rear Admiral James described his dealings with Rickover as "a distasteful association" with "a man I have never trusted." James interview, 290.

31. Duncan, *Rickover and the Nuclear Navy*, 5. Rickover's responsibility extended to "the

entire propulsion system for a ship that was the first to use a particular reactor. For later ships he had cognizance only over the reactor and its associated systems; other parts of the [Bureau of Ships] had responsibility for the remaining portion." Ibid., 22.

32. Ibid., 18. In the designation S5W, "S" stood for submarine and "5W" for the fifth model designed by Westinghouse. A pressurized-water plant worked as follows: Within the reactor, U–235 elements began bombarding each other as the control rods inserted between the fuel rods were withdrawn. Pressurized water, the medium for transferring heat from the core to a turbine, was contained in two separate loops. In the primary loop, water circulated through the reactor core to a steam generator, where it gave off its heat to a secondary loop of uncontaminated water which flashed into the steam that drove the turbines. Ibid., 3–4. Patrick Tyler, *Running Critical* (New York: Harper and Row, 1986), 39.

33. Duncan, *Rickover and the Nuclear Navy*, 52–55. The figure of 1,300 feet comes from Polmar and Moore, *Cold War Submarines*, 150. Weir, *Forged in War*, 221.

34. Duncan, *Rickover and the Nuclear Navy*, 55–56; Weir, *Forged in War*, 221–225, 261–262.

35. Duncan, *Rickover and the Nuclear Navy*, 59–61. Brazing consists of soldering with an alloy that is relatively infusible.

36. Ibid., 56–57; Weir, *Forged in War*, 221–223.

37. Duncan, *Rickover and the Nuclear Navy*, 64, 66, 73–74.

38. Ibid., 87–89, 95–96; *Jane's Fighting Ships, 1969–1970*, 441–442.

39. Duncan, *Rickover and the Nuclear Navy*, 22–23.

40. Ibid., 28–31; Senate Cte on Armed Svcs, *U.S. Submarine Program*, 90 Cong, 2 sess, 118.

41. "Record of Decision" memo, Sec McNamara to President Johnson, "Submarine, Anti-Submarine, and Destroyer Forces," 12 Jan 68, 8, binder "DPMs, FY 1969," box 121, Glass Papers, RG 330, OSD/HO.

42. Duncan, *Rickover and the Nuclear Navy*, 35, 34.

43. Tyler, *Running Critical*, 38–44 (quoted passage, 44); Duncan, *Rickover and the Nuclear Navy*, 35–36; Polmar and Moore, *Cold War Submarines*, 76–77. The Soviets' *Victor*-class attack submarine entered service in 1967–1968.

44. Duncan, *Rickover and the Nuclear Navy*, 38–41; Polmar and Moore, *Cold War Submarines*, 267–271; Tyler, *Running Critical*, 61–71. Congress also funded the "quiet" *Glenard P. Lipscomb*. Commissioned in 1974, it proved to be the only electric-drive submarine.

45. Draft, "Torpedo Development and Production," 2 Oct 67, 1–2, fldr Torpedoes/ASW Weapons Study (10–2–67), box 110, Glass Papers, RG 330, OSD/HO; Frederick J. Milford, "U.S. Navy Torpedoes, Part Four," <www.geocities.com/Pentagon/1592/ustorp4.htm>; Tom Pelick, "U.S. Navy's First Active Acoustic Homing Torpedoes," <www.personal.psu.edu/faculty/p/q/pq9/active.html>; email, Tom Pelick to W.S. Poole, 24 Jan 06.

46. *Jane's Naval Weapon Systems*, issue 34, 467.

47. Interview, Dr. Joseph Marchese with Bernard Abrams, 28 Aug–5 Sep 89, 40–48, 53, 57, Naval Historical Center.

48. Interview, Dr. Joseph Marchese with Robert Blouin, 1 Aug 89, 4–7, Naval Historical Center.

49. Blouin interview, 9–11. Westinghouse later sued the government, claiming that contract requirements were beyond the state of the art. An out-of-court settlement was reached.

50. Interview, Dr. Joseph Marchese with Rear Admiral Jeffrey C. Metzel, USN (Ret.), 17 Jul 89, 4–5, Naval Historical Center. The test facility sent its classified data to the Naval Ordnance Laboratory, White Oak, Maryland, which took three weeks. But in that interval, the firing team was charged with making as many torpedo runs as possible, so the same problems kept recurring. Email, Pelick to Poole, 24 Jan 06.

51. Interview, Dr. Joseph Marchese with Victor Dawson, 9 Aug 89, 2, Naval Historical Center; Abrams interview, 59–63, 70; "Torpedo Development and Production," 4–6.

52. Abrams interview, 65; Metzel interview, 8; email, Pelick to Poole, 31 Jan 05.

53. The Mod 1 was fired against targets moving at medium speed, without evasive maneuvers or countermeasures. Westinghouse's Mod 2 did undergo three weeks of testing against comprehensive countermeasures and performed quite successfully. However, the Navy decided to exclude those runs from its scoring and analysis. Abrams interview, 77, 79, 83–84; Metzel interview, 13–15; emails, Pelick to Poole, 31 Jan 05 and 8 Jul 06. Gould/Clevite's Mod 1 had comb filters, enhancing the signal-to-noise ratio and allowing tracking by target angle as well as range, while Westinghouse's Mod 2 had superior resistance to countermeasures. Pelick, who spent most of his career with ORL, believed the Navy made a serious error by not combining the best features of both torpedoes, as was done eventually, but much later.

54. "MK–48 Torpedo Cost Estimate History," atchmt to memo, Vice Adm. Shear to CNO, 21 Jan 72, fldr 8000, Jan-Apr 72, box 148, Op-00 Subject Files (1972), 7121 through 8000 (Jan-Apr), Naval Historical Center.

55. Memo, Vice Adm. Shear to CNO, "Situation Report on the MK 48 Torpedo Operational Evaluation," 29 Oct 71, fldr 5, "MK 48 Torpedo," box 165, Op-00 Subject Files (1971), 8500 to 8800, Naval Historical Center; memo, George Halvorson to the Chief of Naval Material, "MK 48 Torpedo Production," 15 Dec 71, fldr 8500 June-July, box 150, 8500 (Jan-Jul), Op-00 Subject Files (1971), Naval Historical Center; Abrams interview, 87.

56. A warshot torpedo had a full fuel tank and explosive material. The lightweight torpedo used for most tests lacked explosive material and carried only half as much fuel. Email, Pelick to Poole, 23 Jul 06.

57. Memo, Adm. Cousins to Under SecNav, "MK 48 Torpedo Program," 21 Jan 72; "Proposed Response to Mr. Jack Anderson's 26 March 1972 Article on the MK 48 Torpedo," atchmt to memo, Vice Adm. Shear to CNO, 19 Mar 72, both in fldr 8500 (Jan-Mar), box 150, Op-00 Subject Files (1972), 8500 (Jan-July), Naval Historical Center; memo, CNO to Sec Nav, "Status Report on MK 48 torpedo; submission of," 11 Dec 73, fldr 8000 Oct, box 109, Op-00 Subject Files (1973) 8000 (Apr-Dec), Naval Historical Center.

58. Basically, according to Norman Friedman, "in a conventional ship the hull is designed to minimize resistance at cruising speed, about 20 knots, to achieve maximum endurance . . . balanc[ing] power plant efficiency at cruising speed against the need for much more power at maximum. However, a [nuclear] plant that can operate indefinitely at cruising speed permits a hull design optimized for the high-speed end of the performance envelope." Friedman*, U.S. Destroyers*, 341.

59. For a more complete comparison of the relative advantages and disadvantages of conventional and nuclear-power aircraft carriers, see U.S. General Accounting Office, "Navy Aircraft Carriers: Cost-Effectiveness of Conventionally and Nuclear-Powered Reactors," GAO/NSIAD-98-1 (August 1998).

60. Malcolm Muir, Jr., *Black Shoes and Blue Water* (Washington, DC: Naval Historical Center, 1996), 91–92; Duncan, *Rickover and the Nuclear Navy*, 101; James M. Roherty, *Decisions of Robert S. McNamara* (Coral Gables: University of Miami Press, 1982), 149.

61. Duncan, *Rickover and the Nuclear Navy*, 103–107, 123.

62. Ibid., 108, 113–114.

63. Ibid., 119, 125, 129.

64. Ibid., 118–119. The Hayward quotation appears in Roherty, *Decisions of Robert S. McNamara*, 153–155.

65. Duncan, *Rickover and the Nuclear Navy*, 120, 129–130.

66. Ibid., 131–132. The sentence about the Naval Research Advisory Committee comes from Roherty, *Decisions of Robert S. McNamara*, 154.

67. McNamara's assumption about greater cost might have been wrong. Nuclear-powered ships cost more to build, but their greater reliability minimized maintenance and repair, possibly making them cheaper over a complete life cycle. Email, Frosch to Poole, 24 Feb 07.

68. Duncan, *Rickover and the Nuclear Navy*, 133–136, 142; Roherty, *Decisions of Robert S.*

McNamara, 155–158.

69. Duncan, *Rickover and the Nuclear Navy*, 144–146. Information provided by Dr. Edward Drea, OSD/HO.

70. Duncan, *Rickover and the Nuclear Navy*, 148–153; *FRUS 1964–1968*, vol. 10, 482.

71. Duncan, *Rickover and the Nuclear Navy*, 154.

72. Ibid., 158–159; Elmo R. Zumwalt, Jr., *On Watch* (New York: Times Book Co., 1976), 101–104. Zumwalt cites a figure of 16 to 19 frigates (103). As CNO during 1970–1974, he promoted a "high/low" mix of ships and tangled frequently with Rickover.

73. Duncan, *Rickover and the Nuclear Navy*, 160–162; Friedman, *U.S. Destroyers*, 319–320, 341–342.

74. Duncan, *Rickover and the Nuclear Navy*, 160–162. A *California*-class frigate carried two Tartar surface-to-air missile launchers, one antisubmarine rocket launcher, and two 5-inch guns. In addition to those systems, a *Virginia*-class frigate carried two helicopters. Each ship displaced roughly 10,000 tons. *Jane's Fighting Ships, 1977–1978*, 582–583.

75. Friedman, *U.S. Destroyers*, 350, 285; Muir, *Black Shoes and Blue Water*, 78, 81.

76. Draft memo, Secretary McNamara to President Johnson, "Navy Shipbuilding and Conversion Program," 11 Dec 63, in binder "Recommended FY 1965–FY 1969 Defense Programs," box 117, OSD/HO.

77. Friedman, *U.S. Destroyers*, 362, 355, 357, 473–475; *Jane's Fighting Ships, 1971–1972*, 483, 480.

78. Friedman, *U.S. Destroyers*, 360.

79. Ibid., 318, 360; *Jane's Fighting Ships, 1971–1972*, 481–482; *Jane's Fighting Ships, 1977–1978*, 604–605; Capt. Robert H. Smith, USN, "A United States Navy for the Future," U.S. Naval Institute *Proceedings* 97, no. 3/817 (March 1971): 22.

80. Friedman, *U.S. Destroyers*, 362.

81. Ibid, 362–368.

82. Ibid., 318–319 (quotation, 319); memo 162–66 by CNO, fldr Yellows, Jan-Apr 1966, #1–194, box 145, Op-00 Files (1966), Naval Historical Center (copy provided by Dr. Edward Drea).

83. Friedman, *U.S. Destroyers*, 369–374.

84. Ibid., 374–377; Muir, *Black Shoes and Blue Water*, 188 (quotation, 192); *Jane's Fighting Ships, 1981–1982*, 654.

85. Norman Friedman, *U.S. Naval Weapons* (London: Conway Maritime Press, 1983), 152–154; *Jane's Weapon Systems, 1976*, 121–122; Friedman, *U.S. Destroyers*, 219–223; Muir, *Black Shoes and Blue Water*, 99–104.

86. Muir, *Black Shoes and Blue Water*, 105; interviews, John T. Mason with Vice Adm. Eli T. Reich, USN (Ret.), 1978–1979, 468–475, Naval Historical Center.

87. Muir, *Black Shoes and Blue Water*, 139.

88. Ibid.; Reich interview, 507–508, 498, 545–548.

89. According to Paul Nitze, secretary of the Navy during 1963–1967, "the basic problem was that the technology was constantly being upgraded; designs never became frozen. For example, the design of the Terrier system . . . was different from one ship to the next, and no one seemed to be able to maintain an accurate and reliable record of design differences." Nitze, "Running the Navy," 76.

90. Reich interview, 478, 523–526, 599, 565–566, 572. Rear Admiral Reich may not have fully understood how the Special Projects Office functioned. Within the office, a Steering Task Group drawn from government, industry, and academia supervised technical studies that defined the system's architecture.

91. Muir, *Black Shoes and Blue Water*, 138–140.

92. Memo, Asst SecDef (I&L) Thomas Morris to Director of Defense Research and Engineering et al., "Monthly Highlights–Major Programs–October 1963," 31 Oct 63, N–15 through N–18, box 974, OSD/HO.

93. *FRUS 1964–1968*, vol. 10, 496; Muir, *Black Shoes and Blue Water*, 140–141, 158. The final buy of Terriers and Tartars occurred in FY 1966; Bendix produced the last Talos in 1970. Muir, 176.

94. Friedman, *U.S. Naval Weapons*, 157.

95. Muir, *Black Shoes and Blue Water*, 141; Reich interview, 582, 586–588.

96. *Jane's Weapon Systems 1976*, 120; Friedman, *U.S. Destroyers*, 224; Reich interview, 588–590.

97. Reich interview, 591–592; Muir, *Black Shoes and Blue Water*, 141, 177, 182; Friedman, *U.S. Destroyers*, 224–225.

98. Muir, *Black Shoes and Blue Water*, 168–170, 174. The U.S. Navy's anti–surface ship missile, Harpoon, was still in the design stage.

99. *FRUS 1964–1968*, vol. 10, 378, 384–385 (quotations, 384). The SQS–26 sonar, installed on many surface combatants, supplied an example of shortcomings in quality control. SQS–26s often failed after a few hours of operation, needing days and sometimes weeks to repair. General Electric won a $35 million fixed-price contract to effect major improvements. Doing so actually cost $75 million; GE took a $10 million loss, while DoD absorbed the remaining $30 million of the overrun. Nitze, "Running the Navy," 75.

100. "Record of Decision" memo, Secretary McNamara to President Johnson, "Submarine, Anti-Submarine, and Destroyer Forces," 12 Jan 68, 8, 10, binder "DPMs, FY 1969," box 121, Glass Papers, RG 330, OSD/HO. According to Robert Frosch, assistant secretary of the Navy (R&D) during 1966–1967, the Navy had some success in trailing Soviet missile submarines, but keeping them under constant surveillance was very difficult, even dangerous, and absorbed large forces. Soviet attack submarines could be tracked fairly well, but converting detection into likely kills at close range appeared to be more difficult. Evidently, though, U.S. attack submarines could be quite effective in protecting convoys and carrier task forces. Email, Frosch to Poole, 25 Feb 07. A useful overview is Owen R. Cote, Jr., *The Third Battle* (Newport, RI: Naval War College, 2003), 40–48.

I. "President Orders Rickover to Leave Navy Atomic Post", *Current News, Weekend Edition*, 13-15 November 1981, fldr: Rickover, Box 590, OSD/HO; Norman Polmar and Thomas B. Allen, *Rickover* (New York: Simon and Schuster, 1982); Francis Duncan, *Rickover and the Nuclear Navy: The Discipline of Technology* (Annapolis: Naval Institute Press, 1990), 7-12, 49-50, 287-291; Admiral Hyman G. Rickover Biography. Available at: http://www.history.navy.mil/bios/rickover.htm (accessed 23 May 2012).

CHAPTER X

Space Ventures: A Mixed Record

When the Soviet Union placed the Sputnik satellite into orbit on 4 October 1957, it took the lead in the race to dominate space. As the United States sought to catch up, it had to determine the relative roles of manned versus unmanned operations as well as military versus civilian applications and control of space programs. While the Air Force sought to develop a reusable space glider and a manned orbiting laboratory (MOL) in the 1960s, the newly created National Aeronautics and Space Administration eventually assumed responsibility for manned space flight. Other than providing military pilots to fly NASA missions, DoD's contribution to the national space program ultimately would be limited to designing and building satellites and launch vehicles. This outcome, according to one NASA historian, reflected "the desire to make the American space program stand out as a positive, peaceful beacon for Western-style democracy."[1]

MISSION RIVALRY: DOD AND NASA

On 7 February 1958, four months after the launch of Sputnik, Secretary of Defense Neil McElroy established the Advanced Research Projects Agency. One of ARPA's major functions was to control all military space projects. In September 1959, McElroy made the Air Force responsible for developing, producing, and launching military space vehicles as well as for integrating their payloads. Air Force doctrine at that time defined *aerospace* as "an operationally indivisible medium consisting of the total expanse beyond the earth's surface." Air, ballistic missile, and space vehicle systems would all comprise "the fundamental aerospace forces of the nation."[2]

When NASA began operating on 1 October 1958, its statutory functions included carrying out "such activities as may be required for the exploration, scientific investigation, and utilization of space for peaceful purposes" and developing "space vehicles for use in such activities." While the Defense Department retained authority for developing such systems and conducting such space research and development as were "necessary to make effective provision for the defense of the United States,"[3] the potential for conflict between DoD and NASA was evident from the start of the civilian space program.

Shortly after his election, President Kennedy appointed a committee to assess the nation's space efforts. Jerome Wiesner, who would become Kennedy's special assistant for science and technology, served as its chairman. Reporting on 10 January 1961, the committee sharply criticized both NASA's management of its space efforts and what it called DoD's "fractionated" space program. It recommended that the Air Force take responsibility for all space systems "except those of a purely scientific nature assigned by law to NASA." On 6 March 1961, Secretary McNamara made the Air Force responsible for all research, development, testing, and engineering of DoD space development programs. Within the newly established Air Force Systems Command, General Bernard Schriever responded by creating a Space Systems Division to manage the effort. But delineating military from "purely scientific" space systems would not prove easy.[4]

CANCELLATIONS: DYNA-SOAR AND THE MANNED ORBITING LABORATORY

The promise of hypersonic flight at five or more times the speed of sound opened the possibility of delivering weapons and conducting reconnaissance by boost-glide, in which a rocket would lift or boost a piloted vehicle into orbit and the vehicle then would glide back to Earth. By autumn 1957, the Air Force was funding three studies by industry. The National Advisory Committee for Aeronautics (NASA's predecessor), also pursuing programs on its own, recommended that the Air Force sponsor development of a flat-bottomed, delta-winged, reusable glider. On 10 October 1957, the Air Force consolidated its three programs into Dyna-Soar, a name coined by combining "dynamic ascent" with "soaring flight."[5]

The Air Research and Development Command, AFSC's predecessor, worked out a three-step plan for Dyna-Soar. Step one involved developing a manned test vehicle to obtain flight data. In step two, a two-stage launch vehicle would boost a manned reconnaissance vehicle to 170,000 feet, from which it would glide to Earth over a range of 5,500 nautical miles. Step three would see a more sophisticated vehicle lifted into orbital flight. Thus, Dyna-Soar would progress from an experimental glider to a reconnaissance vehicle and ultimately to an aerospace bombardment system.[6]

Of nine contractor teams that submitted proposals, four were chosen to work as two teams. Martin and Bell proposed a two-man vehicle weighing 13,300 pounds and lifted by a modified version of Martin's Titan ICBM. Boeing and Vought proposed a 6,500-pound glider using solid-propellant units from the Minuteman ICBM. In June 1958, the Air Force decided on a 12- to 18-month competition between the two teams.[7]

ARDC looked upon Dyna-Soar as the prototype of a piloted military spacecraft. But the Eisenhower administration hoped to conclude a treaty barring weapons of mass destruction from outer space.[8] In November 1958, the assistant secretary of the Air Force for R&D warned that if Dyna-Soar was presented as a weapon system, OSD probably would terminate it. A month later, OSD agreed to fund Dyna-Soar strictly as an R&D project. In April 1959, the DDR&E established Dyna-Soar's primary goal as the suborbital exploration of hypersonic flight—in other words, a research project. Yet ARDC continued to champion its military use, defining Dyna-Soar in May as potentially a boost-glide weapon system that could provide research data about flight characteristics.[9]

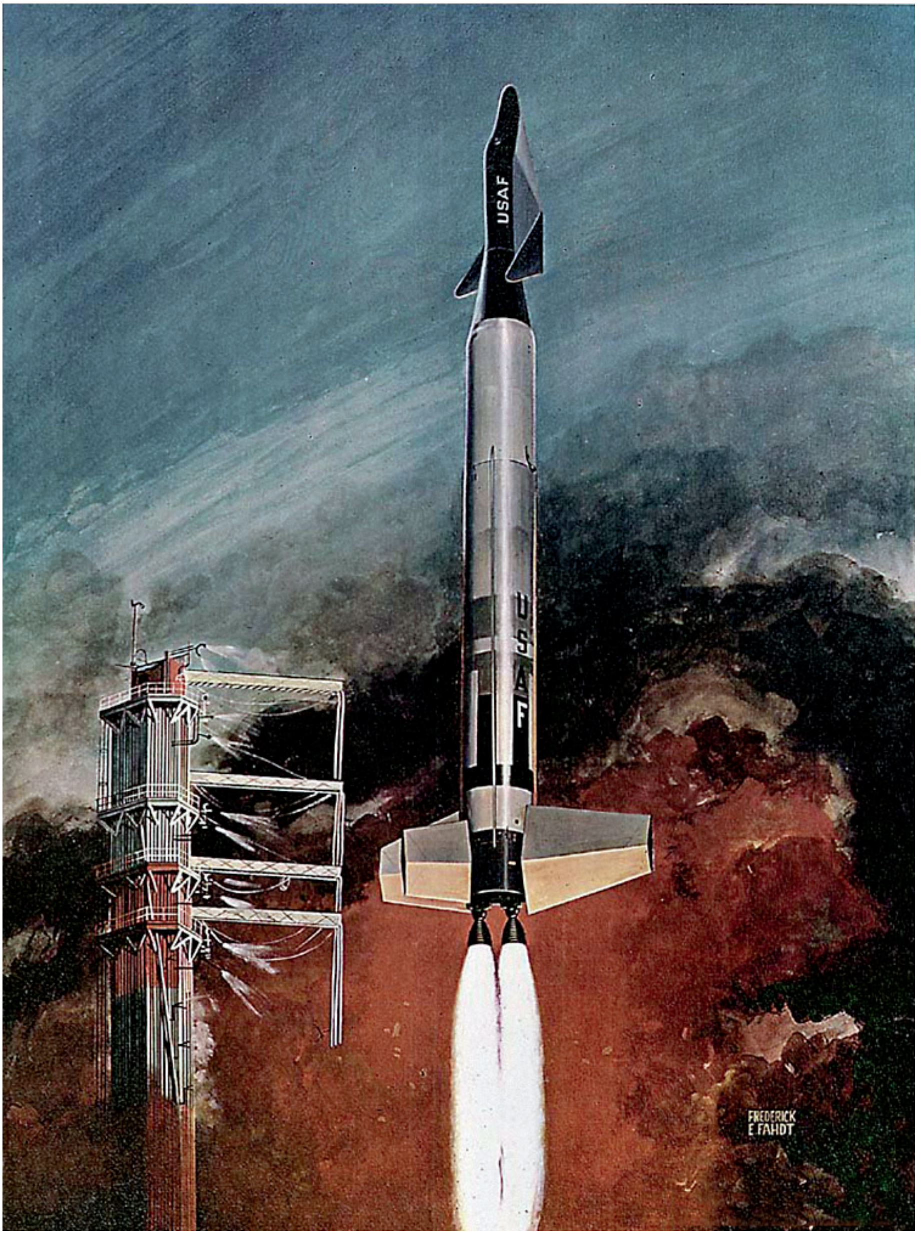
In November 1959, the Air Force announced that Boeing, with its delta-wing design, had won the prime contract. Martin became an associate contractor and gained responsibility for developing the launch vehicle. Bell, whose work had inspired much of the program, won some subcontracts. Vought's share primarily involved work on the nose cap. Ultimately, Dyna-Soar would resemble Bell's original concept more closely than the winning Boeing-Vought entry.[10]

Air Force headquarters directed ARDC to start step one. But Assistant Secretary of the Air Force for R&D Joseph V. Charyk ruled against obligating funds pending completion of a new study, called Phase Alpha. When finished, Alpha conceived a low-wing, delta-shaped glider weighing about 10,000 pounds. Step one was expanded to encompass four objectives: explore regions of maximum heating, investigate maneuverability during reentry, demonstrate conventional landing, and evaluate how well humans could function during hypersonic flight. OSD released funds on 22 April 1960. Five days later, the Air Force completed a letter contract with Boeing.[11]

Pressed by Air Force headquarters, the Dyna-Soar project office proposed combining step one with the first part of step two, which would involve sending a reconnaissance vehicle to 170,000 feet. Success could advance a manned orbital launch by as much as 17 months. In May 1961, Boeing presented what it called a "streamline" plan for accelerating Dyna-Soar. Choosing the right launch vehicle would be key. In 1959, DDR&E Herbert York had inquired about the development of a booster for Dyna-Soar that would also serve as a second stage for NASA's Saturn moon rocket. The Ballistic Missile Division of ARDC judged that approach to be infeasible. By the summer of 1961, the Dyna-Soar program office, consultants from the nonprofit Aerospace Corporation, and the newly created Space Systems Division of Air Force Systems Command all favored using a version of Martin's Titan II ICBM for Dyna-Soar.[12]

In August 1961, Secretary of the Air Force Eugene Zuckert initiated the streamline plan, but problems soon appeared. A committee drawn from Air Force Systems Command, RAND, The MITRE Corporation, and the Air Force Scientific Advisory Board failed to draft a manned military space plan. The Air Force wanted to continue Dyna-Soar, but a group chaired by the Aerospace Corporation favored terminating it and tasking Boeing to develop a lifting vehicle.[13]

After hearing presentations on the system, Secretary McNamara questioned whether Dyna-Soar represented the best use of national resources. The Air Staff reacted by making a crucial change. Before trying to show any military applications, Dyna-Soar would demonstrate manned orbital flights and safe landings at preselected sites. This effort to rescue Dyna-Soar by narrowing the mission ultimately would doom it.[14]



Artist's concept of Dyna-Soar launch on Air Force Titan II rocket, 1961 (*Marshall Space Flight Center*)

On 7 October 1961, Dyna-Soar officials finished an abbreviated streamline plan. Eliminating suborbital flight meant that Titan II, previously approved for step one, no longer sufficed. The Dyna-Soar glider now had to be adapted to a Titan III–C because much greater engine thrust was needed to achieve Earth orbit. On 11 December, Secretary Zuckert agreed to compress the three steps into two, use Titan III–C, and define early attainment of orbital flight as the central objective. On 23 February 1962, McNamara gave his approval.[15]

McNamara saw potential in Gemini, a two-person space capsule being developed by NASA that could be put into orbit by Titan II. Late in 1962, he tried to take control of the Gemini project from NASA or at least gain a share in its management. Jerome Wiesner in the White House supported McNamara, but NASA thwarted them both, claiming that "a monolithic [DoD] effort would inevitably cause the total program to be characterized as military with substantial loss of flexibility in our international posture." In the end, an agreement signed in January 1963 established a NASA–DoD Planning Board to ensure that Gemini would respond to Defense Department interests and requirements.[16]

With Dyna-Soar and Gemini moving forward together, McNamara wanted to find out which system had more military potential. In May 1963, a subcommittee of the Defense Science Board strongly recommended continuing Dyna-Soar because it was "the only program that has among its major aims the thorough exploration of aerodynamic problems of hypersonic reentry flight, the development of reentry techniques in a piloted, maneuverable vehicle, and the confirmation of structural and materials design data for radiation-cooled structures." Gemini, the subcommittee contended, merited no DoD support "beyond adding a few simple experiments."[17]

Nonetheless, McNamara was turning against Dyna-Soar. In March 1963, after hearing briefings on Dyna-Soar, Gemini, and Titan III, he said that the Air Force was justifying Dyna-Soar through controlled reentry without defining any real objectives for orbital flight. Harold Brown, who had succeeded York as DDR&E, replied that it made no sense to describe orbital missions until Dyna-Soar proved the feasibility of controlled reentry. Unsatisfied, McNamara called for comparisons between Dyna-Soar and Gemini from the standpoints of conducting space reconnaissance, inspecting and defending satellites, and housing orbiting offensive weapon systems.[18]

An Air Force committee, working under the leadership of Space Systems Division in AFSC, argued that Dyna-Soar could adapt rapidly and with relative economy to test military subsystems and operations. For reconnaissance, Dyna-Soar could develop operational techniques and ground recognition ability, while Gemini was oriented toward rendezvousing and orbiting for long durations. Both Gemini and Dyna-Soar could be modified to carry out reconnaissance, inspection, satellite defense, and logistical missions. But neither provided a direct means of putting offensive weapons into orbit.[19]

Still unsatisfied, McNamara repeated his question: if Dyna-Soar had no purpose beyond demonstrating maneuverable reentry, how could spending $1 billion be justified? Changing his position, Brown on 14 November recommended canceling Dyna-Soar and developing, for about the same cost, a manned orbiting laboratory or space station promoted by NASA. At that point, 10 airframes for Dyna-Soar were on order. Secretary Zuckert made a final appeal to Brown, who retorted, "You want $1 billion for ten shots: that's $100 million per shot. What can you do that is worth $100 million?" The Air Force's Samos satellite imaging system, as he pointed out, would transmit images in near real time. "What," Brown wanted to know, "can you do that Samos can't?"[20] The Air Force had no satisfactory answer.

On 10 December 1963, McNamara publicly announced Dyna-Soar's cancellation. Its purpose, he said, had been to demonstrate maneuverable reentry and landing at a precise point, not to create a capability for conducting operations in space. More than $400 million had been spent, and another several hundred million dollars would be needed to achieve a very narrow objective. One mordant wit, channeling Edgar Allan Poe, captured the dismay among Boeing workers:

> Ah, distinctly I remember it was early last December.
> It was felt that very shortly we would be employed no more.
>
> *
>
> "Prophet!" said I, "Thing of evil! Tell me, agent of the devil,
> Whether McNamara axed the program or just cut it back some more?"
>
> *
>
> "Is there funding in the budget? Tell me, tell me I implore."
> Quoth the raven, "Nevermore."[21]

In September 1963, with NASA preparing a $3.5 million contract to study a manned orbital research laboratory, General Schriever's Space Systems Division also started conceptualizing a military version. McNamara and NASA Administrator James E. Webb agreed to coordinate studies and follow-on actions and to confine manned orbital requirements within a single project. Still, McNamara worried that NASA might move ahead with a design that did not meet the Defense Department's needs. He pressed for concurrence, rather than simple coordination, by one agency in the other's proposed actions.[22] Again, NASA successfully resisted.

In November 1963, Brown suggested developing a four-person reconnaissance station, using the Gemini capsule as a ferry vehicle. Titan III–Cs would launch the station and the capsule separately. A space panel of the President's Science Advisory Committee disagreed. In its judgment, the advantages of manned military reconnaissance systems had yet to be demonstrated. Nonetheless, when McNamara canceled Dyna-Soar in December, he authorized the Air Force to proceed with the MOL project but warned that it needed a clear military mission in order to win OSD and White House approval. Accordingly, the Air Force began developing experiments with a full range of military applications: early warning, ballistic missile defense, satellite detection and inspection, reconnaissance and surveillance of land and sea, and nuclear test detection.[23]

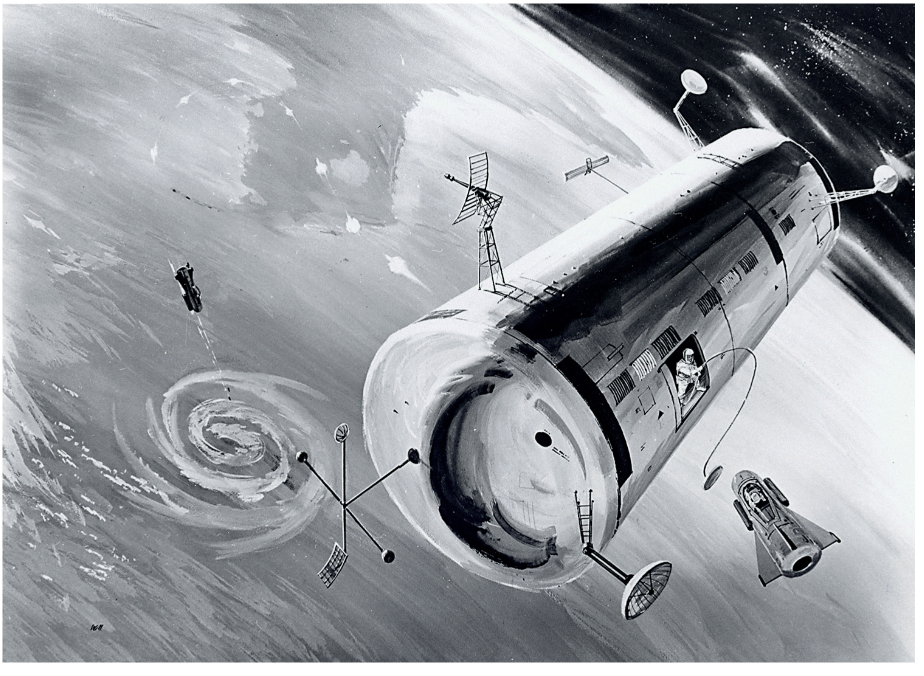
James E. Webb (*Great Images in NASA*)

Both the Air Force and OSD ruled that MOL would use proven hardware as much as possible, relying heavily on NASA's experience. Twelve firms submitted designs to the Space Systems Division. In February 1964, the Air Force awarded study contracts to Douglas Aircraft, Martin, and General Electric with the understanding that their responses would provide the basis of formal RFPs. A MOL management office, run by Col. R.K. Jacobson, was established under Air Force Systems Command. Brigadier General Joseph S. Bleymaier, who had been supervising Titan III, transferred to become deputy commander for manned systems in the Space Systems Division, directing the overall field-level program. As with Titan III, there was no prime contractor. Instead, the MOL management office created a control center that monitored aspects of the project as well as a daily schedule of status and review meetings.[24]

In May 1964, contracts were awarded to study system interfaces and integration. The Gemini capsule and the Laboratory Module had to be combined into an orbital vehicle that, in turn, had to be made compatible with Titan III–C. The equipment for planned experiments then would be integrated into the Laboratory Module. Despite objections from the MOL management office, McNamara decided that all contract studies would be fixed-price. Technical problems, however, forced costly redesigns of components, driving up overall contract costs and negating the benefits of fixed-price contracting.[25]

Late in 1964, NASA began promoting its Apollo Extension Program, or Apollo X, as a substitute for the MOL. Experimental requirements described by the Air Force and Navy, NASA claimed, could be carried out just as well by Apollo X. The Defense Department reacted by looking at ways to strengthen MOL's justification, such as sustaining a crew for 30 to 120 days or assembling a double MOL by tail-to-tail docking. The Navy even defined MOL's ocean surveillance experiment in a way that worked against merging it with Apollo X, while the Air Force proposed experiments to assemble radar antennae and large cameras in space. Interagency coordination existed only insofar as the Air Force informed NASA of its requirements and NASA advised when Apollo hardware would be available for Air Force purchase without disrupting NASA's lunar landing schedule. With open competition, the Air Force found itself unable to diverge far from the missions planned for Apollo X.[26]

In January 1965, the Air Force solicited proposals for designing an orbital vehicle. Seventeen companies responded. On 1 March, contracts were awarded to Boeing, Douglas, General Electric, and Lockheed. Each teamed with subcontractors—Douglas, for example, joined with IBM, Collins, and Sperry Rand. After a briefing on 2 June, McNamara wanted two teams to conduct more parallel studies. But events outpaced him. Three months earlier, a Soviet cosmonaut had made a 10-minute space walk. In June, a U.S. astronaut, Maj. Edward H. White II, took a 22-minute walk outside a Gemini capsule. Gemini's photographs of roads, buildings, and launch pads showed that MOL could help verify arms control agreements and gather intelligence. A subcommittee of the House Committee on Government Operations recommended starting full-scale development "without further delay." Accordingly, on 25 August 1965, President Johnson announced that MOL would proceed immediately at an estimated cost of $1.5 billion, with the first manned flight taking place in 1968.[27]



Artist's concept of Manned Orbiting Laboratory (*Great Images in NASA*)

To carry out contract definition, the Air Force distributed funds among five associate contractors. Douglas would create the MOL. General Electric would design and integrate the experiments, which included tracking ground and space targets, acquiring targets of opportunity, and making bomb damage assessments. McDonnell would produce five modified Gemini Bs, while Martin would build five Titan III cores, with United Technology Center supplying five pairs of solid-fuel rocket motors. The Air Force also created a high-powered supervisory structure, making General Schriever the MOL program director. Brigadier General Harry L. Evans, special assistant to the secretary of the Air Force for MOL, worked in the Pentagon as vice director. Brigadier General Russell A. Berg, as the deputy director, was assigned to Space Systems Division headquarters in Los Angeles.

By September 1966, contract definition was essentially completed, and Berg's office had negotiated engineering development contracts with the five associates. On 3 November, a Titan III–C lifted a Gemini B to 125 miles and 5,500 nautical miles down range, with the capsule landing about 7 miles off target. This mating of the launch and ferry vehicles was successful. By May 1967, contractors had finalized the design configuration of MOL/Gemini B hardware. The entire assembly would reach 72 feet in length with a gross weight of 30,000 pounds. Even with the extra power provided by a four-segment motor strapped on each side of the rocket core, Titan III–C could not provide enough lift. Development of a Titan III–M with seven-segment motors was deemed necessary. Delay in deciding whether to use a single source or competitive bidding for Titan III–M pushed back the MOL's timetable by eight months, helping to raise the total estimated cost to $2.2 billion.[28]

During 1968, even as major MOL components reached varying stages of completion, the budgetary squeeze created by the Vietnam War began taking a toll. Funding cuts by Congress postponed plans for the first manned flight until late 1971 or early 1972. Some congressmen called for saving money by merging DoD programs with those of NASA. In May 1969, a static test-firing of the seven-segment motor for Titan III–M was successful. But that was the last positive achievement. On 10 June, after a White House meeting, the administration announced cancellation of the MOL project, effectively ending the Air Force's institutional, military "man-in-space" program. The immediate justification lay in saving an estimated $1.5 billion. More important, unmanned satellites appeared able to perform most of the essential missions at a lower cost.[29]

WORKHORSE: TITAN III

What Secretary McNamara called the best managed program in the Defense Department originated in November 1959, when the Air Research and Development Command proposed developing a space launch vehicle distinguished by versatility and low cost. Preliminary work was assigned to TRW's Space Technology Laboratories and then transferred in August 1960 to the Aerospace Corporation.[30] Eight months later, General Schriever pointed to a lack of powerful rocket motors and boosters as a critical deficiency in the U.S. space program and a key reason why the Soviet Union appeared to be winning the space race.[31]

Early in May 1961, NASA and DoD jointly recommended setting a national goal of putting a man on the moon before the decade's end. On 25 May, President Kennedy publicly committed the United States to that mission, with NASA's Apollo program as its centerpiece. No existing systems, the two agencies determined, could satisfy the heavy-lift requirements for space flight. What new launch vehicles were needed? Might it be possible to create a single national fleet?[32]

John Rubel, deputy director of defense research and engineering, suggested creating a standardized "workhorse" able to lift either a 10,000-pound spacecraft into an orbit of 300 nautical miles or a 1,500-pound craft with enough velocity to escape the Earth's gravitational field. Atlas, Titan, and Minuteman ICBMs followed suborbital trajectories; all had warheads that were much lighter than any space vehicle would be. The Space Systems Division of Air Force Systems Command proposed using Titan II, the largest ICBM, and adding a solid-fuel auxiliary or booster to its core. The likelihood of using Titan II to lift the Dyna-Soar spacecraft was a prime consideration.[33]

On 7 July 1961, Secretary McNamara and NASA Administrator Webb established the Large Launch Vehicle Planning Group headed by Nicholas E. Golovin, NASA's deputy associate administrator, and Lawrence L. Kavanau, special assistant for space under the DDR&E. While the Air Force and DDR&E opinions diverged on sizes of payloads and heights of orbits, they agreed that there should be a new and more powerful space launch vehicle. Titan III could be created by using Titan II as its core and adding a strap-on, solid-fuel rocket motor to each side. A preliminary plan prepared by Space Systems Division and the Aerospace Corporation at Rubel's direction and completed on 5 October forecast a full-scale test flight in January 1964. The Golovin-Kavanau group recommended that NASA continue developing a giant Saturn C–1 rocket to carry out the moon mission. It also wanted the Air Force to press ahead with Titan III, filling the needs of NASA and DoD by lifting into low Earth orbit a payload between 5,000 and 30,000 pounds.[34]

Having defined distinct phases to guide the development of weapon systems, Rubel wanted Titan III to prove their utility.[35] Phase one would identify the principal areas of technical risk and specify "with considerable precision . . . the undertakings necessary to give a high confidence of success." Rubel insisted that major contractors set up centralized, project-type organizations dedicated entirely to Titan III. He also directed that R&D work statements distinguish the "definable," "uncertain," and "unknown" tasks on which cost estimates would be based.[36] Rubel further required the creation of PERT networks linking OSD, the system program office, and the contractors' internal operations. Finally, and quite importantly, he approved developing a standardized upper stage for launch vehicles. Colonel Joseph Bleymaier, who had extensive experience with space and missile projects, became the Air Force SPO director.[37]

Because Secretary McNamara made Titan III a test bed for managerial innovations, such as cost-plus-incentive-fee contracts, he placed the project under unusually close scrutiny. By the spring of 1962, four associate contractors had been chosen: Martin Marietta at Denver for the core vehicle and systems integration, AC Spark Plug for guidance systems, United Technology Center for large solid-fuel motors, and Aerojet General for the large liquid-fuel engines. There was no prime contractor. Instead, Bleymaier, by then a brigadier general, managed all facets of the program, working under the Space Systems Division and supervising 161 officers and civil servants at the system program office in Los Angeles.[38]

Intended to boost Dyna-Soar as well as serve as the second stage for Thor, Atlas, and Titan III launch vehicles, Agena D became a showpiece of commonality. Agena's ambitious objective called for a reliable second stage or booster at minimum cost in the shortest time. Remarkably, the initial delivery and launch dates were advanced by seven months.[39]

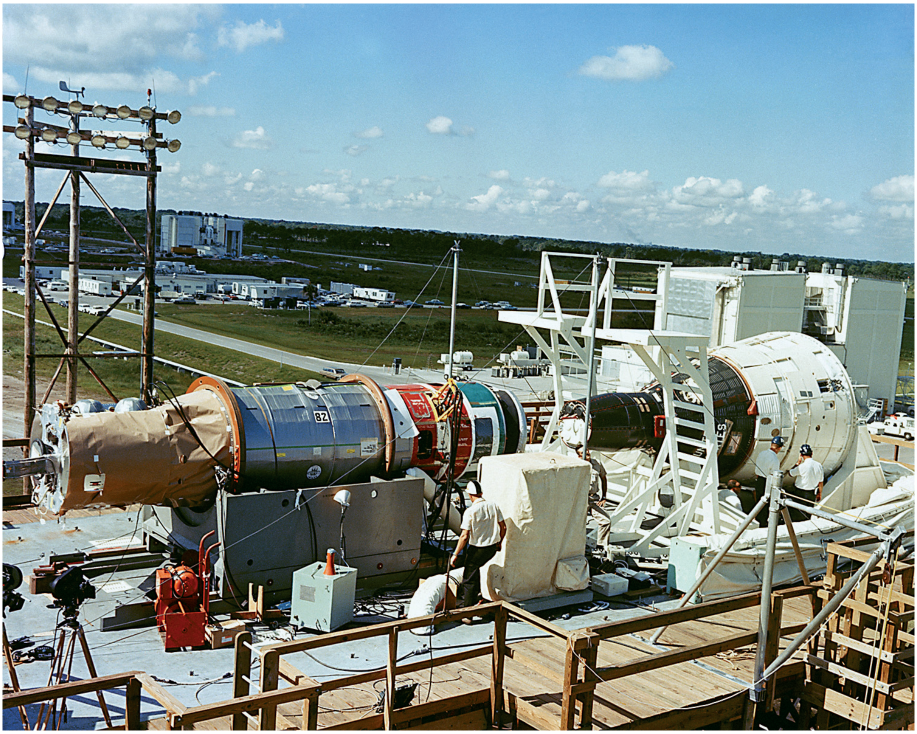
Maj. Gen. Joseph S. Bleymaier (*www.af.mil*)

From the outset, Agena D enjoyed two advantages. First, because it would be used in several programs, the project was awarded the highest national priority. Second, after giving initial approval, the DDR&E fully delegated implementation to the Air Force. Agena D was a small project; its technical objectives were straightforward and carefully defined. There was only one customer, Space Systems Division, and the work statement allowed maximum freedom. The engineering effort, essentially one of repackaging, involved no new or advanced state-of-the-art improvements. Judging schedule delays and technical problems to be unlikely, the Air Force accepted a high degree of concurrency.

In June 1961, Space Systems Division authorized Lockheed to begin design work for Agena D; a letter contract followed two months later. In October, Charyk, now under secretary of the Air Force, appointed a committee headed by Lockheed's vice president for engineering to investigate how to produce a more reliable Agena on an accelerated schedule. Acceleration could occur, the committee concluded, if unusual technical and contractual relationships were accepted. The Air Force subsequently established a program office that reported directly to the commander of Space Systems Division.[40]

At Sunnyvale, California, Lockheed ran what was in many respects "a company within a company," rather like the "skunk works" that had produced the U–2 spy plane. With all workers assigned to the same location, Lockheed's Agena program director was able to select those most qualified. The Air Force system program office director and his staff spent three days each week with Lockheed's engineers. The initial 12-vehicle contract was cost-plus-incentive-fee, switching to fixed-price incentive thereafter. The two teams completed a test vehicle on 31

March 1962 and launched the first Agena D on 27 June, nearly seven months ahead of schedule. Total costs for 12 vehicles came to $31.7 million, half the original estimate.



Agena D target vehicle and Gemini 6 spacecraft testing docking capability, 1965 (*Great Images in NASA*)

Admittedly, though, this style of management was unsuited to larger programs. Lockheed supplied only minimal documentation because, within the Air Force, only Systems Command used the Agena D. Vehicles would be launched shortly after they left the factory, always under the control of Systems Command and Lockheed personnel. By contrast, the C–141 transport also employed state-of-the-art technology but involved three Air Force commands: Systems, Logistics, and Training.[41]

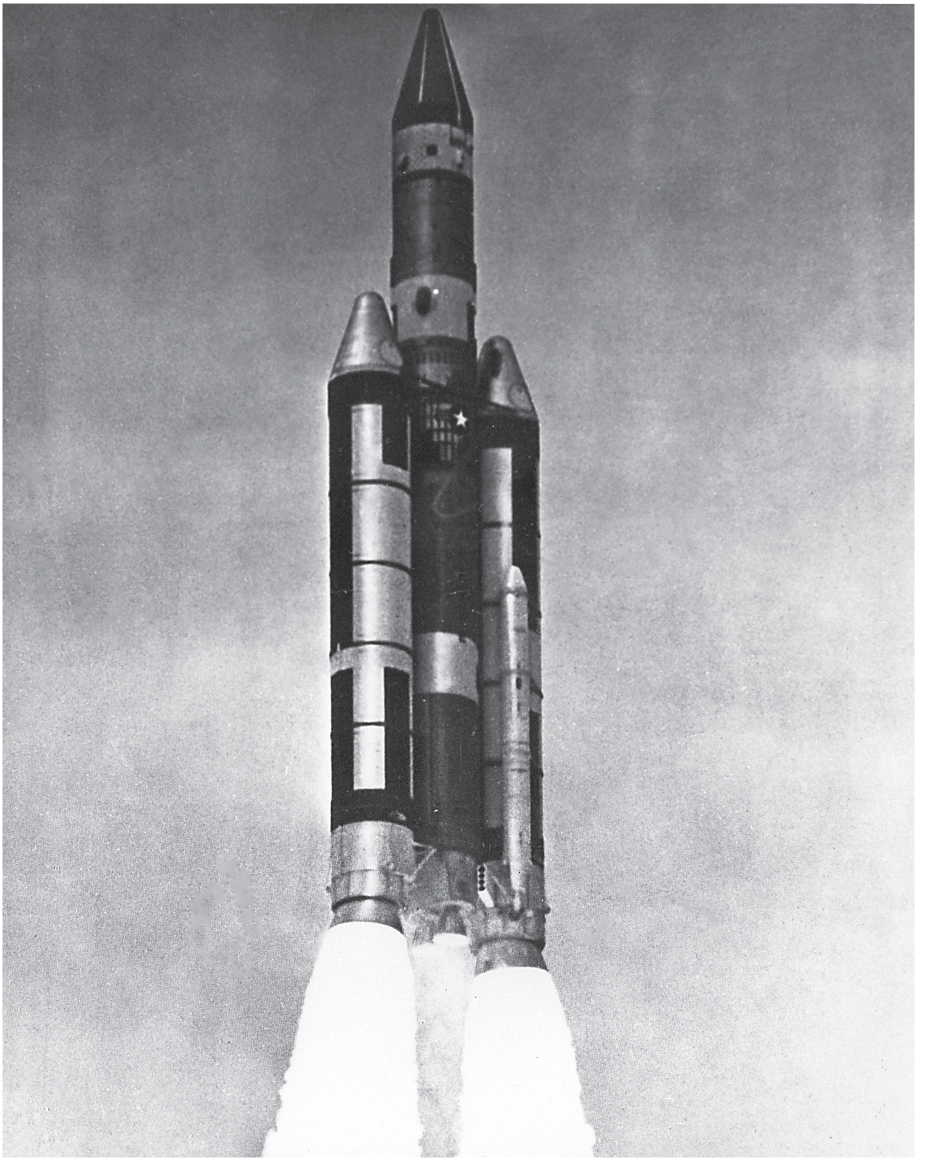
In sum, the Titan III emphasized reliability, simplicity, and conservative design. Its guidance system, for example, was carried over from Titan II. One departure did become necessary. Launching Dyna-Soar—at that time, the only mission assigned to Titan III—required four-segmented, slow-burning, solid-fuel motors, one strapped on each side of the core. The problem was that a Titan III–C with four-segment motors could place only 1,400 to 1,700 pounds of payload into 24-hour synchronous (stationary) orbit. But many space missions seemed likely to run into the 8,000- to 20,000-pound range. By the spring of 1962, moreover, McNamara had raised questions that put Dyna-Soar's survival in doubt. Accordingly, Rubel relegated Dyna-Soar's requirements to second place, behind an ability to lift either a very heavy payload into low orbit or a medium payload into geosynchronous orbit, moving from west to east so that it stayed over the same spot. That change prompted the development of fast-burning, five-segmented motors.[42]

By December 1962, all major contracts for Titan III had been finalized. However, the old guidance system proved to be inadequate. The weight of the inertial computer, its excessive consumption of power, and the limited flexibility of the airborne computer and inertial measurement unit led the Air Force to award AC Spark Plug a cost-plus-incentive-fee contract to upgrade its system.[43]

Then McNamara and the President's Science Advisory Committee raised a basic issue: was Titan III really worth continuing? What, for example, was the cost difference between launching a Titan III and a Saturn C–1? NASA saw no overwhelming need for Titan III. Low-orbit missions of Gemini and Apollo would be completed before Titan III became operational. NASA had scheduled 10 moon probes using the Atlas-Centaur combination of rocket and booster.[44]

The Air Force responded with a three-volume justification, claiming that Titan III would perform better than Saturn and was definitely cheaper at $11 million versus $18.9 million per launch.[45] Not surprisingly, NASA disagreed. Brigadier General Bleymaier then worked out a paper of understanding with a NASA representative. Acknowledging that statistical projections of reliability were far from absolute, the paper recognized that military requirements imposed performance specifications that Titan III alone could fulfill. By mid-June 1963, the program office completed a production plan.[46] July witnessed the first firing of a five-segmented motor. McNamara advised President Kennedy that, even if savings evaporated, Titan III still deserved to go forward. Among other things, it provided insurance that space payloads could be launched on very short notice.[47]

By mid-1964, with Dyna-Soar canceled, the Manned Orbiting Laboratory was the only payload assigned to Titan III. In contrast, numerous NASA and DoD programs were programmed for Atlas-Agena launch vehicles, and NASA continued its strong commitment to Saturn and Atlas-Centaur. Harold Brown, the DDR&E, informed McNamara that analyses by his office did not project substantial savings from using Titan III. Instead, the main benefits from the Titan III family lay in its adaptability for a variety of uses. Brown recommended assigning special project payloads to Titan III–Agena starting in 1966. Otherwise, NASA would press for using Saturn to lift heavy payloads, and DoD would "continually be plagued with the problem of incremental upgrading schemes." Brown expressed confidence in Titan III–Agena becoming a superior combination with more growth potential, for military purposes, than Atlas-Agena.[48]



Titan III–C launch (*Great Images in NASA*)

Fortuitously, Titan III found a critical mission. Project Advent, begun in 1958 by ARPA and then transferred to the Air Force and the Army Signal Corps, created a complex, power-hungry platform and a 1,250-pound communications satellite that was too heavy for available boosters to place in orbit. Concurrently, however, Hughes Aircraft invented spin stabilization, which eliminated much of Advent's requirements for power, weight, and space. Hughes also sponsored development of a lightweight traveling-wave tube, leading to the creation of a satellite weighing only 55 to 65 pounds. The Hughes synchronous communications satellite would go far toward revolutionizing global telecommunications.[49]

In 1962, McNamara canceled Advent and approved an Air Force plan to orbit lightweight satellites 5,000 miles above the Earth. Industry presented proposals relying on Atlas–Agena B vehicles. In August 1964, however, Titan III was chosen to send these satellites into much higher orbits. Titan III–A, identical to Titan II except for a stretched core and a small "transtage" consisting of an additional propulsive unit and a control module, first flew on 1 September 1964. Titan III–B, with an Agena upper stage and an ability to put 7,500 pounds into low Earth orbit, quickly followed. Titan III–C, using Agena D and the five-segmented, strap-on motors powerful enough to lift 28,000 pounds into orbit, made its maiden test flight in June 1965.[50] On 16 June 1966, a Titan III–C lifted 7 satellites 21,000 miles into near-synchronous equatorial orbits. So began the Initial Defense Satellite Communications System, which became fully operational with 26 satellites in June 1968.[51]

Thereafter Titan III performed a multitude of missions, truly becoming "the DC–3 of the space age."[52] Between 1964 and 1979, 111 of 119 launches were successful, validating the forecasts of its great reliability.[53] In the end, Titan III's development costs totaled $1.06 billion, which was quite reasonable when taking account of inflation, program changes, and a protracted process.[54] In the case of Titan III, fixed-price incentives worked because development followed a consistently conservative course. But the circumstances that made it successful would be difficult to replicate.

* * * * *

By 1969, many of the Air Force's dreams for space had evaporated. The service had hoped to exploit its standing as executive agent responsible for the "research, development, test, and engineering of satellites, boosters, space probes, and associated systems" necessary to support NASA projects. Instead, the lunar mission precipitated a rapid growth in NASA's funding and responsibilities. The Air Force was confined to missions that neither NASA's spacecraft nor its launch vehicles could perform.[55]

For both Dyna-Soar and MOL, the fault lay not with the acquisition process but with efforts to carve out unique missions. Limiting Dyna-Soar to a demonstration of controlled reentry ultimately doomed the project. NASA's Gemini could more cheaply and easily prove or disprove the military value of human space flight. The Air Force tried to justify MOL as a reconnaissance craft, carrying cameras with a ground resolution of four inches and providing near-real-time intelligence. By then, however, the promise of wide-area surveillance satellites rendered MOL costly and redundant. Titan III survived not so much because it was well managed but because it promised a multitude of uses, even though none had been specifically identified when it approached operational status.[56]

Ultimately, for manned flight, NASA's reusable Space Shuttle and its Skylab space station were all that survived. More and more, as years passed, the Air Force came to regret Dyna-Soar's demise. McNamara was right to have worried that NASA's design would not meet Defense Department needs. The Air Force had to limit some of its key payloads to make them compatible with the shuttle. Worse, in the 1980s, shuttle launches fell far behind schedule, and their costs rose considerably. Over NASA's objections, the Air Force then moved to fill its needs by developing Titan IV, a space launch vehicle with seven-segmented motors.[57]

Endnotes

1. Dwayne A. Day, "Invitation to Struggle: The History of Civilian-Military Relations in Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, ed. John M. Logsdon, vol. 2, *External Relationships* (Washington, DC: NASA History Office, 1996), 233.

2. Spires, *Beyond Horizons,* 57, 60, 54 (quotations from Air Force Manual 1–2, *United States Air Force Basic Doctrine*, 1 December 1959).

3. *U.S. Government Manual, 1960–1961* (Washington, DC: GPO, 1961), 453; Spires, *Beyond Horizons*, 63.

4. Spires, *Beyond Horizons*, 77, 87, 89, 90, 94. However, all R&D proposals beyond the preliminary stage had to be evaluated by the DDR&E and then reviewed by the secretary or deputy secretary of defense.

5. Clarence Geiger, "Strangled Infant: The Boeing X–20A Dyna-Soar," in *The Hypersonic Revolution: Case Studies in the History of Hypersonic Technology*, ed. Richard P. Hallion, vol. 1, *From Max Valier to Project PRIME, 1924–1967* (Washington, DC: Air Force History and Museums Program, 1998), x–xi, 195–196; Andrew J. Butrica, "The Quest for Reusability," in *To Reach the High Frontier,* ed. Launius and Jenkins, 445–446.

6. Geiger, "Dyna-Soar," 201–202, 209.

7. Ibid., 210–212.

8. The 1967 Treaty on Outer Space prohibited "nuclear or other weapons of mass destruction" but not passive activities like surveillance and reconnaissance.

9. T.R. Heppenheimer, *The Space Shuttle Decision, 1965–1972* (Washington, DC: Smithsonian Institution Press, 2002), 50; Geiger, "Dyna-Soar," 215–217, 219–220.

10. Geiger, "Dyna-Soar," xii.

11. Ibid., 227, 236–239.

12. Ibid., 253–254, 223–224, 256–257. Aerospace Corporation provided systems engineering and technical direction for ICBM programs; Boeing handled assembly, testing, and installation of Minuteman ICBMs.

13. Ibid, 258–261.

14. Ibid.

15. Ibid., 261–263, 266. Congress had appropriated extra money for Dyna-Soar, which the administration declined to spend.

16. Ibid., 264, 276–277; Logsdon, *Exploring the Unknown*, vol. 2, 338–339.

17. Geiger, "Dyna-Soar," 276; Minutes of the Executive Committee, Defense Science Board, 13 March 1963, 6, box 837, OSD/HO; "Dyna-Soar, Gemini, and MODS Report of 20 May 1963," atchmnt to "A Report by the Defense Science Board Subcommittee on the Military Role in Space," 5 December 1963, quotations on 9–10, box 837, OSD/HO. Because Dyna-Soar's later missions would involve multiple orbits, a transtage with restartable rocket motors would be needed for on-orbit maneuvers, orbit changes, and de-orbiting.

18. Geiger, "Dyna-Soar," 276.

19. Ibid., 292–294.

20. Ibid., 300–301, 304–305 (Brown quotations, xvii). R. Cargill Hall, "Samos to the Moon: The Clandestine Transfer of Reconnaissance Technology Between Federal Agencies," Office of the Historian, National Reconnaissance Office, 2001.

21. Geiger, "Dyna-Soar," 309. The "poem" appears in Walter A. McDougall, . . . *The Heavens and the Earth* (Baltimore: Johns Hopkins University Press, 1985), 513 fn 60.

22. Spires, *Beyond Horizons*, 124; Logsdon, *Exploring the Unknown*, 356–360.

23. Geiger, "Dyna-Soar," 304–305, 309; memo, Hornig for Wiesner, "PSAC Space Panel's Evaluation of the Requirements for a Manned Space Station," 22 Nov 63, fldr MOL 1963–1966, box 2, 74098, RG 330, WNRC; Donald D. Pealer, "A History of the Manned Orbiting Laboratory (MOL) Part I," *Quest* 4, no. 3 (Fall 1995): 6.

24. Pealer, "MOL Part I," 4–7.

25. Ibid., 7.

26. Ibid., 12–13.

27. Ibid., 13–14; *Public Papers of the Presidents of the United States: Lyndon B. Johnson, 1965* (Washington, DC: National Archives and Records Service, 1966), 917–918.

28. Donald D. Pealer, "Manned Orbiting Laboratory, Part II," *Quest* 4, no. 4 (Winter 1995): 33, and "Manned Orbiting Laboratory, Part III," *Quest* 5, no. 2 (1996): 19, 16, 20.

29. Pealer, "Manned Orbiting Laboratory, Part III," 21–22; Spires, *Beyond Horizons*, 132–133. The Titan III–M also was canceled.

30. Chapter VIII in this volume describes the creation and functions of STL and Aerospace Corporation.

31. Col. David Miller, USAF, "How the Air Force Maintained Cost, Schedule on Titan III," *Armed Forces Management* 11, no. 2 (September 1965): 61; Robert F. Piper, *History of Titan III, 1961–1963*, vol. 1, Air Force Systems Command Historical Publication Series 64–22–1 (Washington, DC: Air Force Systems Command, June 1964), 10, 11, 15–16.

32. Logsdon, *Exploring the Unknown*, vol. 2, 318–319; Roger D. Launius, "Titan: Some Heavy Lifting Required," in Launius and Jenkins, *To Reach the High Frontier*, 166.

33. Piper, *Titan III*, 18–20. The first Titan II, which was the Air Force's largest ICBM and carried a multimegaton warhead, reached operational status in April 1962.

34. Ibid., 30–32; Logsdon, *Exploring the Unknown,* vol. 2, 320–323. Subsequently, Rubel concluded that the Air Force's arrangements with its contractors "were importantly less streamlined than the NASA organization for Apollo." Another of NASA's advantages, he believed, was that administrator James Webb possessed great expertise and reported directly to the president. Ltr Rubel to Poole, 24 Oct 08.

35. Chapter II in this volume describes how phases in the acquisition cycle were defined.

36. Rubel imposed a principle of "functional integration with operational separation," meaning that the redesign of one element need not require the redesign of others. Ltr Rubel to Poole, 4 Oct 2008.

37. Piper, *Titan III*, 36–38, 41, 46–47, 66 (quotations, 37, 37–38, 46). Chapter VIII in this volume describes how PERT functioned. For this project, PERT did not meet expectations and, in July 1962, was scaled back to scheduling and cost estimating for the contractor's day-to-day performance as well as furnishing data for PERT-COST management.

38. Spires, *Beyond Horizons*, 114; Miller, "How the Air Force Maintained Cost, Schedule on Titan III," 62–63.

39. Memo, Under SecAF Joseph Charyk for DDR&E, "Agena D Program," 10 Dec 61; memo, J.H. Rubel for Robert Seamans, 17 May 62; memo, L.L. Kavanau to AsstSecDef (Research and Engineering), "Agena D," 10 Oct 62, all in fldr Agena Chronology 1961–1968, box 2, 74–0098, RG 330, WNRC.

40. Robert Perry et al., "System Acquisition Strategies," RAND Report R–733–PR/ARPA, June 1971, 24.

41. Memo, Under Sec Air Force Brockway McMillan for Sec McNamara, "Agena D

Management" with atchmnt "Management Approach," 19 Aug 63, fldr Agena Chronology 1961–1968, 74–0098, RG 330, WNRC; Perry et al., "System Acquisition Strategies," 25–26.

42. Piper, *Titan III*, 53–64.

43. Ibid., 113.

44. Centaur's tank was filled with liquid hydrogen; a rocket so fueled could lift approximately 40 percent more payload per pound than conventional kerosene-based fuels. Virginia P. Dawson, "Taming Liquid Hydrogen: The Centaur Saga," in Launius and Jenkins, *To Reach the High Frontier*, 334–335.

45. Rubel had advised McNamara that Saturn could not serve as a workhorse because, among other things, its upper-stage engines were of a very advanced, unproven design. Moreover, NASA was aiming at bigger, more powerful Saturns that would prove even less economical for launching DoD payloads. Rubel, *Time and Chance,* 439 fn 17.

46. Bleymaier's briefings struck some civilians as being more upbeat than informative. The Office of the Assistant Secretary of the Air Force for Financial Management could not obtain reliable information about the relationship between costs incurred and progress achieved. Titan III was fairly typical in that the technical nature of engineering development, combined with unavoidable change orders, made it well-nigh impossible for outsiders to tell whether the Air Force obtained what the contract specified. Email, J. Ronald Fox to Walter S. Poole, 7 Aug 06. From 1963 to 1965, Fox was deputy for management systems under the assistant secretary of the Air Force for financial management. See also Piper, *Titan III*.

47. Piper, *Titan III*, 78–91; *FRUS 1961–1963*, vol. 8, 498–499.

48. Memo, Harold Brown for Sec McNamara, "Titan III Production—Tentative Recommendation," 20 Jul 64, atchmnt to "Titan III Production Memo and Final Report—Ballistic Missile/Space Launch Vehicle Problems," 20 Jul 64, fldr Titan III Production Memo and Final Report, box 3, 74–0098, RG 330, WNRC.

49. The first synchronous communications (SYNCOM) satellite placed in orbit approximately doubled the bandwidth available for communication with Europe and, later, Asia. Ltr Rubel to Poole, 14 Oct 08. Rubel provides a detailed account of SYNCOM's development in *Time and Chance,* 168–209.

50. Ray A. Williamson and Roger D. Launius, "Rocketry and the Origins of Space Flight," in Launius and Jenkins, *To Reach the High Frontier*, 59–60.

51. Spires, *Beyond Horizons*, 138–141.

52. Ibid., 127.

53. Ibid., 144, 145, 159, 160. These included missions for Lincoln Experimental Satellites, tactical satellite communications, and the Missile Launch Detection Alarm System, followed by much improved Defense Support System satellites.

54. Ibid., 165. By fiscal year 1967, the original cost estimate of $745 million had risen to $885 million. Technical difficulties during development accounted for $55 million of the increase; another $84 million came from starting work on a seven-segment motor and stretching out the Titan III–C's schedule of flight testing. The extension was ordered by OSD, largely to protect the production base until the scope of production could be determined. "Summary of RDT&E Program by Fiscal Year, Titan III," atchmnt to memo, Harold Wakefield for ODD (S&SS), 2 May 69, fldr Titan Correspondence—1969, box 3, 74–0098, RG 330, WNRC.

55. This was the language of DoD Directive 5030.18 (Department of Defense Support of National Aeronautics and Space Administration), 24 Feb 62 (quoted in Spires, *Beyond Horizons*, 108).

56. Spires, *Beyond Horizons*, 133–134; Day, "Invitation to Struggle," 260–263.

57. Day, "Invitation to Struggle," 266–267; Spires, *Beyond Horizons*, 225–229.

CHAPTER XI

Vietnam: Proving Ground and Graveyard

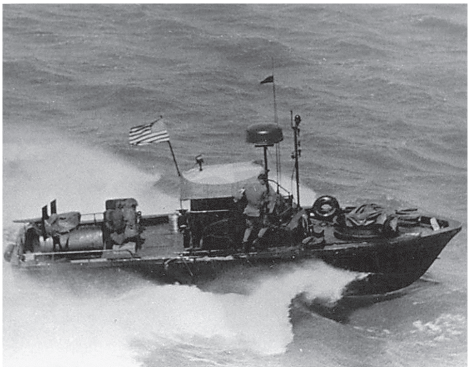
American military involvement in South Vietnam grew from about 600 advisors in 1960 to more than 16,000 uniformed personnel by late 1963. The large-scale introduction of air and ground combat units started early in 1965, when a Communist victory looked imminent. By mid-1968, the number of troops had reached 549,000. Naval task forces operating in the South China Sea and Air Force units based in Thailand and on Guam complemented the combat units. Within South Vietnam, the Army and Marine Corps conducted large-scale search-and-destroy operations against Viet Cong guerrillas and main force units as well as North Vietnamese regulars. They also carried out clear-and-hold pacification missions in villages and rural areas while furnishing advisory support and combat assistance to South Vietnamese forces. Army Special Forces organized ethnic Montagnards and other minorities along the rugged western borders of South Vietnam. The Navy ran carrier-based airstrikes against North Vietnam, bombarded coastal targets, set up maritime patrols to stop the flow of supplies and munitions, and operated along South Vietnam's rivers and canals, transporting sea-air-land teams to carry out counterguerrilla operations. The Air Force bombed targets in North Vietnam, conducted a large-scale interdiction campaign along the Ho Chi Minh Trail in Laos, and provided close air support in South Vietnam.[1]

The array of missions required in Vietnam challenged the services to shift tactically and technically from their usual emphasis on large-scale conflict with the Soviet Union. Some soldiers and Marines exchanged their M–14 rifles for M–16s only when they arrived in country, thus going on operations with unfamiliar weapons. The need for a helicopter gunship to support airmobile operations became apparent early on. Although the Bell Helicopter Company reconfigured its UH–1 Huey to make an AH–1G Cobra gunship, and 90 percent of the parts were interchangeable, the first gunships did not arrive in Vietnam until September 1967. The Air Force needed better capabilities for dogfighting and precision bombing. Its best answer, the F–4E Phantom, went through compressed flight testing. Even so, the first F–4Es reached Southeast Asia only in November 1968, after the bombing of North Vietnam had been suspended. Laser-guided bombs promised huge improvements in accurate delivery and aircraft survivability, but they also came late.[2]

M113 armored personnel carriers clear the way during the Vietnam War (*U.S. Army Center of Military History*)

In sum, combat capability in Vietnam depended on how well existing weapon systems could be adapted to unexpected circumstances. In one instance, the Army sent large numbers of M113 armored personnel carriers to South Vietnam. Designed for European battlefields, not a land of jungles and rice paddies, M113s often performed as "the tanks of the rice paddies," conveying infantrymen through the killing zones and then offloading them to fight on foot. Combat revealed that the M113 had critical weaknesses: the soldier operating its externally mounted machine gun was exposed to enemy fire, and the vehicle was vulnerable to land mines. Modifications developed during 1966 included shielding the .50 caliber machine gun with armor plate, adding two similarly shielded M–60 machine guns, and installing a titanium antimine plate on the M113's underside. Fires started by rocket-propelled grenades were also a danger, but replacement of gasoline models with diesel M113A1s was not completed until July 1968.[3]

The core of the Navy's coastal surveillance force, the 50-foot Swift Boat, was adapted from craft used to support oil-drilling rigs in the Gulf of Mexico. The Navy acquired 84 Swift Boats, each carrying a mortar and machine guns and able to reach 23 knots. The mainstay of the River Patrol Force was a civilian pleasure craft, bought in the United States and militarized as the patrol boat river (PBR). Powered by Jacuzzi jet pumps that enabled it to maneuver at 25 knots, each PBR carried a grenade launcher, machine guns, and surface radar. Weeds and other detritus could foul the water jets of the Mark I model. Mark IIs, introduced in December 1966, boasted improved pumps that raised their speed to 29 knots. An experiment with air cushion vehicles able to move quickly over shallow, marshy terrain failed when the craft proved to be too noisy and too mechanically sophisticated. Hydrofoil gunboats also failed to work well.[4]



Patrol Boat River (PBR) (*U.S. Army Center of Military History*)

The Air Force, probably the least prepared of the military services for this kind of war, found its F–105D Thunderchiefs poorly suited for carefully controlled conventional attacks. The Air Force's F–4C Phantoms lacked guns for close-in aerial combat. Using sophisticated F–4s to hit trucks coming down the Ho Chi Minh Trail in Laos was an obvious yet unavoidable mismatch of weapons against targets. Propeller-driven A–1 Skyraiders originally designed for the Navy, however, proved to be effective for close air support.

The Air Force, nevertheless, enjoyed great developmental and operational success with fixed-wing gunships. In 1964, three Gatling guns were mounted on a World War II–vintage C–47 transport, tested, and employed on a night defensive mission with excellent effect. The fiery tracers of the miniguns, combined with their distinctive roar, earned the AC–47 the nickname "Puff the Magic Dragon." Turboprop C–130 Hercules transports were similarly converted. These AC–130 Spectre gunships, featuring much heavier firepower and an array of sensors, entered service in 1967. Used in Laos as well as in South Vietnam, the AC–130 was deemed the most cost-effective close support and interdiction weapon in the Air Force inventory.[5]

Top: U.S. Air Force AC–47 gunship's miniguns (inset) provided fire support for air base defense in South Vietnam. *Bottom:* Lockheed AC–130A gunship of the 16th Special Operations Squadron, 8th Tactical Fighter Wing, at Ubon Royal Thai Air Force Base, March 1969. (*National Museum of the U.S. Air Force*)

MANAGING MUNITIONS SHORTAGES

At the end of the Korean War in July 1953, the services had accumulated huge stockpiles of bombs and shells, some of which were sold to allies at fractions of their original cost. Secretary McNamara did not want to see such waste repeated. He intended that, when the Vietnam War ended, the amount of materiel in the pipeline would be based on current rates of consumption—enough to reconstitute peacetime stocks and war reserves but no more. That hope soon evaporated, however, as the steadily increasing tempo of operations depleted inventories. More requirements created a competition for resources that lengthened production lead times.[6] In short, OSD's policy of minimum buying made it difficult to ramp up production to match the rising war tempo. This led to the same munitions shortages that had occurred in the midst of the Korean War.

During the early 1960s, at McNamara's behest, the Navy and Air Force substantially increased their purchases of conventional munitions. The types of bombs they chose to acquire, however, proved to be more important than how many they stockpiled. The Air Force concentrated on stocking cluster bomb units (CBUs) and Bullpup air-to-ground missiles. The CBU, an air-delivered canister that dispensed submunitions, such as explosive bomblets, and the Bullpup, a radio-guided weapon developed by Martin-Orlando and Maxson Electronics of Long Island, promised great improvements over unguided "iron" bombs. CBUs were designed for use against dispersed targets such as personnel and vehicles. Bullpup featured gyroscopes, flares in the tail, and a radio receiver. A crew member kept the weapon in view until impact and sent commands if it deviated from the line of sight.[7] CBUs and Bullpups accounted for 93 percent of Air Force munitions procured in FY 1962, 89 percent in FY 1963, 83 percent in FY 1964, and 75 percent in the original FY 1965 budget, which was unaffected by Vietnam. The Navy also stocked up on Bullpups but shifted back to emphasizing the procurement of iron bombs, even before the onset of extensive air operations in Vietnam. In FY 1962, more than half its funds for procuring nonnuclear air-to-ground munitions went to Bullpups. In FY 1964, Bullpups drew only one-third, with Mark 81 250-pound and Mark 82 500-pound iron bombs taking another third. In the Navy's initial budget proposals for FY 1965 and FY 1966 (neither yet affected by combat operations in Vietnam), Mark 81s and 82s accounted for about 75 percent and 60 percent of its munitions procurement, respectively. The Navy allocated only small amounts for 2.75-inch air-to-ground rockets, deeming the Air Force in possession of an adequate supply.[8]

Bullpups proved to be poorly suited for Rolling Thunder, the bombing campaign against North Vietnam that began on 1 March 1965. The missile's radio guidance was vulnerable to jamming and other countermeasures. Aircraft dropping Bullpups had to remain close enough for crews to see their targets, yet smoke from the missile's rocket engine helped enemy gunners to judge the launch aircraft's position. Moreover, a Bullpup with a 250-pound warhead did not pack enough destructive power to be used against critical but well-defended targets in North Vietnam. By mid-1965, approximately $500 million had been spent on Bullpups, an amount that would have purchased about 1 million Mark 82s with 500-pound warheads.[9]

Martin AGM–12B Bullpup A on display at the National Museum of the U.S. Air Force. Bullpup A was armed with a 250-pound warhead. (*National Museum of the U.S. Air Force*)

Early models of cluster bomb units could not be used against well-defended targets in North Vietnam because they had to be dropped from 300 feet, rendering the aircraft extremely vulnerable to ground fire. Nor were they an appropriate weapon against most of the other targets of the Rolling Thunder campaign. Significantly, in the Air Force's revised FY 1966 budget, Bullpups and CBUs accounted for only 8 percent of air-to-ground munitions.[10]

Late in the summer of 1965, as Rolling Thunder expanded in scope and intensity, OSD established a system of "Flagpole Reports" to identify potential munitions shortages. The Flagpole Report that Paul Ignatius, assistant secretary of defense (installations and logistics), sent to McNamara on 30 December 1965 revealed depletion trends for stocks of aerial munitions.[11]

Consumption of Mark 81 bombs with 250-pound warheads, used mainly for counterinsurgency operations by older, smaller aircraft, was outstripping production. It took until July 1966 to establish an adequate pipeline flow and to replace stocks taken from the Atlantic Command. Three of the five producers of Mark 82 bombs with 500-pound warheads experienced production slippages, reducing inventories to the point that the Mark 82's availability remained "critical" throughout 1966. As for M117 bombs with 750-pound warheads, none were in production when B–52s began flying missions over South Vietnam on 18 June 1965. Consumption of M117s stood at 25,000 bombs per month by the end of 1965. Total M117 bombs in stock dropped from 202,000 in November 1965 to 25,000 by July 1966. Finally, since rotary as well as fixed-wing aircraft from all four services could fire the 2.75-inch air-to-ground rocket against the full spectrum of targets, the report projected that consumption would exceed production through April 1966 by more than 1 million rounds, thereby shrinking inventories from 1.6 million rounds in November 1965 to 580,000.[12]

McDonnell Douglas F–4C drops CBU dispenser over A Shau Valley, South Vietnam, 23 June 1967 (*National Museum of the U.S. Air Force*)

The consequences of such shortages were dramatic. By January 1966, there were no bombs in the pipeline to Southeast Asia. In February, three of the five producers of metal parts for 500-pound Mark 82s were failing to meet their schedules. Two firms responded by switching to six-day work weeks, for which they were paid with funds advanced from the FY 1966 supplemental appropriation. U.S. Steel, the mobilization base producer of 250-pound Mark 81s, was exceeding its planned output. However, Buxmont, a new small business contractor plagued by financial and management difficulties, had delivered only 8,000 of its monthly quota of 15,000 Mark 81s.[13]

Admiral U.S. Grant Sharp, commander-in-chief, U.S. Pacific Command, predicted that reductions in bomb loads and the number of B–52 sorties would prove to be necessary. Assistant Secretary Ignatius's staff, collaborating with Systems Analysis, disagreed. Admiral Sharp's requirements, they concluded, were unrealistically high. No cutbacks were necessary. Instead, by bringing unexpended bombs back to home base rather than jettisoning them and by substituting 500-pound Mark 82s for 750-pound M117s, economies could be realized and operations maintained at current levels.[14]

Yet saving and substituting ordnance did not suffice. When Ignatius went to Vietnam at the end of March 1966, the Seventh Air Force commander warned him that "[w]e're running out of ammunition." Ignatius relayed this to McNamara, who told him to confer immediately with Admiral Sharp in Hawaii. Ignatius and Sharp identified several problem areas. First, bomb expenditures in March had outpaced planned consumption by 25 percent. Second, demonstrations by Buddhist dissidents in Hue prevented ammunition ships from unloading their cargoes. Third, Air Force inventory reports were not based on "complete rounds," grouping together a bomb, its fuse, and its fins. In some cases, consequently, there were too many fins and not enough fuses to assemble complete bombs. In others, ammunition was reported "on hand" when components or essential assemblies were still on board ships.[15]

Late in April, President Johnson approved moving several munitions to the highest category of the Defense Department's ordering of production priorities, the Master Urgency List: 250-pound Mark 81, 500-pound Mark 82, and 750-pound M117 bombs, and 2.75-inch rockets.[16] Other measures included lending Navy munitions to the Air Force, drawing on depot reserves in the western states, encouraging the adoption of "complete round" reports, and clarifying the meaning of "on hand." OSD also put production of 2.75-inch rockets under an Army project manager with a joint service staff, which helped keep output consistently at or above the levels forecast.

In May 1966, Ignatius appointed Maj. Gen. Allen T. Stanwix-Hay, USA, to be his special assistant for air and ground munitions. Stanwix-Hay, who became deputy assistant secretary of defense (materiel) in December 1966, developed sophisticated reporting methods. A system of 15- and 30-day reports from Vietnam about the consumption and inventory status of more than 100 items of munitions allowed OSD to make, with increasing precision, monthly adjustments of production and shipping schedules.[17]

Another expedient proved to be controversial. Early in 1964, in a move to free storage space and cut maintenance costs, U.S. Air Forces, Europe had sold 7,562 750-pound bombs to Kaus and Steinhausen, a West German firm, for $1.70 each. The company planned on selling the casings as scrap metal and reducing the bombs' explosive content to basic chemicals that could be sold as fertilizer. Under the contract, the firm had two years in which to complete demilitarization of the bombs. By autumn 1965, however, it had neither developed a process for extracting the explosive content nor built a facility to do so. After negotiations, Kaus and Steinhausen sold back the 5,570 bombs that it had not yet demilitarized for $21 each; the amount was compensation for having rented, conditioned, and then reconverted a storage area. The administration defended this deal on grounds that new bombs would have cost $2.5 million, compared to the $125,000 repurchase price, but critics in the media and Congress focused on the fact that DoD had paid twice for the same bombs.[18]

In April 1966, OSD fixed the output of all aerial munitions at 65,000 tons per month. Production of 500-pound Mark 82 bombs matched consumption by mid-year, but the higher expenditure rate of April 1966 was not regained until January 1967, when significant quantities of Mark 82s from new production reached the combat theater. In February 1967, the rate of production for 750-pound M117s finally equaled the forecast rate of expenditure. Improved cluster bomb units—CBU–24/29s, with delayed detonators that could be dropped from above 3,000 feet—proved to be optimum weapons for flak suppression, but large-scale production did not begin until early in 1967;[19] 20,000 had to be airlifted to Vietnam during 1966–1968.[20]

McNamara raised overall monthly bomb production to 80,000 tons in March 1967 and to 92,000 in May, the latter figure based on 800 B–52 and 30,000 tactical air sorties per month.[21] At the time, senior OSD civilians wondered whether the point of diminishing returns had been reached. Perhaps increasing availability simply whetted the services' appetites. Ignatius was "appalled by the amount of ordnance we were expending on a rural country with no well-established industrial base."[22] Of course, most of the targets outside of North Vietnam were troops or logistic lines, not factories and facilities.

The demand for ammunition for ground combat also kept growing, with similar shortages and outcomes. For 105mm howitzers, OSD's emphasis on actual expenditures of ammunition rather than forecasts of consumption meant that the initial award of a contract for high-explosive rounds destined for Southeast Asia did not take place until August 1966. Consequently, Military Assistance Command, Vietnam, had to restrict the issue of high-explosive 105mm rounds for 4 months in 1966, 10 in 1967, and 1 in 1968. The issue of 105mm illumination rounds was restricted for 12 months in 1966, 2 in 1967, and 1 in 1968.[23] Stepping up production incurred extra costs of $1.7 million, caused by starting and stopping as well as by stretching out and then telescoping schedules. Production finally equaled consumption in April 1967, two years after the first U.S. ground combat troops arrived in South Vietnam.[24]

American ground combat commanders in South Vietnam relied on firepower, in part to minimize their casualties. In most engagements, support from artillery, gunships, and aircraft provided the margin of victory. And although difficult to prove, the greater availability of munitions increased demand. Even during the shortages of 1966, Army artillery fired only 15 percent of its rounds to support troops in combat. The remaining 85 percent went for "harassment and interdiction," unobserved fire with unknown results. Some critics would later claim that firepower became a substitute for strategy.[25]

Faced with acute munitions shortages in May 1966, Secretary McNamara blamed inadequate distribution more than insufficient production. There were important precedents to support him. For example, during World War II, in October 1944, Allied attacks into Germany were curtailed when forward stocks of artillery ammunition ran low. The main cause of that crisis, inadequate transport and discharge capacity, resulted from the August 1944 dash across liberated France. Ammunition shortages during the latter part of the Korean War had a variety of explanations, including distribution failings, production shortages, and extraordinary usage rates.[26] For Southeast Asia, Assistant Secretary Ignatius and Brigadier General Stanwix-Hay had at least unclogged a number of bottlenecks.

Still, OSD's practice of basing future expenditures on current rates of consumption proved to be unreliable. The number of B–52 sorties was seriously and consistently underestimated. In FY 1967, 3,600 were authorized, but 7,638 occurred; in FY 1968, the ratio was 4,800 to 14,607; and in FY 1969, it was 9,600 to 21,592.

Trouble over the Navy's ammunition for its 5-inch gun offers another example. In 1967, high production combined with lower than expected consumption to bring about a drastic cutback of planned output. The Tet offensive occurred in January 1968, with follow-up attacks running into September. Expenditures rose sharply. In the absence of an adequate reserve of 5-inch ammunition, the Pacific pipeline dwindled to dangerously low levels. Additional production remedied the situation late in 1968, but only after significant reductions of naval bombardment missions.[27]

Munitions shortages never gravely handicapped the military effort in Southeast Asia. One way of filling needs was to drain resources from or deny them to other commands. Nearly all the worldwide inventory objectives, which OSD raised substantially early in 1966, remained unmet in January 1968. Consequently, when North Korea seized USS *Pueblo* in that month and the Tet offensive opened days later, the U.S. military did not have enough munitions to contemplate a successful campaign against North Korea.

THE ADVENT OF "SMART" BOMBS

One way to reduce the expenditure of munitions was to make individual bombs more accurate. One method being investigated was to use an intense beam of light, called a laser (Light Amplified by Stimulated Emission of Radiation), to guide the bomb to the target. But generating this type of beam required great amounts of energy. A breakthrough came in 1962 when David J. Salonimer, a civilian engineer working for the Army Missile Command at Redstone Arsenal, showed mathematically that a seeker device could home in on a target designated or "illuminated" by a pulsed laser beam. Using brief bursts rather than steady emissions greatly reduced the size and weight of power supplies, while a very narrow laser beam promised greater accuracy and better discrimination of small targets than radar systems could provide. The Army hoped a portable unit would help it engage enemy tanks.[28]

In June 1963, Army Missile Command awarded contracts to RCA-Burlington and the Autonetics Division of North American Aviation ($58,000 and $98,000, respectively) to develop seekers for pulsed laser beams. One year later, Martin Marietta's Orlando Division also received a contract. By late 1964, RCA and Autonetics had conducted successful demonstrations under laboratory conditions. In September, Missile Command asked Texas Instruments (TI) to explore whether the Shrike anti-radar missile (AGM–45), which homed on emissions from enemy radar sites, could be adapted to track pulsed laser radiation. Weldon Word, recently transferred from sonar work, became TI's project engineer for the venture. Early in 1965, facing an enemy in South Vietnam that did not employ tanks, the Army reduced its funding of laser research.[29]

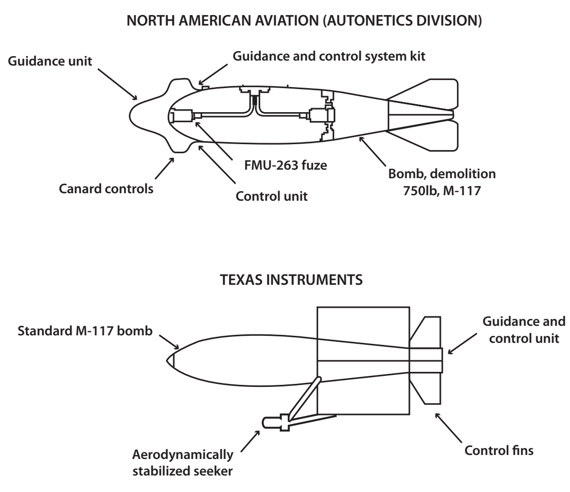
Shifting focus, Salonimer and a colleague, Norman Bell, persuaded a civilian project officer in the Aerospace Systems Division of Air Force Systems Command that laser guidance was worth pursuing. The division's Directorate of Technical Assistance and Support, dubbed Detachment 5, had been created to handle short-term projects addressing immediate tactical and operational needs. Impressed by Martin's laser tracking system, the commander of Detachment 5, Col. Joseph Davis, Jr., asked Salonimer and Bell whether sufficient knowledge existed to start developing a laser guidance system for air-launched bombs. The answer was positive.[30]

Weldon Word persuaded Colonel Davis that TI, despite having no expertise in bombs, was capable of finding a solution. Davis, in turn, asked four companies to submit proposals for prototypes of a laser seeking unit that would be compatible with the 750-pound M117 bomb. When Westinghouse did not respond, and Davis deemed the Martin Company's bid to be inadequate, proposals from TI and Autonetics were accepted.[31]

TI, which received a $99,000 award in September, had until March 1966 to build a dozen prototypes. Relying on existing technologies, TI attached to the M117 a seeker head, guidance electronics, control assembly, and fins. Word's team mounted the laser seeker in a novel birdie-shaped probe so that the angle between the flight path and the target could be measured without gyro stabilization (see figure 11–1). In fact, only the seeker head and the laser designator represented unproven technology. The guidance computer was indistinguishable from computer trays in the Shrike. TI's control hardware copied the Shrike's "bang-bang" design, a term derived from the sound caused by numerous, rapid corrections during the terminal phase of flight.[32]

Autonetics chose to rely on gyro stabilization, in contrast to TI's aerodynamic stabilization, and on proportional instead of "bang-bang" control. Guidance commands would originate from three separate sources: target tracking, roll control, and pitch bias. Autonetics's release sequence, however, became more complicated than TI's.[33]

Figure 11-1: INITIAL CONFIGURATION OF LASER-GUIDED BOMB PROTOTYPES

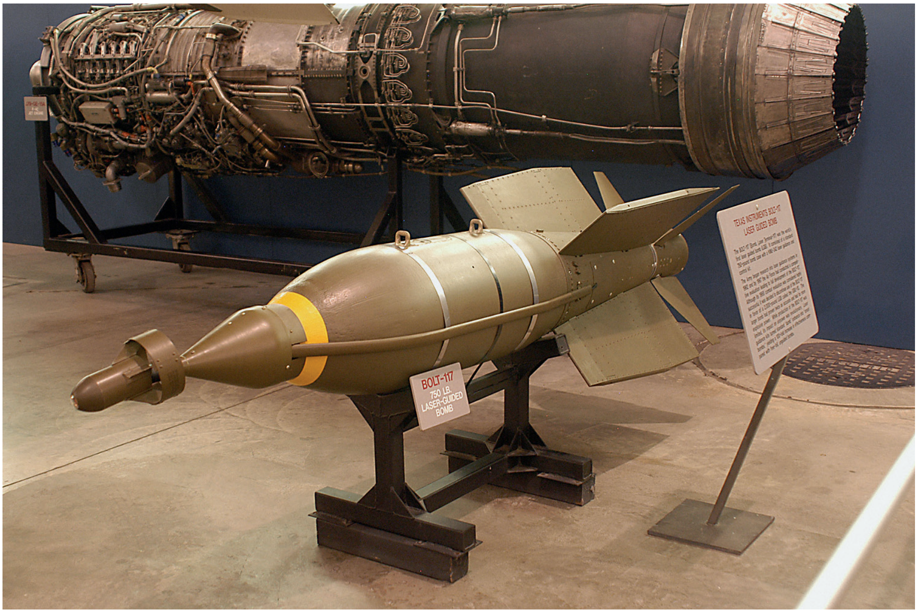


Source: Peter De Leon, *The Laser-Guided Bomb: Case History of a Development*, Report R–1312–1–PR (Santa Monica, CA: RAND, June 1974), 11.

Most experts in Army Missile Command and AFSC's Aerospace Systems Division rated Autonetics's proportional guidance as more promising because it represented a logical extension of the state of the art. What TI proposed was simpler and markedly cheaper but unproven. Accordingly, Aerospace Systems Division decided to hold a prototype competition, awarding fixed-price incentive contracts on 16 November 1965 to TI for $264,000 and to Autonetics for $442,000.[34]

In-flight testing ran through 1966. By the year's end, both prototypes demonstrated their feasibility, but the differences in capability were significant. An aircraft carrying Autonetics's version had to keep its weapons sight on the target until the seeker locked on; an aircraft carrying TI's more innovative seeker could acquire the target after the bomb was released. However, Air Force headquarters decided that TI should stand down for a year or more to allow Autonetics time for improvement. Colonel Davis reacted by persuading his superiors to organize a board of general officers that included the recently retired General Curtis LeMay. Meeting early in 1967, the board urged that TI continue working. Air Force headquarters finally concurred.[35]

At this point, supervision transferred from Detachment 5 to a new program office in the Aerospace Systems Division. On 20 May 1967, TI and Air Force Systems Command signed a $1.35 million contract for 50 seeker kits. Autonetics was encouraged to continue work, but at its own expense. In October, an Air Force interagency organization dubbed "Paveway Task Force" started overseeing engineering and operational flight testing of the laser-guided 750-pound M117 bombs.[36]



Texas Instruments Bolt–117 750-pound laser-guided bomb on display at the National Museum of the U.S. Air Force with jet engine in background (*National Museum of the U.S. Air Force*)

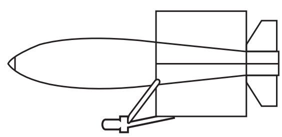
The new weapon was urgently needed in Southeast Asia, where commanders kept emphasizing the requirement for greater bombing accuracy. Secretary McNamara was reluctant to expand the list of targets in North Vietnam because, among other reasons, the Air Force had not been able to destroy all those previously approved. On 17 July 1967, the Air Force chief of staff approved a procurement strategy of "medium risk, early operational date," which meant forgoing further prototype tests. TI obtained a $17.5 million contract for producing laser kits up to the limits of existing plant capacity. The release of money for tooling and full production followed in October and December respectively, with Paveway awarded an extremely high funding priority. All contract work on the Autonetics models ended.[37]

On 21 September 1967, a directive from Air Force headquarters listed the performance characteristics desired in laser-guided bombs: a CEP no greater than 25 feet; guidance reliability of at least 80 percent; delivery from either a dive or a level run; and operational deployment not later than June 1968. The first laser-guided 750-pound M117s reached Southeast Asia during the latter part of 1967. The Air Force had restarted production of 2,000-pound Mark 84s; these arrived in the spring of 1968. Combat evaluations ran from May to August 1968. M117s failed to match stateside results, with a CEP of 75 leaving numerous undestroyed targets. Improved Mark 84s, however, recorded an unprecedented CEP of 20 feet, with one bomb in four scoring a direct hit. On 15 January 1968, Air Force headquarters approved production of 293 seeker kits by mid-year costing approximately $16,000 each. Following these successful combat tests, it contracted for 1,000 more.[38]

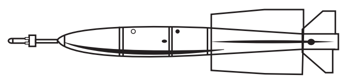
F–4D from the 435th Tactical Fighter Squadron, 8th Tactical Fighter Wing, armed with two Mark 84 laser-guided bombs (GBU–10 Paveway I) (*National Museum of the U.S. Air Force*)

"This is one of the best things we've done in years," wrote Secretary of the Air Force Harold Brown. "Don't let it slip through the cracks." It did not. Development of the laser-guided bomb was remarkable for its speed, cost, and results (see figure 11–2). Unusual factors shaped that outcome. David Salonimer, Col. Joseph Davis, and Weldon Word each played a vital part. At the outset, program funding and visibility were so low that personnel enjoyed exceptional freedom of action. Small costs also facilitated competitive prototyping, which uncovered flaws that could be quickly corrected.[39] Postponing the formal statements of operational requirements and performance characteristics allowed maximum flexibility in development. Contracts were written so that major modifications could be approved without rewriting the performance standards. In addition, the Air Force could reprogram funds to the project instead of submitting time-consuming requests to the director of defense research and engineering. All in all, "flexibility" best explains why only 36 months elapsed between signing the original development contract and starting production.[40]

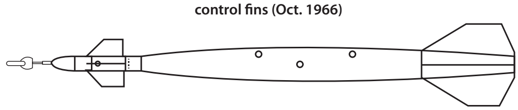
Figure 11-2: EVOLUTION OF TEXAS INSTRUMENTS LASER-GUIDED BOMB



(A) M-117 Guided Bomb with fin seeker (July 1966)



(B) M-117 Guided Bomb with nose seeker and rear control fins (Oct. 1966)



(C) Mk-84 Guided bomb with nose seeker and canard control fins (late 1967)

Source: Peter De Leon, *The Laser-Guided Bomb: Case History of a Development*, Report R–1312–1–PR (Santa Monica, CA: RAND, June 1974), 33.

One crucial caveat must be added. In war, timing can be everything. By May 1968, when combat evaluations of Paveway began, Rolling Thunder had been sharply restricted and would end entirely on 31 October. Paveway, in any case, proved to be poorly suited for attacks against the well-defended targets around Hanoi and Haiphong. While the strike aircraft could leave as soon as it released the bomb, the designator aircraft had to circle the target until impact—usually about 30 seconds, which was dangerous in a high-threat environment. In November 1969 the Air Force gave Philco-Ford a letter contract to start Pave

Knife, a system consisting of a designator pod carried beneath the strike aircraft. This eliminated any need for the second and more vulnerable designator aircraft. The gimbal-mounted laser could track the target as the strike aircraft flew away. In March 1971, the first F–4Ds outfitted for Pave Knife reached Thailand. By 1972, TI was producing more than 2,000 guidance kits every month. During the North Vietnamese offensive, Pave Knife made the Linebacker bombing campaign against North Vietnam far more effective than Rolling Thunder. Earlier, for example, the Thanh Hoa Bridge, a vital artery 70 miles south of Hanoi, had survived more than 700 sorties during which 12,500 tons of bombs were dropped and 29 aircraft lost. But on 13 May 1972, 12 F–4s armed with 24 laser-guided bombs rendered the structure completely unusable.[41]

ROLLING THUNDER AS A WIZARD WAR

Electronic warfare had matured steadily in World War II. In 1940, during the Battle of Britain, the Germans used radio beams to guide their bombers to targets at night. A single beam, defining the course to the target, was intersected by two beams notifying the navigator that the aircraft had flown within certain ranges of the target; then a third beam triggered the bombs' release. The British countered with electronic jamming. Instead of a continuous note, bomber crews heard a mixture of dots and dashes, leaving them unable to locate the center of the beam. Thus began what Winston Churchill called the "wizard war."[42]

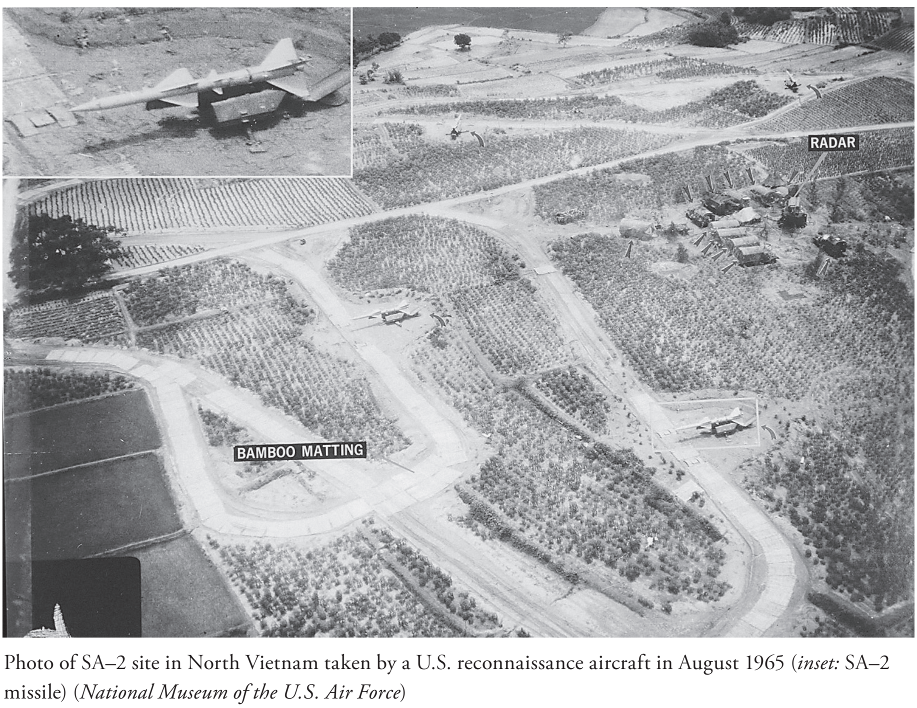


Photo of SA–2 site in North Vietnam taken by a U.S. reconnaissance aircraft in August 1965 (*inset:* SA–2 missile) (*National Museum of the U.S. Air Force*)

When Rolling Thunder opened on 1 March 1965, North Vietnam's air defenses consisted of warning radars and conventional antiaircraft guns, some of which were radar-controlled. Construction of SAM sites started in April. Such sites consisted of several long-range early warning radars, one Fan Song guidance radar, and six missile launchers. The SA–2 Guideline, the standard Soviet SAM, was effective from 3,000 to well above 50,000 feet. On 24 July, an SA–2 downed an F–4C fighter-bomber.[43]

The SAM system had some exploitable weaknesses. Operators of Fan Song radars doubled the frequency of pulse repetitions 30 to 40 seconds before launch; the guidance signal, which could not be delayed more than four seconds after launch, confirmed that an SA–2 had been fired. Radar homing and warning equipment aboard U.S. aircraft could pick up these signals, alerting pilots to make diving or climbing turns that the large, heavy, small-winged missiles could not duplicate.[44]

The Air Force fielded the QRC–160, an electronic countermeasures (ECM) pod derived from packages that had been developed for strategic bombers. During the spring of 1965, QRC–160–1s were installed externally on RF–101 reconnaissance aircraft, but their in-flight vibrations twisted the plane's wing tips, and the pods quickly were withdrawn from service. However, Navy airmen were able to fool Fan Song radars with their ALQ–51, a deception device that transmitted a false position when triggered by radar waves. Unlike a QRC–160–1, the ALQ–51 was built into the undersides of the fuselages of A–6 Intruders and late model A–4 Skyhawks. On 16 September 1965, a flight of A–6s used their deception devices to escape six SA–2s. Previously, the Air Force had decided against using ALQ–51s on the grounds that seeing false targets simply spurred the defenders to fire more guns and missiles. Throughout 1965–1966, however, ALQ–51s helped keep Navy losses over North Vietnam's heavily defended Red River Delta lower than those of the Air Force.[45]

The Joint Staff, in cooperation with the scientific and industrial communities, reviewed the adequacy of equipment for electronic intelligence and countermeasures. In mid-October 1965, it labeled the lack of a timely warning of SAM firings as the most serious deficiency. The Air Force and Navy compiled lists of possible remedies and pushed their development on a crash basis. Nevertheless, the Defense Science Board's task force on electronic warfare reported in May 1966 that the major problem was not insufficient funding. Instead, "recognition and reaction to a need are too slow and there is no anticipation of future needs; i.e., the requirements process has broken down badly."[46]

The immediate response was a more rugged but not radically different ECM pod—the QRC–160–A1, soon redesignated ALQ–71. Testing started during January 1966. After combat trials worked well, the next step was to acquire enough pods for all the fighter-bombers and tactical reconnaissance aircraft committed to Rolling Thunder. This became the first in a series of races against time. Between September and December 1966, 51 F–105Fs were outfitted with one ALQ–71 apiece. Each pod contained four jammers, two programmed against Fan Song SA–2 radars and two against antiaircraft artillery radars. While the F–105 had wiring for two pods, the F–4 could carry only one. But a single pod was marginally effective at best—it could make an SA–2 miss, but not by enough to prevent damage from the warhead's explosion. Until 2 December 1966, about 1,100 SA–2s had destroyed only 34 U.S. aircraft. Then, on that day alone, they downed 5. Technicians modified F–4s so that they could carry two pods. By mid-1967, both F–105s and F–4s were carrying two apiece.[47]

ALQ–71 electronic countermeasures pod on display at the National Museum of the U.S. Air Force (*National Museum of the U.S. Air Force*)

Prior to the arrival of the ALQ–71 pods, to avoid SAMs as long as possible, aircraft had to approach targets at very low altitude, which made them more vulnerable to antiaircraft artillery, and then "pop up" over the target, where they then became vulnerable to SA–2s as well. With the pods, they could roll into the target from 12,000 to 15,000 feet, cutting losses and improving bombing accuracy. Even so, limitations remained. Aircraft had to fly in fairly tight formations, so that the pods' jamming patterns could overlap and supplement each other. Pods restricted maneuverability because steeply banked turns would direct the strongest portion of the jamming signal uselessly into space.[48]

For North Vietnamese defenders, the first months of 1967 proved bitterly frustrating. During an attack near Hanoi on 15 January, jamming by ALQ–71s was so effective and so unlike anything radar operators had seen that only one of a regiment's four battalions was able to launch missiles; none scored a hit. During a strike on 5 May, every missile launched by one regiment either self-destructed or fell back to Earth. The Navy, however, had not adopted ALQ–71s; North Vietnamese missile crews learned how to beat ALQ–51s by distinguishing false from real targets. For example, they would compare differences in the signal quality and characteristics of each target and analyze each target's rate of change in bearing and elevation. On 13 August 1967, two SA–2s destroyed three A–4s.[49]

The North Vietnamese finally countered the ALQ–71 by devising a "three-point" guidance technique. Since jamming incapacitated the SA–2's automatic lock-on and tracking mode, operators manually maintained their target designators on a single, three-dimensional point to track the jamming signal. Course corrections were then transmitted to the SA–2 via the missile's guidance data link. Only five pod-equipped aircraft had been downed between 1 January and 30 September 1967, but during four days in November, massed three-point barrages destroyed eight aircraft.[50]

The defenders' victory was short-lived. On 14 December 1967, Americans began jamming the missile guidance links that were crucial to the three-point method. That task was accomplished by the ALQ–87, originally called QRC–160–8, which came into general use early in 1968. Besides laying down a continuous jamming barrage, an ALQ–87 could introduce random bursts of reinforcing noise. The new pod, therefore, was able to perform any two of three functions: deny range and azimuth data to Fire Can radars;[51] deprive Fan Song radars of range, altitude, and azimuth data; and, most importantly, jam the missile's position beacon or "down link," preventing the missile from receiving corrective guidance after it had been launched. From December 1967 until 1 April 1968, when Rolling Thunder was sharply curtailed, 495 SA–2s were fired at F–105s; only three planes were hit, two of which had been jamming the tracking beam instead of the down link.[52] The ALQ–87's timely appearance and clear success showed that the services were responding to the Defense Science Board task force's charge that the requirements process had broken down badly.

The pendulum swung back a bit after 14 February 1968, when the North Vietnamese recovered an intact jamming pod from a downed F–105. A Vietnamese-Soviet task force started working out a way to protect the data-link signal, but an upgraded SA–2 with a different antenna did not appear until 1971. Their only 1968 improvement was an optical sighting system, enabling missile controllers to visually track aircraft flying as low as 1,000 feet. However, when President Johnson stopped the bombing north of the 20th parallel on 31 March, the threat to Hanoi and the Red River Delta ended.[53]

In hindsight, this is a tale of strategy overriding technological advantage. Several times during Rolling Thunder, American technological advances threatened to overwhelm North Vietnamese defenses. Yet with Soviet help, Hanoi took advantage of deficiencies in U.S. strategy. When petroleum storage tanks outside Hanoi were hit on 29 June 1966, the defense was surprised, slow, and ineffective. But by ruling out more attacks on Hanoi and Haiphong for almost six months, President Johnson gave the North Vietnamese a badly needed respite. Again, late in August 1967, Johnson stopped bombing in the Hanoi area to float another peace initiative. When attacks resumed in October, the North Vietnamese had perfected their three-point missile guidance method. The ALQ–87 bested the three-point method, but Johnson cut back Rolling Thunder soon afterward. Ultimately, the strategy of graduated response and piecemeal aerial offenses sacrificed the achievements of U.S. scientists and engineers.[54]

THE M–16: CONTROVERSY CONTINUES

Bringing a new rifle into service during combat proved to be a wrenching experience. In April 1965, soon after the first Army and Marine combat units arrived in South Vietnam, unanimously favorable reports about the M–16 led the Army chief of staff to anticipate a crash requirement to buy more. General Frank Besson, who headed the Army Materiel Command, urged the Army staff in July to consider large-scale procurement. The staff argued for delay until a study of alternatives could be completed, and Secretary McNamara agreed. But by December 1965, with the influx of ground combat troops accelerating, General William Westmoreland, commander of U.S. forces in South Vietnam, asked for 179,000 M–16s as soon as possible. Having nearly completed its contract for 104,000 rifles, Colt threatened to stop production unless it received new orders. The Army promptly awarded Colt a letter contract for 100,000 rifles, including 38,000 for the Marine Corps, during 1966. Keeping Colt as the sole source, McNamara reasoned, would increase output more quickly.[55]

By September 1966, more than 45,000 of the nearly 350,000 U.S. troops in Vietnam were carrying M–16s. While most had trained extensively with them prior to deployment, some soldiers and Marines exchanged their M–14s for M–16s only when they arrived in country. Soon, reports of malfunctioning weapons attracted wide attention in Congress and the media. One Marine's letter, made public by his congressman, related that "we left with 72 men . . . and came back with 19. . . . Practically every one of our dead was found with his [M–16] rifle torn down next to him where he had been trying to fix it."[56] What could have caused so many malfunctions—poor design, poor maintenance in the field, or something else?

Attention focused on the powder used in the M–16's ammunition, which differed from that used in its predecessor, ArmaLite's AR–15. For the M–14's 7.62mm round, the Army used a ball propellant so named from its shape. For the AR–15, Eugene Stoner, ArmaLite's chief engineer, had favored and Remington had adopted stick-shaped commercial gunpowder called the Improved Military Round (IMR). But engineers at the Army's Frankford Arsenal in Philadelphia discovered a fairly wide variation between Remington's commercial specifications and the IMR's performance. The claimed muzzle velocity of 3,300 feet per second could not be attained consistently while keeping a chamber pressure under 52,000 pounds per square inch—the point where cartridge cases began to fail.[57]

Consisting of Army, Air Force, and Marine Corps representatives and chaired by Col. Harold Yount, USA, a Technical Coordinating Committee managed M–16 purchases. In June 1963, Frankford Arsenal informed the committee that using the stick IMR to meet Army specifications would create serious difficulties.[58] The Air Force, which had been the first service to purchase AR–15s, proposed switching to ball powder. In August 1963, the committee published its specification for a 5.56mm cartridge and solicited bids for one million rounds. No manufacturer responded, as all were convinced that they could not successfully mass-produce cartridges using stick IMR. OSD held out for maximum haste with minimal changes. When the Air Force refused to lower its velocity requirement, Colonel Yount authorized Remington to load one million rounds with stick IMR, but he waived the chamber pressure requirement and asked other manufacturers to submit cartridge lots loaded with propellants of their choice.[59]

In March 1964, Colt tested the first M–16s that came off its production line. When propellants other than IMR were used, rifles did not stay within the contractually specified rate of 650 to 750 cycles per second.[60] But after Frankford Arsenal tested a variety of powders without experiencing any particular malfunction problem, it recommended ball powder as an acceptable alternative. Yount gave Colt a waiver on the maximum cyclic rate and had Remington's one million rounds with stick IMR powder shipped to New England for testing at Colt's plant. Most of the ammunition sent to troop units thus used other propellants.[61]

In November 1965, the Combat Developments Command's Experimentation Center at Fort Ord, California, reported finding a correlation between malfunctions and propellant types. Simultaneously, Colt concluded from further tests that the variations in cyclic rates originated with the propellant and not the rifle. Frankford cautioned, however, that a third characteristic might be influencing the cyclic and malfunction rates. Experimentally, Colt replaced the aluminum ring springs with a polyurethane bumper on the end of the buffer tube. These heavier buffers, which lowered the M–16's cycling rate by absorbing recoil energy, entered production in December 1966.

Chamber corrosion was another problem. At the outset of the M–16 program, the technology for chrome-plating barrels of this caliber did not exist. Colt later retrofitted many rifles with chromed barrels.[62]

Early in October 1966, before buffering and chroming had begun, the Technical Coordinating Committee received reports from Vietnam about widespread jamming and other malfunctions. General Westmoreland asked the committee to send inspectors. A team drawn from Colt, Army Weapons Command, and the M–16 program management office made several trips to the theater. Many soldiers, the team found, had not been instructed on proper maintenance practices; others lacked cleaning rods, patches, and lubricants. One of the Colt team members, a Korean War veteran, declared himself "shocked.

I had never seen equipment with such poor maintenance." By January 1967, corrective actions on all these deficiencies were under way.[63] Also, in January, the rifle was designated M–16A1 and classified Standard A, meaning that it was fully engineered and ready for issue.

Marine cleans M–16 during the battle in Hue City, February 1968 (*OSD/HO*)

Congress soon became involved. On 3 March 1967, the chairman of the House Armed Services Committee appointed a three-person subcommittee to "make inquiry into the development, production, distribution, and sale of M–16 rifles." Rep. Richard H. Ichord (D–MO) served as chairman. He sent Col. E.B. Crossman, recently retired from the Army and with weapons expertise, to the combat zone. After interviewing more than 250 soldiers and Marines, Crossman reported that about half had experienced serious weapons malfunctions, of which about 90 percent were failures to extract spent shell cases. In October, after field trips and hearings, the subcommittee filed a harshly worded report. Among its findings were:

> That the AR–15/M–16 as initially developed was an excellent and reliable weapon.
>
> That certain modifications made to the rifle at the insistence of the Army were unnecessary and were not supported by test data.
>
> That the major contributor to malfunctions experienced in Vietnam was ammunition loaded with ball propellant.
>
> That the failure on the part of officials with authority to cause action to be taken to correct the deficiencies of the 5.56mm ammunition borders on criminal negligence.[64]

To what extent were these findings justified? Responding to the subcommittee's call for independent testing, the Weapons Systems Evaluation Group (WSEG), a DoD agency, collaborated with the federally funded Institute for Defense Analyses to arrange trials in the Panama Canal Zone. For 15 days, 522 Marines fired M–16s with buffers; some rifles had chrome-plated chambers, others did not. The outcome, reported by WSEG in February 1968, was surprising: M–16s with ball propellant proved more reliable than M–16s firing IMR powder. More predictably, chrome-plated rifles suffered fewer extraction failures.[65]

Clearly, the subcommittee's findings were outdated. In December 1967, a Colt expert oversaw the inspection of a Marine battalion's M–16s and condemned 286 of 445 rifles as having pitted chambers rendering them unfit for combat use. Late in 1968, survey teams found higher levels of troop satisfaction. New arrivals had been trained on M–16s, cleaning equipment became available, and rifles had new buffers and chrome-plated bores. Although M–16s now performed reasonably well with either ball or IMR stick powder, the Defense Department decided to ban stick powder entirely.[66]

Even before one controversy subsided, another began. In the summer of 1966, the Republic of Singapore sought to purchase 20,300 M–16s. Colt requested an export license and received one early in 1967 from the State Department's Office of Munitions Control. Colt intended to raise its monthly output from 25,000 to 27,500, spreading Singapore's order over 18 months to keep U.S. Army deliveries on schedule. The government of South Korea, whose soldiers in Vietnam carried M–1s of World War II vintage, was bitterly critical. Colt sold only about 3,000 rifles to Singapore. In February 1967, it negotiated an agreement licensing the manufacture of 150,000 rifles by that country.[67]

Was sole-source U.S. production adequate? Army Weapons Command, in mid-1963, had directed Colonel Yount to negotiate an option for buying Colt's manufacturing rights and its technical data package. Colt declined, on grounds that the one-time purchase of 104,000 rifles was not a sufficient incentive. Paul Ignatius, who was then assistant secretary of the Army for installations and logistics, had started the push for a rights provision but decided against pressing it further. In October 1964, Colt reopened the issue by submitting four proposals, one of which involved selling a technical data package to the Army for $5.4 million. However, the Army reversed its position and refused Colt's offers, calculating that future production would not be large enough to recoup the $5.4 million outlay.[68]

As deployments to Vietnam rose, the Army rethought its position. In February 1966, at Weapons Command's request, Colonel Yount started planning for procurement from a second source. He estimated the lead time to be 13 months, at the very least. Thus, contract negotiations ran along two tracks, one for supplying additional rifles and the other for acquiring manufacturing rights and data. A breakthrough came on 16 June 1966, with the signing of a firm fixed-price contract to procure 403,905 M–16s from Colt.[69] Additionally, the Army agreed to contract for 27,500 rifles per month, regardless of any subsequent second-sourcing, thereby guaranteeing that Colt would sell 632,500 rifles through April 1970. The company's monthly output during 1966 rose from 8,000 to 25,000.[70]

Soldiers fire M–16s in combat in Vietnam (*U.S. Army Center of Military History*)

In June 1967, Colt and the Army signed letter contracts to transfer manufacturing rights and data, allowing the government to open bidding for production from a second source. In October, the Army issued a request for proposals, calling for procurement of 167,000 rifles starting in August 1969. By December 1967, eight firms had made $1,000 bid deposits for the technical data package.[71]

The Tet offensive, which began on 30 January 1968 and ran through most of February, created demand for more and quicker deliveries. Nearly all South Vietnamese soldiers carried weapons of World War II vintage. During the country-wide Tet battles, Communists with Soviet-designed AK–47 assault rifles outgunned South Vietnamese with M–1 rifles and M–2 carbines.[72]

In January 1968, Colt was working three shifts, five days a week, with monthly output expected to reach 40,000 and deliveries for the year totaling about 350,000. On 5 March, President Johnson instructed his subordinates: "Let's get Colt working around the clock on those M–16s. Also let's consider opening two additional sources of supply. . . . Don't wait until June. . . . Let's also give the South Vietnamese the best equipment we can."[73]

By then, the search for other producers had reached a point at which four firms were refining their technical proposals. With the deputy secretary of defense's approval, the Army departed from its normal competitive process and negotiated with all four simultaneously. General Besson appointed a five-member source selection advisory council chaired by the commanding general of Weapons Command. A much larger evaluation board scored the prospective producers. The council received the board's ratings and then consulted individuals who were knowledgeable about specific areas. On 19 April 1968, letter contracts were awarded to Harrington & Richardson in Massachusetts and to Hydramatic Division of General Motors in Michigan, each to deliver 240,000 rifles, starting in February 1969, and reaching an output of 25,000 per month by November.[74]

Members of Congress protested. Representative Ichord's subcommittee reconvened, and the Senate Armed Services Committee created a similar body under Sen. Howard W. Cannon (D–NV). The losing firms, Saco-Lowell of Maine and Cadillac Gage, obtained sympathetic hearings. Rep. Peter N. Kyros (D–ME) appealed to the General Accounting Office, challenging the awards' legality.

The Army's original "Determination and Finding," dated 27 September 1967, had stated that "the purpose of this procurement is to establish a sound second-source producer who will supply a quality product in an economical manner and act as an additional production base." But on 28 March 1968, that finding was superseded by the goal of providing "the maximum number of rifles at the earliest possible date with minimum risks of production interruption . . . while maintaining good quality."[75]

The Army asked the winners to submit ceiling prices, with Hydramatic proposing $56.2 million and Harrington & Richardson citing $41.2 million. These prices were incorporated in the letter contracts of 19 April, with the understanding that negotiations for definitive prices would continue. The Army had not asked the losers to submit bids, although Saco-Lowell and Cadillac Gage supposedly were ready to offer ceilings of $36.5 and $36.8 million, respectively.

The GAO defined the basic issue as whether the Army's failure to obtain price proposals from Saco-Lowell and Cadillac Gage invalidated the awards to Hydramatic and Harrington & Richardson. The Army had reevaluated all technical proposals in light of the push to deliver more rifles faster, basing its award on schedule rather than cost. The GAO decided that the history of the relevant legislation showed this to be "a matter of administrative discretion," so that from a legal standpoint the awards should stand. By October 1968, project managers reported that Colt, Hydramatic, and Harrington & Richardson were all meeting their accelerated schedules.[76]

A public perception lingered that flaws in product improvement had caused deaths on the battlefield. But ultimately, by all accounts, the M–16 proved to be an extremely good weapon and, with some improvements, was still in service at the century's end.[77]

ARMY HELICOPTERS: EN MASSE

When the ground war expanded in Southeast Asia, the Army had ready a family of helicopters and a well-tested operational concept for employing them (see chapter V). On 28 July 1965, President Johnson announced that the 1st Cavalry Division (Airmobile) with its complement of 434 helicopters would deploy to South Vietnam. Monthly production was running at 60 UH–1 utility and 5 CH–47 Chinook cargo helicopters, but McNamara wanted to boost output of both. Bell executives told Assistant Secretary Ignatius that they would deliver 100 UH–1 Hueys monthly by May 1966, a goal the company met by greatly expanding its subcontractor and vendor base.[78]


CH–47 Chinook delivers 105mm howitzer with ammunition pallet (*U.S. Army Center of Military History*)

Ignatius asked Boeing-Vertol to turn out 15 CH–47 Chinooks per month. Ignatius and McNamara approved a company plan for reaching that rate by November 1966. But problems soon arose. When Boeing bought Vertol in 1960, its executives had not intruded on Vertol's operations, believing that rotary-wing aircraft required special knowledge that Boeing's fixed-wing designers lacked. In fact, Vertol had only limited production experience. When goals were not met, Ignatius appealed to Boeing's chief executive officer, who placed one of Boeing's top production officials in charge. That step put Vertol's deliveries back on schedule, although Boeing claimed that it would lose $200 million.[79]

Increased production created other problems. The accelerated output of UH–1s was achieved by using repair parts and components scheduled for use in the field. Between August 1965 and August 1966, the value of undelivered repair parts thus rose from $41 million to $185 million. When difficulties in obtaining resources lengthened the lead time for UH–1 production from 13 to 15 months, Secretary of the Army Stanley Resor, in August 1966, recommended moving the UH–1 into the highest priority category of the Master Urgency List. The Joint Chiefs of Staff, however, brought up a "more fundamental problem": Did industry have the capacity to fulfill, on time, all the requirements for critical components? Defense Department–wide, between January and June 1966, only 41 of the 231 items for which priority assistance was sought had been delivered on schedule. In the end, OSD officials chose to centralize inventory control for utility helicopters under General Besson, who would decide whether to fly parts to Vietnam for repair and maintenance or send them to manufacturers for new production.[80]

In the near term, demand simply outstripped deliveries. Eleven Army helicopter companies went to Vietnam between January and June 1966, but only three more followed between July and December. Huey output was boosted again, averaging 150 per month from December 1966 through June 1967. Sixteen helicopter companies arrived in Vietnam during the first half of 1967, and 23 more during the second half of the year. By October 1967, Military Assistance Command, Vietnam had 2,039 Hueys and 249 Chinooks, as well as 391 heavy-lift and light observation helicopters in service. New helicopters arrived in Vietnam at a rate of 140 per month (see table 11–1).[81]

Table 11–1: ARMY HELICOPTER PURCHASES, 1965-1968

	1965	1966	1967	1968
UH-1	759	2,107	753	1,074
CH-47	60	204	120	93
OH-6/58	88	296	687	528
AH-1	--	110	420	308

Source: Butler, *Army Aviation Logistics and Vietnam*, 404–406.

Deliveries of T53 engines failed to keep pace with those of UH–1 airframes. Avco Lycoming, experiencing quality control problems, fell behind schedule. By September 1967, 113 UH–1s in storage awaited engines. But units in Vietnam did not feel the full force of this shortfall thanks to the Army Aeronautical Depot Maintenance Center (ARADMAC), which overhauled engines and aircraft at a rapid pace. In November 1967, while Avco's shipments fell 54 short of the 195 slated, ARADMAC delivered 49 more than the 209 scheduled. Both sources improved by February 1968, as Avco turned out 263 engines for UH–1s while ARADMAC delivered 362.[82]

The Tet offensive spurred a decision to supply the Vietnamese Air Force with U.S. Army helicopters, thereby raising requirements again. Converting the 101st Airborne into an Airmobile Division added another large customer. During 1968, the Army took delivery of 796 UH–1s, 120 CH–47s, and 420 AH–1 gunships. Engine stocks in the continental United States were drawn down to support the war effort.[83] The Army and Avco invested more than $10.5 million to double the plant size and work force of Avco's Charleston facility, creating a capacity to make 100 more engines every month. Between June and December

1968, Avco received contracts to produce 2,661 engines for Hueys, Chinooks, and Cobra gunships. Deliveries allowed the Army's rotary-wing inventory in Vietnam to keep growing, from 2,945 in January 1968 to a peak of 3,948 in March 1970.[84]

Huey Cobra fires rockets at enemy target (*U.S. Army Center of Military History*)

MARINE HELICOPTERS: UNIQUE AND COMMON

The Marine Corps began to rely heavily on helicopters earlier than the Army. The Corps had one overriding mission: ship-to-shore assault. Knowing that nuclear weapons made another landing on the scale of Iwo Jima or Okinawa impossibly risky, Marines looked for a way to disperse, land, and rapidly reconcentrate forces. In the late 1940s, they initiated work on a doctrine of "vertical envelopment," replacing an initial waterborne amphibious assault with a helicopter attack.[85]

In 1952, the Marine ratio of rotary to fixed-wing aircraft was one to five. By 1967, helicopter expansion created a ratio of almost one to one.[86] The least important of the differences between Army and Marine helicopters was the most visible: the Army used skids, while Marines needed wheels to land on carrier decks. A more significant difference was that, while the Army acquired helicopter types and then worked out an air mobility concept for employing them, the Marines developed their doctrine and helicopter types almost in tandem.

Normally, the commandant of the Marine Corps would send a requirement for a helicopter, such as the HR2S, through the Bureau of Aeronautics and its successor organizations to the CNO and the secretary of the Navy. Selected in 1952 to design and develop what became the HR2S, Sikorsky created the Marines' first assault/transport helicopter. Although production proved to be costly and difficult, the first HR2S was delivered in March 1955. Meantime, in 1954, Sikorsky had started producing the SH–34, which was designed for antisubmarine warfare. To create a utility version of the SH–34, Sikorsky only needed to remove ASW equipment, strengthen the cabin floor, and install cargo tie-down rings. The UH–34 Sea Horse, able to carry 12 Marines, first flew in January 1957. Since changes were so slight, deliveries to tactical units began one month later. Although the UH–34 had been intended simply to span a gap between the HR2S and a successor, production ran until 1964 and exceeded 540. Until 1968, the UH–34 remained the mainstay of the Marines' helicopter fleet.[87]

UH–34 Seahorse training operations aboard the USS *Tripoli* off the coast of California, 1967 (*U.S. Marine Corps*)

Introducing turbine engines promised a quantum jump in helicopter lift capability. In 1957, Sikorsky started designing the HSS–2, a new ASW helicopter for the Navy. It had two turbine engines, a watertight fuselage, and a large door on the cabin's starboard side. The commandant of the Marine Corps wanted an assault version of the HSS–2. Detailed requirements published in March 1960 included a rear loading ramp and availability for operational testing by 1963. In finalizing the design, however, tests of the HSS–2's ASW version revealed problems. If more powerful engines were installed in later models, there would have to be extensive and expensive alterations to the transmission and crank shafts.

Addition of a rear ramp for vehicles would require that the forward fuselage be extended to restore balance.[88]

The Vertol Division of Boeing, learning of Sikorsky's troubles, offered its experimental model 107 as a rival. Marine test pilots were impressed and convinced their superiors, who in turn persuaded the Bureau of Naval Weapons, which selected the Vertol model in February 1961. Since Vertol's price offer (which underbid Sikorsky) was about to expire, the bureau urged immediate acceptance. President Kennedy had just ordered the services to expedite contracts in areas of high unemployment. Vertol's plant in Morton, Pennsylvania, lay in such an area. Nonetheless, Secretary of the Navy Fred Korth carried out his own study before giving approval, so the contract with Vertol closed at a higher price.[89]

CH–46 Sea Knight lifts a 1,780-pound Mighty Mite vehicle on its 10,000-pound-capacity external cargo hook (*U.S. Marine Corps*)

Modifying Vertol's 107 for Marine Corps use proved to be more difficult than modifying SH–34s into UH–34s. The most pressing problem was installing a blade-folding mechanism so that the helicopters could be stored on amphibious assault ships. Since 107s had fully articulated rotor heads,[90] adding weight for a blade-folding system required a major reworking of the entire rotor. That, in turn, called for strengthening the transmission and those parts of the fuselage to which it was attached. Also, cutting a large hole in the rear of the airframe so weakened the 107's shell that the surrounding fuselage had to be greatly reinforced. Installing the latest turbines, which were much more powerful than those in 107s, meant that drive shafts had to be redesigned to reduce high-frequency vibrations. The CH–46 Sea Knight that emerged in April 1962 superficially resembled the 107 but was basically an entirely new helicopter, capable of carrying either 4,000 pounds of equipment or 17 combat-equipped Marines. Extensive testing and postponements followed, aimed at reducing vibrations caused by the blade-folding mechanism and the high-speed shafts. The solution—adding 3 absorbers—trimmed the payload by 335 pounds. Operational units began receiving CH–46s in June 1964. The inventory grew to 133 in mid-1966 and 280 by mid-1968.[91]

Sikorsky S–60 Flying Crane (*U.S. Marine Corps*)

For heavier lifting, OSD in 1958 had ordered the Bureau of Aeronautics to study whether a single, vertical takeoff and landing aircraft could meet the needs of all three services. But the Army went ahead with Vertol's CH–47 Chinook, the Air Force wanted more range, and the Navy decided that a four-engine, tilt-wing aircraft was unsuitable. What about the Marines? In 1962, when the Bureau of Naval Weapons invited bids, Vertol proposed modifying its CH–47. This time, though, Sikorsky received the contract. With its own funds, Sikorsky had been developing a "flying crane" for sale to West Germany. For the Marines, Sikorsky proposed simply reattaching a cargo and passenger cabin. Why not, Secretary

McNamara asked, just buy more CH–47s? The Marine Corps persuaded him that extensive modifications for shipborne operations made that impractical. Sikorsky made a slow start, having laid off many skilled workers during 1960–1961, and had to call on other manufacturers to assist in the design effort. When design changes added weight, the main steel rotor head had to be replaced with a lighter titanium rotor head. Shortages of parts supplied by subcontractors further delayed delivery of the first CH–53 Sea Stallions to an operational unit until September 1966.[92]

CH–53 Sea Stallion delivers ammunition to Marines (*U.S. Marine Corps*)

Marine Corps insistence on having a separate family of helicopters might seem extravagant. Given the Marine Corps' worldwide mission, however, its helicopters required a unique design for shipboard. Yet in Vietnam, Marine helicopter units were based ashore at Phu Bai, Da Nang (Marble Mountain), and Chu Lai. There the Army's smaller, agile Hueys proved to be more suitable for search-and-destroy operations. CH–46s also suffered from environmental problems—fine white sand damaging engines and rotor blades, and structural failures in the tail section causing fatal crashes—that were not fixed completely until 1968. The larger CH–53s functioned best as retrievers of downed helicopters, while the older UH–34s continued to fly combat missions until August 1969.[93]

AH–1J Sea Cobra stands ready for inspection at Bell Helicopter's Fort Worth plant before delivery to Marine Corps (*U.S. Marine Corps*)

Along with its own helicopters, the Marine Corps acquired versions of the Army's Huey and the Cobra gunship. Deliveries of a Marine UH–1E, intended for observation and target acquisition, began in March 1962. The UH–1E differed from Army versions in only two ways. First, rotor brakes were added because landing on a crowded deck required that rotor blades stop quickly, so the machine could be moved to a parking area. Second, corrosion from salt water and air required the substitution of aluminum for magnesium in much of the construction. Like the Army, the Marine Corps in Vietnam tried arming its Hueys but found that they needed more firepower. Marines tested and praised the AH–1G gunship but insisted upon developing a twin-engine version, mainly on grounds that the helicopter and probably the crew would be lost if the lone engine malfunctioned at sea. A Marine AH–1G squadron began flying combat missions in April 1969, but twin-engine AH–1J Sea Cobras did not see action until February 1971, only a few months before the last Marine combat units left Vietnam.[94]

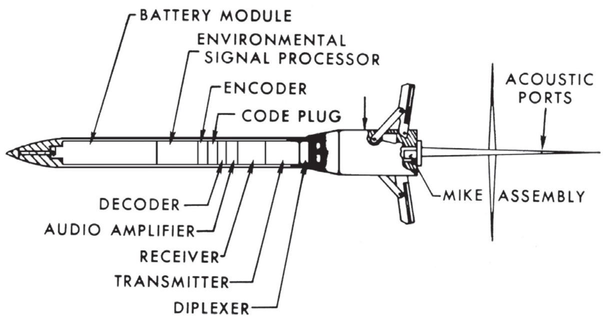
BUILDING AN INFILTRATION BARRIER

American firepower killed enemy troops in large numbers, but that meant little unless the flow of North Vietnamese regulars coming through eastern Laos down the Ho Chi Minh Trail could be stopped. A campaign of aerial interdiction over Laos began in December 1964, but infiltration doubled in 1965 and again during 1966. Roger Fisher, a Harvard professor and consultant to DoD, in January 1966 suggested creating a barrier of barbed wire, mines, chemicals, and air-delivered ordnance. Although the JCS strongly opposed the concept, deeming it another Maginot Line doomed to fail, Secretary McNamara was enthusiastic. The Institute for Defense Analyses won a contract to explore the feasibility of erecting a barrier across infiltration routes. Reporting on 30 August 1966, one of IDA's subgroups described a concept that would apply existing technology. For stopping trucks and troops along the Ho Chi Minh Trail, the barrier would consist of pebble-size "gravel" antipersonnel mines, which were already in production, and battery-run sensors adapted from the Navy's acoustic sonobuoys. Both would be air-dropped, either by fixed-wing aircraft or by helicopter.[95]

On 15 September 1966, Secretary McNamara appointed Army Lt. Gen. Alfred Starbird (later program manager for the Sentinel ABM system; see chapter VIII), to direct a joint task force charged with erecting an anti-infiltration barrier within one year. The "McNamara Line," as it came to be called, would consist of an array of obstacles just below the Demilitarized Zone that divided North and South Vietnam. In southern Laos, a system of sensors would detect trucks and troops, while air-dropped mines and bombs would destroy them. In October, Starbird requested and McNamara approved monthly production of 10 million antipersonnel gravel mines and 3.5 million antitruck bomblets, the latter containing tooth-shaped pellets nicknamed Dragonteeth.[96]

In November 1966, the Air Staff's Directorate of Operations began designing a command and control center for managing the surveillance portion of the barrier. Meanwhile, Lieutenant General Starbird's project office proceeded with sensor development. An acoubuoy, intended to hang from jungle growth by its parachute, was given a longer life battery and a sensor in place of a sonar device. It came in three modes: line spectrum detection of movement; activation by the detonation of gravel mines or bomblets; and a combination of those two. An air-delivered seismic intrusion detector (see figure 11–3) had an internal geophone that processed motion and determined whether the object was a man or a vehicle.[97]

Figure 11-3: ACOUSTIC AND SEISMIC INTRUSION DETECTOR



Source: National Museum of the U.S. Air Force

By early 1967, Air Force Systems Command was testing air-dropped sensors in the Panama Canal Zone, while construction of the infiltration surveillance center in Thailand ran from July to October 1967. An officer from AFSC's Electronic Systems Division served as site activation manager. The principal contractors, Radiation Systems Company and IBM, leased a computer to the Air Force.[98]

Air drops of acoubuoys and seismic intrusion detectors began on 25 November 1967; by the end of the year, Navy aircraft had sowed 49 sensor strings. McNamara hoped that truck destruction would increase by 200 or 300 percent and that attrition against personnel would rise from 2 to 30 percent. Almost immediately, however, problems appeared. The antipersonnel portion worked poorly, for example, mainly because rain and high humidity quickly neutralized the explosive charges in gravel mines.[99]

Leonard Sullivan, Jr., deputy director of defense research and engineering for Southeast Asia matters, visited the surveillance center in mid-1968. Praising it as "the Mecca of U.S. R&D quick reaction in this war," Sullivan described the center as "virtually fully automated with direct evaluated print-out available to the Tactical Analysis Officers every five minutes, untouched by human hands from its origin in the implanted sensor." Still, Sullivan worried about the shift of effort from finding people to detecting trucks, when the enemy's only known reaction to monitoring truck routes had been to increase antiaircraft defenses. Of 4,665 possible targets nominated between December 1967 and March 1968, air crews had succeeded in verifying only 547 and attacking slightly more than half of those.[100]

Air Delivered Seismic Intrusion Detector (*National Museum of the U.S. Air Force*)

During the summer of 1968, a committee of scientists and military officers headed by retired Admiral James S. Russell evaluated the effort. Major weaknesses were the lack of wide-area bombs and the inability of sensors to locate troops, unless someone actually stepped on a gravel mine and the transmitter broadcast the sound of the explosion. Consequently, the committee recommended giving top priority to interdicting the road net itself.[101]

A second generation of sensors entered service in October 1968. Batteries of first-generation devices had run continuously, monopolizing reporting channels and shortening their lives. Since the new sensors transmitted only in response to commands from the surveillance center, they could keep silent but count the number of impulses and respond when queried. Still, activations had to be timely, meaning that they had to derive from careful study of sensor locations and patterns of enemy behavior.[102]

A third generation, appearing late in 1969, provided even more channels so that a larger field could be seeded without the danger of signal interference. One model included an engine detector that responded to electromagnetic signals from unshielded ignitions, thereby helping to locate truck parks and transshipment points. Others boasted a microphone that could pick up the sounds of voices, indicating the presence of foot paths or bivouac areas. Implanted during the monsoon season, these new devices made the interdiction campaign from October 1970 through March 1971 the most successful to date.[103]

But there were limits to what a blocking belt could accomplish. During the winter of 1971–1972, laser-guided weapons created road cuts, which were then seeded with antipersonnel mines. Next came air drops of magnetic-fused antivehicle systems, plus sensors to detect breaches or bypasses of the belts. Yet according to Air Force historians, the North Vietnamese "not only succeeded in concealing many of their roads, trails, and support installations"; they also "emplaced antiaircraft guns and missiles that hampered air attacks, aerial photography and sensor delivery." Thus, the North Vietnamese were able to position enough soldiers and supplies to launch their spring 1972 offensive.[104]

* * * * *

In September 1965, Harold Brown, soon to leave his post as DDR&E to become secretary of the Air Force, predicted to his successor that the Vietnam War would be over before technology could have a real effect.[105] Even though combat went on much longer than U.S. policymakers expected in 1965, Brown's prediction proved to be correct in some respects. The development of electronic countermeasures kept abreast or ahead of enemy air defenses, with requirements being either foreseen or rapidly filled, but strategic choices sometimes negated that advantage. The development of laser-guided bombs was swift—requests for proposals went out in April 1965, and the first combat test occurred in March 1968—but the Paveway system's limitations made it impractical for use against well-defended targets. Hence, Paveway, even if it had been deployed sooner, might not have turned Rolling Thunder into a success. Pave Knife was fielded in March 1971 and proved to be effective in 1972 against fixed targets in North Vietnam. By then, however, U.S. involvement in the war was near an end. Even though the anti-infiltration barrier employed three generations of devices between 1967 and 1969, weaknesses persisted. What could have made the barrier effective, Brown believed, was technology that only became available 10 to 15 years later.[106] While no technology could make up for shortcomings in U.S. strategy or weaknesses in the Saigon regime, the acquisition process had achieved some successes that improved operational and tactical performance during the course of the war.

Endnotes

1. The military history of the Vietnam War has been studied extensively. Prominent works include Phillip B. Davidson, *Vietnam at War: The History 1946–1975* (Novato, CA: Presidio Press, 1988); David W.P. Elliott, *The Vietnamese War: Revolution and Social Change in the Mekong Delta, 1930–1975* (Armonk, NY: M.E. Sharpe, 2006); George C. Herring, *America's Longest War: The United States and Vietnam, 1950–1975* (New York: Wiley, 1979); Richard A. Hunt, *Pacification: The American Struggle for Vietnam's Hearts and Minds* (Boulder, CO: Westview, 1995); Lien-Hang T. Nguyen, *Hanoi's War: An International History of the War for Peace in Vietnam* (Chapel Hill: University of North Carolina Press, 2012); and John Prados, *Vietnam: The History of an Unwinnable War, 1945–1975* (Lawrence: University Press of Kansas, 2009).

2. Knaack, *Post–World War II Bombers*, 277–279.

3. Haworth, *The Bradley and How It Got That Way*, 30–33; Hunnicutt, *Bradley*, 387.

4. Marolda, *By Sea, Air, and Land*, 147, 149, 150, 166–168.

5. Werrell, *Chasing the Silver Bullet*, 15–23. Next came the AC–119 Stinger gunship, which made its combat debut early in 1969. The budgetary, contractual, and technical problems that delayed the AC–119's full deployment for more than two years are described in William P. Head, *Shadow and Stinger* (College Station: Texas A&M University Press, 2007), particularly 92–96 and 115–127.

6. Report by the Joint Logistics Review Board, *Logistic Support in the Vietnam Era*, May-June 1970, vol. I, A–84, box 321, OSD/HO.

7. David R. Mets, *The Quest for a Surgical Strike: The United States Air Force and Laser Guided Bombs* (Eglin AFB, FL: Office of History, Armament Division, Air Force Systems Command, 1987), 44.

8. Memo, Glass to Sec McNamara, "Brief History of Ammunition Procurement Policies Prior to Vietnam Buildup (January 1961–January 1965)," 21 Apr 66, 4, 7, fldr "Subcommittee for Special Investigations Report on Military Shortages, Etc.," box 90, AsstSecDef (Comptroller) files, RG 330, OSD/HO.

9. Thompson, *To Hanoi and Back*, 234, 49; Paul C. Gillespie, *Weapons of Choice: The Development of Precision Guided Munitions* (Tuscaloosa: University of Alabama Press, 2006), 101–102; memo, Glass to McNamara, "Brief History of Ammunition Procurement," 7.

10. Thompson, *To Hanoi and Back*, 234, 49; Gillespie, *Weapons of Choice*, 101–102; memo, Glass to McNamara, "Brief History of Ammunition Procurement," 7.

11. Memo, AsstSecDef (I&L) Ignatius to Sec McNamara, "Status of FLAGPOLE Ammunition Items," 30 Dec 65, fldr 51–66, box 23, 69–A–3542, RG 330, WNRC.

12. Ignatius, *On Board*, 135. One factor delaying the acceleration of production was that government-owned tooling used to manufacture iron bombs had been sold for scrap. Ibid., 132. Memo, Ignatius to Sec McNamara, "Status of FLAGPOLE Ammunition Items."

13. *Logistic Support in the Vietnam Era*, monograph 2, "Ammunition," app. D, D–7; memo, Ignatius to McNamara, "Bomb Production Status," 8 Feb 66, fldr S–330–66, box 23, 69–A–3542, RG 330, WNRC.

14. Memo, AsstSec Ignatius to Sec McNamara, "Southeast Asia Ordnance Requirements," 25 Feb 66, fldr S–503–66, box 23, 69–A–3542, RG 330, WNRC.

15. Ignatius, *On Board*, 131. Temporarily, each service was given loading limits (for example, 2.4 tons for the Air Force and 1.8 tons for the Navy for each sortie over North Vietnam). In the opinion of air commanders and pilots, reductions in sorties and shortages of optimum munitions led to higher aircraft losses. Jacob Van Staaveren, *Gradual Failure* (Washington, DC: Air Force History and Museums Program, 2002), 264–265.

16. Memo, Sec McNamara to SecArmy et al., "Changes in the Top National Priority Category . . . of the Department of Defense Master Urgency List," 27 Apr 66, fldr "400.174–Priorities and Military Urgencies, 1966," box 64, 70–A–4443, RG 330, WNRC. Items dropped from the highest category were the Titan II ICBM, the Ballistic Missile Early Warning System, and Permissive Action Links for nuclear weapons.

17. Ignatius, *On Board*, 132–134; Hearings, House Cte on Approp, *Department of Defense Appropriations for 1967*, 89 Cong, 2 sess, pt. 4, 497. Earlier, Brigadier General Stanwix-Hay had headed a region of the Defense Contract Administration Services. Management of the 2.75-inch rocket is described in *Logistic Support in the Vietnam Era*, vol. I, 8, and monograph 2, app. D, D–14.

18. Hearings, *DoD Appropriations for 1967*, pt. 4, 450–451; "U.S. Buys Back German Junk Bombs," *Ocala Star Banner*, 17 April 1966, 1. Dr. Edward Drea provided the figures of $1.70 and $21.00.

19. Even then, the rate of 500 per month was only one-eighth of the Air Force's stated requirement—and the Navy also wanted some. Thompson, *To Hanoi and Back*, 50.

20. *Logistic Support in the Vietnam Era*, monograph 2, "Ammunition," app. D, D–6, D–7, D–10; Thompson, *To Hanoi and Back*, 49–50.

21. The Korean War surplus that McNamara criticized was useful in tiding over recurring shortages. According to Gregory A. Freeman, when the carrier *Forrestal* launched strikes against North Vietnam in July 1967, it had aboard 1,000-pound bombs dating from 1953. Freeman, *Sailors to the End: The Deadly Fire on the USS* Forrestal *and the Heroes Who Fought It* (New York: HarperCollins, 2002), 85–88, 285.

22. Ignatius, *On Board*, 132–133 (quotation, 133). During Rolling Thunder, the Air Force expended 18,703 100-/125-/250-pound bombs, 227,304 500-pound bombs, 358,941 750-pound bombs, 43,658 cluster bomb units, 1,944 Bullpups, and 868,424 rockets. Thompson, *To Hanoi and Back*, 306.

23. In April 1966, 105mm illumination rounds were moved to the top category of the Master Urgency List. Memo, Sec McNamara to SecArmy, "Changes in the . . . Department of Defense Master Urgency List," 27 Apr 66.

24. *Logistic Support in the Vietnam Era*, monograph 2, app. D, D–26, D–27.

25. John M. Carland, *Stemming the Tide* (Washington, DC: U.S. Army Center of Military History, 2000), 359, 361.

26. Van Staaveren, *Gradual Failure*, 264; Roland G. Ruppenthal, *Logistical Support of the Armies, Vol. II* (Washington, DC: U.S. Army Center of Military History, 1958), 247–257; Doris M. Condit, *History of the Office of the Secretary of Defense*, vol. II, *The Test of War: 1950–1953* (Washington, DC: GPO, 1988), 157–161.

27. *Logistical Support in the Vietnam Era*, monograph 2, app. H, H–7, app. D, D–27, D–37, D–39.

28. Mets, *Quest for a Surgical Strike*, 50–51; Peter DeLeon, *The Laser-Guided Bomb: Case History of a Development*, RAND Report R–1312–1–PR (Santa Monica, CA: RAND, 1974), 6.

29. DeLeon, *Laser-Guided Bomb*, 6–7; Mets, *Quest for a Surgical Strike*, 55; Gillespie, *Weapons of Choice*, 74–75.

30. DeLeon, *Laser-Guided Bomb*, 7–9.

31. Ibid., 9–10; Gillespie, *Weapons of Choice*, 77–78.

32. Gillespie, *Weapons of Choice*, 81, 83, 84.

33. Ibid., 91, 93.

34. DeLeon, *Laser-Guided Bomb*, 12–18; Gillespie, *Weapons of Choice*, 107.

35. DeLeon, *Laser-Guided Bomb*, 12–18; Gillespie, *Weapons of Choice*, 107.

36. DeLeon, *Laser-Guided Bomb*, 18–19; Mets, *Quest for a Surgical Strike*, 59–60; Gillespie, *Weapons of Choice*, 108.

37. DeLeon, *Laser-Guided Bomb*, 19–21.

38. Ibid., 22–23, 25; Gillespie, *Weapons of Choice*, 110–111; Mets, *Quest for a Surgical Strike*, 59, 67. The Navy began combat use of Walleye, a glide bomb without its own propulsion, in May 1967. Relying on a TV screen aboard the aircraft, the crew would lock on a target and release the weapon. Because the gyro-stabilized TV camera had to lock on to a point with a very sharp light/dark contrast, and weather often was overcast, launching aircraft usually had to come very close to the target. The Navy introduced an improved, more powerful Walleye II in 1971. The Air Force chose not to purchase any, high cost being a factor. Mets, *Quest for a Surgical Strike*, 60–61; Gillespie, *Weapons of Choice*, 103–106.

39. A major flaw was the satellite spot caused by multiple laser reflection. The solution lay in adjusting the seeker's sensitivity threshold. DeLeon, *Laser-Guided Bomb*, 31–32.

40. Ibid., 27, 31, 34, 37, 39–42.

41. Mets, *Quest for a Surgical Strike*, 67, 73, 80–92; Knaack, *Post–World War II Fighters*, 275–276; Thompson, *To Hanoi and Back*, 230–236. In North Vietnam, between April 1972 and January 1973, the Air Force expended 3,917 laser-guided 2,000-pound bombs. Ibid., 306; Gillespie, *Weapons of Choice*, 115–116, 194 fn 63.

42. R.V. Jones, *The Wizard War: British Scientific Intelligence, 1939–1945* (New York: Coward, McCann & Geoghegan, 1978), xix, 84-86, 95-99, 102, 127-129, 172-180.

43. Van Staaveren, *Gradual Failure*, 163; Marshall Michel III, *Clashes: Air Combat Over North Vietnam, 1965–1972* (Annapolis, MD: Naval Institute Press, 1997), 29, 32.

44. Bernard C. Nalty, *Tactics and Techniques of Electronic Warfare: Electronic Countermeasures in the Air War Against North Vietnam, 1965–1973* (Washington, DC: Office of Air Force History, 1977), 6; Michel, *Clashes*, 34. Later, as North Vietnamese radars proliferated, this equipment gave too many warnings to be useful.

45. Nalty, *Tactics and Techniques of Electronic Warfare*, 53; Michel, *Clashes,* 13, 37, 38; Van Staaveren, *Gradual Failure*, 116; Thompson, *To Hanoi and Back*, 48.

46. Van Staaveren, *Gradual Failure*, 195; ODDR&E, "Minutes of DSB Electronic Warfare Task Group Meeting, 28 March 1966," 12 Aug 66, 7, box 836, OSD/HO; ODDR&E, "Minutes, Executive Committee, Defense Science Board, 11 May 1966," 5, box 837, OSD/HO.

47. Nalty, *Tactics and Techniques of Electronic Warfare*, 57, 59; Michel, *Clashes*, 61–62; Thompson, *To Hanoi and Back*, 50.

48. Nalty, *Tactics and Techniques of Electronic Warfare*, 53, 66.

49. Merle L. Pribbenow, "The –Ology War: Technology and Ideology in the Vietnamese Defense of Hanoi, 1967," *Journal of Military History* 67, no. 1 (2003): 182, 186–187, 179.

50. Ibid., 189–192, 195; Nalty, *Tactics and Techniques of Electronic Warfare*, 59.

51. Fire Can was used with antiaircraft artillery, while Fan Song radars were used with surface-to-air missiles.

52. Pribbenow, "The –Ology War," 196–197; Nalty, *Tactics and Techniques of Electronic Warfare*, 63–64.

53. Pribbenow, "The –Ology War," 198; Nalty, *Tactics and Techniques of Electronic Warfare*, 6. During the 1972 bombing of North Vietnam, air defense units still relied heavily upon optical tracking and engagement of targets. Stephen P. Randolph, *Powerful and Brutal Weapons: Nixon, Kissinger, and the Easter Offensive* (Cambridge, MA: Harvard University Press, 2007), 315.

54. Pribbenow, "The –Ology War," 176, 179–180, 192–193, 200.

55. McNaugher, *The M–16 Controversies*, 123–125; Ezell, *Great Rifle Controversy,* 206; Chivers, *The Gun*, 296; House, Cte on Armed Svcs, *Report of the Special Subcommittee on the M–16 Rifle Program*, 90 Cong, 1 sess, 5339.

56. Ezell, *Great Rifle Controversy*, 213–216, 208.

57. Stevens and Ezell, *The Black Rifle*, 136. Muzzle velocity did much to determine a bullet's range and lethality. The cartridge case imposed a limitation because it would begin to fail when chamber pressures exceeded 52,000 pounds per square inch. McNaugher, *M–16 Controversies*, 146.

58. McNaugher, *M–16 Controversies*, 147–149; Ezell, *Great Rifle Controversy*, 211. Colonel Yount held this position until he was reassigned in June 1967.

59. McNaugher, *M–16 Controversies*, 150–152.

60. Slower burning ball powder gave a more constant chamber pressure as the bullet traveled down the barrel. For a given muzzle velocity, the stick IMR produced higher peak chamber pressures but yielded lower gas-port pressures than ball powder, thus contributing less cycling energy. Ibid., 147.

61. Ibid., 153–154.

62. Ibid., 155–156, 158; Stevens and Ezell, *The Black Rifle*, 198–201, 218.

63. McNaugher, *M–16 Controversies*, 140–142; Ezell, *Great Rifle Controversy*, 216–220; Stevens and Ezell, *The Black Rifle*, 209–211, 214.

64. Stevens and Ezell, *The Black Rifle*, 215–216; House, Cte on Armed Svcs, *Report of the Special Subcommittee on the M–16 Rifle Program* (no. 26), 90 Cong, 1 sess, 5368–5370 (quoted paragraphs are 10, 11, 6, and 17).

65. Stevens and Ezell, *The Black Rifle*, 273–274; Chivers, *The Gun*, 327–329, 333; McNaugher, *M–16 Controversies*, 160.

66. Stevens and Ezell, *The Black Rifle*, 273–274; Chivers, *The Gun*, 327–329, 333; McNaugher, *M–16 Controversies*, 160. In 1969, Frankford experts isolated calcium carbonate as the sticky residue that ball powder left in the rifle chamber, and steps were taken to remove it. *M–16 Controversies*, 159.

67. Ezell, *Great Rifle Controversy*, 206–207; Stevens and Ezell, *The Black Rifle*, 205–206, 319.

68. Stevens and Ezell, *The Black Rifle*, 277–279.

69. Strictly speaking, this was Modification 13 of a letter contract dated 6 December 1965.

70. Stevens and Ezell, *The Black Rifle*, 279, 205, 282.

71. Ibid., 282, 284; House, Cte on Armed Svcs, *M–16 Rifle Procurement Program*, 90 Cong, 2 sess, 10998.

72. Between April and August 1967, General Westmoreland had requested 118,436 M–16s for the South Vietnamese. Five thousand were delivered late that year, with the rest scheduled for the first eight months of 1968. Jeffrey J. Clarke, *Advice and Support: The Final Years* (Washington, DC: U.S. Army Center of Military History, 1988), 283–284.

73. *FRUS 1964–1968*, vol. 6, 275, 331 (quotation, 331).

74. House, Cte on Armed Svcs, *M–16 Rifle Procurement Program* (no. 67), 90 Cong, 2 sess, 11008–11010; Stevens and Ezell, *The Black Rifle*, 284–285.

75. *Hearings on M–16 Rifle Procurement Program* (no. 67), 11066–11072 (quotation, 11071).

76. Ibid. (quotations, 11072); Stevens and Ezell, *The Black Rifle*, 286. The Source Selection Advisory Council claimed that Saco-Lowell lacked access to a pool of surplus skilled workmen, needed a large quantity of new machinery, did not have adequate test-firing facilities, and lacked a room with constant humidity and temperature for storing test equipment. The Cannon subcommittee challenged all these points, to no avail. Ezell, *Great Rifle Controversy*, 224–225.

77. Often, in the mid-1960s, the M–16 was compared unfavorably with the AK–47. According to Chivers, an AK–47 looked primitive, but its main operating system had a loose fit and massive parts, which made excess energy available in each firing cycle and hence resistant to jamming. The AK–47's bore and chamber were chromed, and an excellent protective finish coated the rifle. An M–16's tight fit helped make it more accurate than an AK–47, but the small mass of its bolt generated little excess energy which, coupled with the tight fit, added to problems of reliability. *The Gun*, 309.

78. Ignatius, *On Board*, 128–129.

79. Ibid.

80. JCSM–535–66 to Secretary McNamara, "Military Urgencies (UH–1 Helicopter Series)," 23 Aug 66, fldr 400.174—"Priorities and Military Urgencies, 1966," box 64, 70–A–4443, RG 330, WNRC; Ignatius, *On Board*, 135.

81. George L. MacGarrigle, *Taking the Offensive* (Washington, DC: U.S. Army Center of Military History, 1998), 17; Butler, *Army Aviation Logistics and Vietnam,* 329.

82. Ibid., 347–352, 389–390, 382–383.

83. The laterite content of the soil in Vietnam wore out reciprocating engines and moving parts more rapidly than expected.

84. Butler, *Army Aviation Logistics and Vietnam*, 347–352, 389–390, 382–383; *FRUS 1964–1968*, vol. 6, 329–330.

85. Eugene W. Rawlins, *Marines and Helicopters, 1946–1962* (Washington, DC: History and Museums Division, HQ, U.S. Marine Corps, 1976), 12–13, 65–66; Christopher C.H. Cheng, *Air Mobility* (Westport, CT: Praeger, 1994), 69–70, 183–189.

86. Fails, *Marines and Helicopters, 1962–1973*, 42. The Corps operated within a limit of 1,425 aircraft, rotary and fixed-wing.

87. Rawlins, *Marines and Helicopters, 1946–1962*, 54–57, 68–69; Fails, *Marines and Helicopters, 1962–1973*, 5–9.

88. Fails, *Marines and Helicopters, 1962–1973*, 47–49.

89. Ibid., 49–52.

90. When a helicopter starts moving forward, the amount of lift generated on opposite sides becomes drastically out of balance. Igor Sikorsky had found a way to equalize lift: "As his rotor blades moved around the helicopter, they automatically changed pitch, flexed, twisted, and even adjusted speed so that no matter where they were in relation to the wind, they produced the same amount of lift. The result was termed a 'fully articulated' rotor head." Ibid., 3–4.

91. Ibid., 52–55.

92. Rawlins, *Marines and Helicopters, 1946–1962*, 83–84; Fails, *Marines and Helicopters, 1962–1973*, 58–62.

93. Allan R. Millett, *Semper Fidelis: The History of the United States Marine Corps* (New York: Macmillan, 1980), 582; Fails, *Marines and Helicopters, 1962–1973*, 94, 99–102, 115–119, 126.

94. Fails, *Marine Helicopters, 1962–1973*, 86–90, 151–157.

95. Jacob Van Staaveren, *Interdiction in Southern Laos: 1960–1968* (Washington, DC: Center for Air Force History, 1993), 301, 256–260.

96. Ibid., 262, 264.

97. Ibid., 267–268.

98. Ibid., 268, 271; Bernard C. Nalty, *The War Against Trucks* (Washington, DC: Air

Force History and Museums Program, 2005), 268.

99. Van Staaveren, *Interdiction in Southern Laos*, 277, 279; *FRUS 1964–1968*, vol. 5, 570.

100. Nalty, *War Against Trucks*, 19–23 (quotation, 21). As antiaircraft defenses grew more effective, P–2s had to be replaced by CH–3 helicopters and then, in February 1969, by F–4Ds. Ibid., 27–28.

101. Ibid., 24–25.

102. Ibid., 83–85.

103. Ibid., 147–148.

104. Randolph, *Powerful and Brutal Weapons*, 55–59. The quoted passages come from Nalty, *War Against Trucks*, 302.

105. Notes by W.S. Poole on conversation with Dr. John S. Foster, Jr., 3 Oct 07, at the U.S. Army Center of Military History.

106. Unrecorded remarks during an interview of Harold Brown by Walton S. Moody and Walter S. Poole, 28 Jan 04, conducted at the Center for Strategic and International Studies, Washington, DC.

CHAPTER XII

Conclusion

In 1961, the Kennedy administration moved quickly to replace the Eisenhower administration's reliance on nuclear weapons with a national security strategy that built up conventional capability to allow flexible responses to crises. Re-equipping the services' weapons inventories for different and more wide-ranging tasks took longer than anticipated, with ramifications that senior civilians did not fully appreciate. New operational requirements also imposed stringent technological demands. To increase the accuracy of strategic nuclear missiles, for example, guidance systems became more sophisticated but experienced major cost and schedule overruns. Similarly, fighter-bombers of the 1950s that had been designed to deliver tactical nuclear weapons now had to be replaced by aircraft with fire control systems that could satisfy the greater accuracy required in conventional weapons delivery. For the technologically advanced Mark II avionics system, cost and schedule were grossly underestimated.

Like his predecessors, Secretary McNamara worked to promote economy and efficiency and to ensure that weapons development harmonized with the requirements of national strategy. But unlike them, he exercised his statutory authority fully, relying upon economic or cost-effectiveness analysis to rationalize and centralize decisionmaking. After a short honeymoon, friction between McNamara and the services steadily increased. Military officers grew increasingly wary of the whiz kids and their cost-effectiveness studies; McNamara interpreted their attitude as outdated and parochial. Under pressure, service leaders adopted the form more than the substance of cost-effectiveness analysis. When some initial appointments for service secretaries did not work well, McNamara chose people from his own office to succeed them. Cyrus Vance, who was OSD general counsel, became secretary of the Army in 1962. Paul Nitze, assistant secretary of defense (international security affairs), was appointed secretary of the Navy in 1963; Paul Ignatius, assistant secretary of defense (installations and logistics), followed Nitze in 1967. Harold Brown, director of defense research and engineering, became secretary of the Air Force in 1965. It has been said that "McNamara's men really became vice presidents of DoD rather than heads of the

Army, Navy, or Air Force."[1] But most uniformed personnel retained their service-oriented perspectives. Recurring interservice splits hobbled the effectiveness of the JCS, which helps to explain why in 1965 McNamara elevated Alain Enthoven to the post of assistant secretary of defense (systems analysis). Increasingly, McNamara relied upon Enthoven and his methodology.

The services each instituted major organizational changes for acquisition, with consequences that varied widely. When the Air Force Systems Command was created in March 1961, General Schriever's colleagues joked that AFSC meant "All for Schriever's Convenience." Soon, however, the general concluded that AFSC also served McNamara's convenience, because centralizing Air Force acquisition made it much easier for OSD analysts to intervene and influence decisionmaking. Army Materiel Command was established, in part, to eliminate what McNamara viewed as the conservatism and inefficiency of the technical services. From OSD's perspective, AMC was at best a partial success, and Army acquisition continued to be characterized by ad hoc improvisation. The Navy's tradition of decentralization and delegation struck McNamara as evidence of a poorly organized and managed service.[2] Replacing the material bureaus with systems commands ended the separation of producer from consumer logistics, but the chief of naval material still ran a decentralized headquarters.

In choosing weapon systems, the mating of OSD's systems analysis with the services' "mature military judgment" produced more conflicts than consensus. The Air Force became most disaffected. General Schriever was convinced that new technologies would deliver cascading breakthroughs, as outlined in Project Forecast. As Schriever saw it, McNamara relied on flawed analyses to justify small steps in weapons development instead of the large advances that were possible. Although the Air Force and OSD were in full accord about pressing ahead with multiple independently targetable reentry vehicles, McNamara used MIRVs to justify capping Minuteman launchers at 1,000, allowing the Soviets to erase a U.S. lead that, in his opinion, was made irrelevant by MIRVs. Then, he refused to proceed with a new manned bomber, substituting an adaptation of the F–111 fighter-bomber that most senior officers in the Strategic Air Command saw as an awkward fit. Additionally, as a result of OSD's emphasis on economy and efficiency, the Air Force's tactical inventory was filled with F–4s, F–111s, and A–7s, none of which originated with the Air Force and none of which was ideally suited to combat in Southeast Asia.

McNamara agreed with the Navy that Poseidon, with its MIRVs, was the best weapon system in the U.S. strategic arsenal. Conflicts between the secretary and the service sprouted in other areas, however. When McNamara conceived the carrier-based F–111B as a showpiece of commonality and efficiency and a model for future weapons programs, the Navy held to its long-standing conviction that war at sea created special requirements only sea warriors fully understood. At least in this instance, the Navy was probably right. The F–111B's shortcomings as a carrier airplane made its termination almost certain. In choosing power plants for surface ships, McNamara's cost-effectiveness calculations collided with Vice Admiral Rickover's crusade for nuclear power. Although McNamara finally approved additional nuclear-powered aircraft carriers to follow USS *Enterprise*, he promoted gas turbine engines for other surface combatants.

McNamara's relationship with the Army was no better. To OSD civilians, the superiority of Armalite's AR–15 rifle was clear, and the doggedness with which many senior Army officers defended the Springfield Arsenal's M–14 was incomprehensible. The Army fielded good utility, cargo, and light observation helicopters but, as McNamara saw it, civilians had to force the service to develop a better operational concept for employing them. The Shillelagh antitank missile proved to be unsatisfactory, which both the Army and OSD failed or refused to recognize during its long and troubled gestation. The aborted Main Battle Tank was McNamara's initiative. Even without the technological leaps required, very different U.S. and West German perspectives almost certainly would have doomed the project. Ballistic missile defense promised to keep the Army on a par with the Air Force and Navy in the missile age. For McNamara, though, being able to hit a bullet with a bullet was not proof of the system's operational feasibility. Supported by a majority of scientific opinion, he insisted that MIRVs, decoys, and penetration aids could saturate any defense. The "light" Sentinel program was a concession to Congress that, as he had hoped, withered and died.

Although McNamara set out to promote commonality and jointness in acquisition, the increasing specialization of weapon systems frustrated many of his hopes. Each service, and sometimes a branch within a service, filled a unique niche. McNamara was able to persuade the Air Force to turn the Navy's F4H–1 Phantom into the mainstay of its tactical inventory, but he envisioned the F–111 as multimission, serving Tactical Air Command, Strategic Air Command, and the Navy. The outcome was an F–111A fighter-bomber that excelled in the much more restricted role of low-level night penetrator and an FB–111 strategic bomber that SAC disliked. When air mobility became a reality, the Army and OSD believed that utility "Hueys" also would serve as attack helicopters. Battlefield experience quickly proved otherwise, resulting in the development of the Cobra gunship. Poseidon gained a clearly defined role, in part because Rear Adm. Levering Smith deliberately limited its capabilities to counter-city and "soft" counterforce targets. Smith thereby ensured that Poseidon would not conflict with the Air Force's Minuteman II, which was designed to destroy hardened silos and command and control centers.

At the outset, McNamara accorded reducing lead time and controlling cost equal priority with achieving performance. Switching from cost-plus to fixed-fee contracts was the principal means that OSD employed to achieve his goal. But the seemingly precise language of such contracts proved to be open to a range of interpretations. Technical project personnel interpreted the words in ways that would allow them to perform work in an economical way. Contractors interpreted clauses in ways that would bring them the most money. Financial personnel and auditors interpreted them in ways that would minimize apparent expenditures. OSD underestimated the creativity of the services and contractors to press ahead on the programs they wanted, finding new ways to funnel funds into those projects.[3]

According to one observer, McNamara "wanted to put government contracting on the same basis as that of an oil or chemical company which enters into a fixed-price agreement with an engineering or construction firm to design and build a plant capable of producing materials at a specified rate." During the planning phase, DoD often was deficient in estimating costs and in providing the documentation needed to implement new procedures. Consequently, for contractors, the competitive study phase of contract definition proved to be particularly agonizing. In four to six months, they had to develop preliminary program designs, evaluate the feasibility of meeting specified objectives, plan development and production in some detail, estimate costs, and prepare a contract proposal. Instead of independently estimating performance and cost for each element and then for the total system, contractors tended to accept DoD requirements and tried to fit their design, development, and production proposals within them. Complexity, combined with constant program changes, meant that technical engineering decisions "tended to be made at a very low level of the [contractor's] organization, and when they eventually filtered upward, it was too late to do anything but concur." Consequently, successful contractors filled their lower echelons "with well-educated, intelligent managers who . . . were grossly overqualified for their work."[4] Their opposite numbers in DoD, who usually lacked comparable training and experience, were badly overmatched. The services put a lower priority on workforce improvement, and OSD penalized itself by not pressing them harder.

Designed to benefit both DoD and industry, fixed-price incentives and total package procurement satisfied neither. Profits did not rise, and cost control did not improve. For contractors, reducing cost uncertainties mattered more than pursuing the possibility of rewards for future efficiency. And, as Peck and Scherer found, incurring higher costs by improving system performance or adding capabilities usually proved to be profitable. With total package procurement, inaccurate cost estimates alone could eliminate a company's profit and even imperil its survival. For the C–5A, Lockheed claimed that meeting performance guarantees left no leeway for tradeoffs with cost and scheduling. The Air Force acquired an excellent transport along with a massive cost overrun. By 1968, practically every contract formula had been tried, and none had delivered any significant improvements.

During the 1960s, the management structures of diversified corporations came under strain from another quarter. As their overall capacity increased while costs rose and prices fell, companies began buying unrelated but apparently more profitable ventures. But adding more divisions through diversification created information overloads, breaking down communications between top management and the operating divisions. Senior managers often lacked knowledge about the technological processes and markets of the businesses they had acquired. Without the time to maintain personal contacts with division heads and the expertise to evaluate proposals and monitor performance, "senior executives . . . had to rely on impersonal statistical data to carry [out] those critical tasks. . . . Top managers began to lose the competence essential to maintaining a unified enterprise whose whole is greater than the sum of its parts."[5] As an example, during discussions about the F–111's troubled development, "the General Dynamics people had shown lack of familiarity with the specifications," causing the president of General Dynamics's Fort Worth division "to lose his temper in an open meeting."[6]

Secretary McNamara also confronted an information overload created by a growing span of control. Like the heads of diversified firms, he relied heavily on "impersonal statistical data." That similarity in approach should have made DoD-contractor exchanges easier and more productive, but other factors prevented major benefits from materializing. There were two forums in which senior Defense Department officials conferred regularly with their corporate counterparts: the Defense Industry Advisory Council and the "Icarus" meetings about the F–111. In 1963, the DIAC concluded that stressing incentive contracting and widening the use of PERT would do much toward making cost, schedule, and performance estimates more realistic. Unfortunately, neither contributed much toward meeting that objective. In 1966, the DIAC rated total package procurement as "highly desirable from the standpoint of industry as well as the government."[7] Within three years, experience rendered that assertion inaccurate.

Put broadly, the goals of innovation, efficiency, and profitability usually were mutually exclusive, interacting in ways that eluded statistical control. PERT could help efficiency, and adding incentives might have promoted profitability, but innovation with its "unanticipated unknowns" imposed complications that more than offset any other gains. The C–141 transport and the Titan III space launch vehicle, for example, were held up as models that met cost, schedule, and performance requirements—except when those programs later tried to push beyond the state of the art in navigation and guidance systems. The Logistics Management Institute judged total package procurement effective for state-of-the-art programs, but the C–5A could not be kept within that boundary. Frequently, projects were presented to Congress as being within the state of the art, even though contracts were written with an implicit expectation that they would go beyond it. Thus, for Minuteman II's guidance system, the Air Force had to approve cost overruns; achieving an acceptable mean time between failures had been written into the contract as a "goal" rather than a firm specification. If DoD wanted truly advanced weapon systems, it often had to pay more than the target or even the ceiling price.

The F–111 is a case in point. During Icarus sessions, senior DoD officials confronted intricate design and engineering problems that stymied their drive to force contractors to fulfill performance specifications. Contractors had not been involved in early, critical design decisions: incorporating the unproven swing wing while achieving a low-level, long-distance supersonic dash at one end of the operational envelope and, at the other end, reaching Mach 2.5 at 60,000 feet while making an instantaneous 15-degree change in the angle of attack. At Icarus meetings, McNamara insisted on fulfilling specifications precisely. He warned General Dynamics executives that DoD would no longer accept "junk"—or, as Harold Brown put it, DoD was determined to do away with the mentality that allowed for the acceptance of subpar systems under the assumption that "what's acceptable is what's available."[8] But this was much easier said than done. When Pratt and Whitney's engines began stalling, apparently because of airflow distortion at supersonic speeds, McNamara wanted to know whether contractors had promised to reach Mach 2.5 without stalling. Two of his assistant secretaries answered that holding the company to the requirement would be difficult, because engine specifications had been written in terms of test stand rather than installed engine performance. Who should pay for an unforeseen complication of swing-wing innovation? OSD tried to hold General Dynamics responsible for matching the engine with the airframe, but a company executive countered that "the specification was not written in terms of stalls but of airflow distortion, and even that was not clear."[9] Since the engines were government-furnished equipment, DoD finally paid to correct the stalling problem. Otherwise, DoD would have had to bear the cost of delaying production until it was solved.

A similar outcome occurred when the Air Force tried to insist that all F–111s, after the 236th aircraft produced, must be equipped with the Mark II avionics system, which was plagued by large cost overruns and delays. General Dynamics replied that the Air Force had decided to use the Mark II and dictated its schedule: "Now, if the Air Force was going to be legalistic in terms of meeting specifications (as if General Dynamics had thought of the program), then General Dynamics would have no recourse but to refuse to sign the contract."[10] Autonetics, maker of the Mark II, could have shown that OSD and the Air Force had the technical knowledge to anticipate major troubles in meeting contractual requirements. Ultimately, DoD accepted delays for the Mark II and bore the added costs.

A lesson from the F–111 acquisition, applicable to many other weapon systems, is that no "silver bullet" could have put everything right. The program was buffeted by demanding performance specifications, an innovative design with ramifications that became known only through flight testing, OSD's unwillingness to ease requirements, and widely divergent service requirements. Thus, fixing one problem did not trigger solutions to other difficulties; it sometimes created new snags. This proved to be equally true for the Mark 48 torpedo, the Main Battle Tank, the C–5A transport, and a range of other systems. Often, therefore, program management became not so much a matter of devising solutions as of arranging tradeoffs to diminish the serious obstacles that existed. Like his predecessors and successors, McNamara almost invariably put performance first.

The parameters of acceptable performance expanded because the Kennedy administration came into office determined to impose a new national security strategy. Flexible response required the services to develop the capability to fight successfully across the spectrum of conflict. Fighting successfully, however, did not necessarily mean victoriously in the traditional sense. It required developing capabilities for controlled escalation during conventional operations and controlled response in nuclear war. That meant applying enough force to end a conventional conflict on favorable terms without resorting to nuclear weapons and, if nuclear exchanges did begin, stopping them short of all-out devastation. Such restrictions, to the consternation of many military leaders, might limit the benefits of possessing superior weapons and complicate their use in warfare.

Which weapon systems were designed to permit controlled response or escalation? How well did they fulfill that purpose? Polaris submarines and Minuteman ICBMs in hardened and dispersed silos could permit a controlled response that would stop a nuclear exchange short of annihilating urban centers. During the McNamara years, however, most Soviet ICBMs were liquid-fueled, not well protected, and "relatively inaccurate . . . suitable mainly against large, soft targets such as cities."[11] Thus, a bizarre situation existed in which Soviet capabilities had to improve before U.S. strategy could become feasible. In attacks against North Vietnam, Rolling Thunder provided the test of graduated pressure in limited war, and the experiment failed. The F–105 was ill suited for this task, as were the Bullpups and cluster bomb units available during 1965–1966.

Due in part to a backlash against the way the Johnson administration conducted the Vietnam War, the next administration focused more on determining which elements of the McNamara legacy to discard than on which ones to preserve. David Packard, cofounder of the Hewlett-Packard Company, deputy secretary of defense from 1969 to 1971, and a driving force behind the acquisition reforms of the 1970s and 1980s, claimed that "the two best management programs ever undertaken in the design and development of complex weapon systems" were Minuteman and Polaris, carried out by the Air Force and Navy "before DoD was involved in procurement."[12] In other words, letting the services run cost-reimbursable programs was a formula for success.

Packard's claim is questionable. While both weapons proved effective and were developed and fielded quickly, cost effectiveness was another matter. The Department of Defense could afford only a small number of major programs that followed the same model. Both Minuteman and Polaris had easy access to additional funding when needed, unlike most other weapons programs. The Special Projects Office's claim of having kept Polaris within budget was shaky. Cost-plus-fixed-fee contracts for the Polaris program were negotiated annually. The contractor's job, in practice, was to work on tasks assigned without spending at a faster or slower rate than had been stipulated. At the year's end, any tasks left uncompleted would be negotiated in a new work statement, and their estimated costs would be the basis for negotiating fixed fees. But as long as contractors did not spend faster or slower than planned, the SPO could report that there were no overruns or underruns. Polaris probably reflected excellent funding control but questionable cost control. Minuteman, likewise, used cost-reimbursable contracts until 1962. It beat the original schedule and performance requirements—but claims of having done so without incurring cost overruns were wrong.[13]

In 1961, OSD set out to delineate the phases that comprised a major development effort, define the points of decision, establish who had authority to make critical decisions, and adjust management and control mechanisms appropriately. These required the creation of "strong centralized project-type organizations."[14] Such uniformity, however, would have to be imposed upon a patchwork of service practices.

Justifiably, the Air Force saw itself as a pioneer in weapon system management. For aircraft, the prime contractor became the systems integrator. For missile and space programs, an independent subsidiary of TRW, Space Technology Laboratories, directed designs and integrated development. When industry and Congress complained about conflicts of interest, the nonprofit Aerospace Corporation was created, but STL continued to supply systems engineering and technical direction for the Minuteman ICBM. However, STL and Aerospace had only "recommending" authority. Officers in the Ballistic Missile and later the Space and Missile Systems Divisions held decisionmaking power; Air Force Systems Command retained financial control and hired associate contractors.

The Navy deliberately avoided anything comparable to TRW, STL, or the Aerospace Corporation. Instead, for Polaris, a relatively small Special Projects Office controlled development and made sole-source awards for most of the major subsystems. SPO, together with Lockheed, took responsibility for systems integration. Within SPO, a Steering Task Group drawn from government, industry, and academia supervised the technical studies that defined the system's architecture. SPO was aware that quality frequently suffered when a system moved into serial production. So, while the development groups remained responsible for production, a separate office monitored performance. Thus, SPO controlled the whole life cycle of Polaris and then of Poseidon.

A somewhat different solution was crafted for the Navy's Tartar, Terrier, and Talos. These surface-ship antiaircraft missile systems were plagued by persistent failures. Parochialism among and even within Navy bureaus appeared to rule out the kind of vertical management structure used by SPO. Instead, "Get Well" teams relied upon a Contractor Steering Group, with Bell Laboratories/Western Electric providing systems engineering. Likewise, for the successor Standard missile, the ship design firm of Gibbs and Cox teamed with STL, Northern Ordnance, ITT, Westinghouse, and RCA.

Because more of its weapon systems and other equipment derived from known technology, the Army during the 1950s worked within a well-established buying structure and outpaced the other services in its amount of advertised bidding.[15] But in the 1960s, many projects moved beyond the state of the art. The Army usually improvised, having nothing akin to the Navy's SPO or the Air Force's TRW and STL. Handling of the Shillelagh antitank missile suggests that this approach was unwise. After Aeronutronic won the contract, the Ordnance Corps assigned overall responsibility to its Tank-Automotive Command, with contract supervision delegated to Ordnance Tank-Automotive Center's (OTAC's) subordinate Army Rocket and Guided Missile Agency. The task of ensuring compatibility between the missile and its vehicular-mounted equipment lay with OTAC. By autumn 1960, Aeronutronic complained that it was getting instructions from OTAC, two sources in the Army Rocket and Guided Missile Agency, and the Office of the Chief of Ordnance. In 1962, Army Materiel Command assigned a program manager to Shillelagh/Sheridan and made its new Missile Command responsible for Shillelagh's subsystems. Then in 1963, General Besson transferred the Shillelagh/Sheridan project office from Missile Command to Weapons Command. The division of responsibilities remained unclear, though, and friction between the two commands persisted. So, in September 1964, Besson put a Shillelagh program manager at Missile Command and a Sheridan program manager at Weapons Command. This was almost the antithesis of McNamara's drive to centralize and systematize. Worse, Shillelagh fell well short of expectations; large cost and schedule overruns did not lead to good performance.

Inevitably, such a variety of management styles limited the effectiveness of DoD Directive 3200.9, which specified a phased approach to acquiring a weapon system.[16] Moving from "exploratory" to "advanced," then to "engineering," and finally to "operational" development looked straightforward, but problems were repeatedly downplayed or not identified until fairly late in the cycle. And the later remedial steps came, the greater their impact was upon costs and schedules.

In fairness, though, judgments about the McNamara years need to take a wider time frame into consideration. Over the next decades, despite numerous "reforms," failures to meet cost and schedule targets continued. The story of the Air Force's C–17 transport, which entered service in 1993, much resembled that of the C–5A. There were serious problems during development, causing major delays and cost overruns yet ultimately producing an excellent aircraft.[17] Thus, while the 1960s may not have been much better than other periods, they do not appear to have been any worse.

Performance, of course, was what mattered most. Weapon systems had to outperform those filling the larger arsenals of potential enemies. The services claimed that OSD was putting budget trimming first under the guise of cost-effectiveness, terminating programs that they considered necessary to preserve qualitative leads. How far had the U.S. edge eroded? By the early 1970s, it was not hard to find worrisome examples. The Soviets' T72 tank apparently outgunned the M60A1, and they led in developing explosive reactive armor. The MiG–25 looked superior to the F–4E for aerial combat. Also, the Soviets' November and Victor-class attack submarines ran faster than those in the U.S. Navy's *Permit* and *Sturgeon* classes. But OSD's defenders could cite examples of systems that, thanks to actions taken in the 1960s, would regain or even widen U.S. superiority. For the Army, it was TOW missiles; for the Air Force, laser-guided bombs; and for the Navy, *Los Angeles*-class attack submarines.

In strategic nuclear weaponry, the United States during 1961–1962 held a commanding lead in launchers. After the Cuban missile crisis, a Soviet missile buildup erased the perception of U.S. superiority. Yet McNamara made sure that a projected Soviet lead in launchers would be offset by an American lead in accurate, reliable, survivable warheads. In 1971–1972, the Soviets had nothing comparable to Poseidon and Minuteman III. Since Moscow did not directly challenge vital U.S. interests, it can be inferred that maintaining a capability to inflict "assured destruction" preserved a perception of the sufficiency of U.S. power. Thus, on this vital issue, McNamara could claim vindication.

The 1960s witnessed sweeping changes in the management of acquisition in the Department of Defense. With increased centralization came unprecedented efforts by the secretary of defense to strengthen oversight, impose cost controls, and promote commonality. Schedule and cost overruns in acquisition persisted. Yet many of the systems initiated during this period incorporated cutting-edge technology that advanced the state of the art and provided an advantage against adversaries. The McNamara years showed the difficulty of enacting DoD-wide reforms as well as the hazards of attempting to do so without the confidence of the military services. Although centralization would be relaxed and some decisionmaking responsibilities would be restored to the services during the Nixon administration, the changes in organization, management, and budgeting adopted during the 1960s would shape acquisition for decades to come.

Endnotes

1. Lawrence J. Korb, *The Fall and Rise of the Pentagon* (Westport, CT: Greenwood Press, 1979), 86–87.

2. Thomas C. Hone, *Power and Change* (Washington, DC: Naval Historical Center, 1989), 70, 66.

3. Emails, Frosch to Poole, 14 Mar 07; Fox to Poole, 15 Aug 06.

4. Anderson, "Anguish in the Defense Industry," 166, 169, 163–164.

5. Alfred D. Chandler, Jr., *Strategy and Structure: Chapters in the History of the American Industrial Enterprise* (Cambridge, MA: MIT Press, 1990 paperback edition of the 1962 hardback), 1989 introduction, pages unnumbered.

6. Memcon by Col. Robert Pursley, 29 Sep 66, 2–3, fldr 1, box 16, 75–0104, RG 330, Archives II.

7. DIAC, "Fundamental Issues Affecting Defense-Industry Relationships," September

1963, box 990, OSD/HO; "Summary Minutes—Meeting of the DIAC—18 and 19 February 1966," box 990, OSD/HO.

8. Memcon by Pursley, 28 Jan 67, fldr 2, and 29 Apr 67, fldr 3, both in box 16, 75–0104, RG 330, Archives II.

9. Memcon by Pursley, 16 and 18 Feb 67, fldr 2, box 16, 75–0104, RG 330, Archives II.

10. Memcon by Pursley, 19 Aug 67, fldr 3, box 16, 75–0104, RG 330, Archives II.

11. *FRUS 1964–1968*, vol. 10, 440.

12. *Defense 88*, 1.

13. Email, Fox to Poole, 17 Mar 04. The claim about Minuteman appears in Johnson, *Culture of Innovation*, 101.

14. Memo, Deputy DDR&E to Asst Secs of Army, Navy, and Air Force (R&D), "Management of Research and Engineering," 9 Oct 61, fldr, "Rubel, John H., Viewpoints, 1961–1962," box 19, Phillips Papers, LC.

15. "What's Ahead in Procurement?" *Armed Forces Management* 7, no. 2 (November 1960): 97–100.

16. An Army officer quipped that industry tended to see the services as follows: the Navy owned its contractors; the Air Force was in league with its contractors; and the Army feared its contractors. *Changing an Army: An Oral History of Gen. William E. DePuy, USA (Ret.)*, CMH Publication 70–23 (Washington, DC: U.S. Army Center of Military History, 1987), 197.

17. General Accounting Office, "Military Airlift: Cost and Complexity of the C–17 Aircraft Research and Development Program," NSIAD–91–5 (March 1991).

APPENDIX

KEY ACQUISITION OFFICIALS, 1959–1969

Secretaries of Defense	
Neil H. McElroy	October 1957–December 1959
Thomas S. Gates, Jr.	December 1959–January 1961
Robert S. McNamara	January 1961–February 1968
Clark M. Clifford	March 1968–January 1969
Deputy Secretaries of Defense	
Thomas S. Gates, Jr.	June 1959–December 1959
James H. Douglas, Jr.	December 1959–January 1961
Roswell L. Gilpatric	January 1961–January 1964
Cyrus R. Vance	January 1964–June 1967
Paul H. Nitze	July 1967–January 1969
Directors of Defense Research and Engineering	
Herbert F. York	December 1958–April 1961
Harold Brown	May 1961–September 1965
John S. Foster, Jr.	October 1965–June 1973
Assistant Secretary of Defense (Supply and Logistics)	
E. Perkins McGuire	December 1956–January 1961
Assistant Secretaries of Defense (Installations and Logistics)	
Thomas D. Morris	January 1961–December 1964
Paul R. Ignatius	December 1964–August 1967
Thomas D. Morris	September 1967–February 1969
Assistant Secretary of Defense (Systems Analysis)	
Alain C. Enthoven	September 1965–January 1969

Chairmen of the Joint Chiefs of Staff

Gen. Nathan F. Twining, USAF	August 1957–September 1960
Gen. Lyman L. Lemnitzer, USA	October 1960–September 1962
Gen. Maxwell D. Taylor, USA	October 1962–July 1964
Gen. Earle G. Wheeler, USA	July 1964–July 1970

Directors, Advanced Research Projects Agency

Roy W. Johnson	February 1958–November 1959
Brig. Gen. Austin W. Betts, USA	January 1960–January 1961
Jack P. Ruina	January 1961–September 1963
Robert L. Sproull	September 1963–June 1965
Charles M. Herzfeld	June 1965–March 1967
Eberhardt Rechtin	November 1967–December 1970

Commanders, Defense Supply Agency

Lt. Gen. Andrew T. McNamara, USA	October 1961–June 1964
Vice Adm. Joseph M. Lyle, USN	July 1964–June 1967
Lt. Gen. Earl C. Hedlund, USAF	July 1967–July 1971

Secretaries of the Army

Wilber M. Brucker	July 1955–January 1961
Elvis J. Stahr, Jr.	January 1961–June 1962
Cyrus R. Vance	July 1962–January 1964
Stephen Ailes	January 1964–July 1965
Stanley R. Resor	July 1965–June 1971

Under Secretaries of the Army

Hugh M. Milton II	August 1958–January 1961
Stephen Ailes	February 1961–January 1964
Paul R. Ignatius	January 1964–December 1964
Stanley R. Resor	April 1965–July 1965
David E. McGiffert	November 1965–February 1969

Assistant Secretary of the Army (Logistics)

Courtney Johnson	April 1959–January 1961

Assistant Secretaries of the Army (Installations and Logistics)

Paul R. Ignatius	May 1961–February 1964
Daniel M. Luevano	July 1964–September 1965
Robert A. Brooks	October 1965–February 1969

Director of Research and Development

Richard S. Morse	June 1959–March 1961

Assistant Secretaries of the Army (Research and Development)

Richard S. Morse	March 1961–May 1961
Finn J. Larson	August 1961–July 1963
Willis Moore Hawkins	October 1963–September 1966
Russell D. O’Neal	October 1966–September 1969

Chiefs of Staff of the Army

Gen. Maxwell D. Taylor	June 1955–June 1959
Gen. Lyman L. Lemnitzer	July 1959–September 1960
Gen. George H. Decker	October 1960–September 1962
Gen. Earle G. Wheeler	October 1962–July 1964
Gen. Harold K. Johnson	July 1964–July 1968
Gen. William C. Westmoreland	July 1968–June 1972

Vice Chiefs of Staff of the Army

Gen. Lyman L. Lemnitzer	July 1957–June 1959
Gen. George H. Decker	August 1959–September 1960
Gen. Clyde D. Eddleman	November 1960–March 1962
Gen. Barksdale Hamlett	April 1962–August 1964
Gen. Creighton W. Abrams, Jr.	August 1964–April 1967
Gen. Ralph E. Haines, Jr.	July 1967–August 1968
Gen. Bruce Palmer, Jr.	August 1968–June 1972

Deputy Chiefs of Staff, Logistics

Lt. Gen. Carter B. Magruder	January 1956–July 1959
Lt. Gen. Robert W. Colglazier, Jr.	July 1959–July 1964
Lt. Gen. Lawrence J. Lincoln	August 1964–June 1967
Lt. Gen. Jean E. Engler	July 1967–August 1969

Chiefs of Research and Development

Lt. Gen. Arthur G. Trudeau	April 1958–June 1962
Lt. Gen. Dwight E. Beach	July 1962–August 1963
Lt. Gen. William W. Dick, Jr.	August 1963–March 1966
Lt. Gen. Austin W. Betts	March 1966–December 1970

Chiefs of Ordnance*

Lt. Gen. John G. Hinrichs	February 1958–May 1962
Maj. Gen. Horace F. Bigelow	June 1962–July 1962

**The Office of the Chief of Ordnance was abolished on 31 July 1962.*

Chief Signal Officers*

Lt. Gen. James D. O'Connell	May 1955–April 1959
Maj. Gen. Ralph T. Nelson	May 1959–June 1962
Maj. Gen. Earle F. Cook	July 1962–June 1963
Maj. Gen. David P. Gibbs	July 1963–February 1964

**Title changed to Chief of Communications-Electronics in 1964 and to Assistant Chief of Staff for Communications-Electronics in 1967.*

Chief of the Chemical Corps*

Maj. Gen. Marshall Stubbs	September 1958–July 1962

**The Office of the Chief of the Chemical Corps was abolished on 31 July 1962.*

Chiefs of the Transportation Corps

Maj. Gen. Frank S. Besson, Jr.	March 1958–March 1962
Maj. Gen. Rush B. Lincoln, Jr.	March 1962–June 1963

U.S. Continental Army Command

Gen. Bruce C. Clarke	August 1958–September 1960
Gen. Herbert B. Powell	October 1960–January 1963
Gen. John K. Waters	February 1963–February 1964
Gen. Hugh P. Harris	March 1964–June 1965
Gen. Paul L. Freeman, Jr.	June 1965–June 1967
Gen. James K. Woolnough	July 1967–October 1970

U.S. Army Materiel Command

Gen. Frank S. Besson, Jr.	April 1962–March 1969

U.S. Army Combat Developments Command

Lt. Gen. John P. Daley	June 1962–July 1963
Lt. Gen. Dwight E. Beach	August 1963–May 1965
Lt. Gen. Ben Harrell	May 1965–July 1967
Lt. Gen. Harry W.O. Kinnard II	July 1967–September 1969

Secretaries of the Navy

Thomas S. Gates, Jr.	April 1957–June 1959
William B. Franke	June 1959–January 1961
John B. Connally	January 1961–December 1961
Fred H. Korth	January 1962–November 1963
Paul H. Nitze	November 1963–June 1967
Paul. R. Ignatius	September 1967–January 1969

Under Secretaries of the Navy

William B. Franke	April 1957–June 1959
Fred A. Bantz	June 1959–January 1961
Paul B. Fay, Jr.	February 1961–January 1965
Kenneth E. BeLieu	February 1965–July 1965
Robert H.B. Baldwin	July 1965–July 1967
Charles F. Baird	August 1967–January 1969

Assistant Secretaries of the Navy (Material)

Fred A. Bantz	April 1957–April 1959
Cecil P. Milne	April 1959–January 1961

Assistant Secretaries of the Navy (Installations and Logistics)

Kenneth E. BeLieu	February 1961–February 1965
Graeme C. Bannerman	February 1965–February 1968
Barry J. Shillito	April 1968–January 1969

Assistant Secretaries of the Navy (Research and Development)

James H. Wakelin, Jr.	June 1959–June 1964
Robert W. Morse	July 1964–June 1966
Robert A. Frosch	July 1966–December 1972

Chiefs of Naval Operations

Adm. Arleigh A. Burke	August 1955–August 1961
Adm. George W. Anderson, Jr.	August 1961–August 1963
Adm. David L. McDonald	August 1963–August 1967
Adm. Thomas H. Moorer	August 1967–July 1970

Commandants of the Marine Corps

Gen. Randolph McC. Pate	January 1956–December 1959
Gen. David M. Shoup	January 1960–December 1963
Gen. Wallace M. Greene, Jr.	January 1964–December 1967
Gen. Leonard F. Chapman, Jr.	January 1968–December 1971

Vice Chiefs of Naval Operations

Adm. James S. Russell	July 1958–November 1961
Adm. Claude V. Ricketts	November 1961–July 1964
Adm. Horacio Rivero, Jr.	July 1964–January 1968
Vice Adm. Bernard A. Clarey	January 1968–October 1970

Deputy Chiefs of Naval Operations, Logistics

Vice Adm. Ralph E. Wilson	January 1958–June 1960
Vice Adm. John Sylvester	August 1960–August 1964
Vice Adm. Lot Ensey	August 1964–August 1967
Vice Adm. Ralph Louis Shifley	September 1967–February 1971

Deputy Chiefs of Naval Operations, Development

Vice Adm. John T. Hayward	April 1959–March 1962
Vice Adm. William F. Raborn, Jr.	March 1962–August 1963
Vice Adm. Horacio Rivero, Jr.	August 1963–October 1963
Vice Adm. Charles T. Booth II	October 1963–March 1965
Vice Adm. Harold G. Bowen, Jr.	June 1965–May 1967
Rear Adm. Edward A. Ruckner	April 1967–December 1970

Chiefs of Naval Material

Vice Adm. Edward W. Clexton, Jr.	February 1956–June 1960
Vice Adm. George F. Beardsley	July 1960–June 1963
Vice Adm. William A. Schoech	July 1963–February 1965
Vice Adm. Ignatius J. Galantin	March 1965–June 1970

Chiefs of Naval Research

Rear Adm. Rawson Bennett II	January 1956–January 1961
Rear Adm. L.D. Coates	January 1961–June 1964
Rear Adm. John K. Leydon	June 1964–June 1967
Rear Adm. Thomas B. Owen	July 1967–June 1970

Chief, Bureau of Aeronautics

Rear Adm. Robert E. Dixon	July 1957–December 1959

Chiefs, Bureau of Ordnance

Rear Adm. Paul D. Stroop	March 1958–September 1959
Rear Adm. M.S. Hubbard	September 1959–December 1959

Chief, Bureau of Ships

Rear Adm. Ralph K. James	April 1959–March 1963

Chiefs, Bureau of Naval Weapons

Rear Adm. Paul D. Stroop	September 1959–October 1962
Rear Adm. Kleber S. Masterson	November 1962–March 1964
Rear Adm. Allen M. Shinn	May 1964–May 1966

Naval Material Command

Vice Adm. Ignatius J. Galantin	March 1965–May 1970

Secretaries of the Air Force

James H. Douglas, Jr.	May 1957–December 1959
Dudley C. Sharp	December 1959–January 1961
Eugene M. Zuckert	January 1961–September 1965
Harold Brown	October 1965–February 1969

Under Secretaries of the Air Force

Malcolm A. MacIntyre	June 1957–July 1959
Dudley C. Sharp	August 1959–December 1959
Joseph V. Charyk	January 1960–March 1963
Brockway McMillan	June 1963–September 1965
Norman S. Paul	October 1965–September 1967
Townsend Hoopes	October 1967–February 1969

Assistant Secretaries of the Air Force (Materiel)

Dudley C. Sharp	October 1955–January 1959
Philip B. Taylor	April 1959–February 1961
Joseph S. Imirie	April 1961–October 1963
Robert H. Charles	November 1963–February 1964

Assistant Secretary of the Air Force (Installations and Logistics)

Robert H. Charles	February 1964–May 1969

Assistant Secretaries of the Air Force (Research and Development)

Richard E. Horner	July 1957–May 1959
Joseph V. Charyk	June 1959–January 1960
Courtland D. Perkins	February 1960–January 1961
Brockway McMillan	June 1961–June 1963
Alexander H. Flax	July 1963–March 1969

Directors of Space Systems

Brig. Gen. Richard D. Curtin	August 1960–June 1962
Brig. Gen. John L. Martin	July 1962–August 1964
Maj. Gen. James T. Stewart	August 1964–February 1967
Brig. Gen. Russell A. Berg	February 1967–June 1969

Chiefs of Staff, U.S. Air Force

Gen. Thomas D. White	July 1957–June 1961
Gen. Curtis E. LeMay	June 1961–January 1965
Gen. John P. McConnell	February 1965–July 1969

Vice Chiefs of Staff

Gen. Curtis E. LeMay	July 1957–June 1961
Gen. Frederic H. Smith, Jr.	July 1961–June 1962
Gen. William F. McKee	July 1962–July 1964
Gen. John P. McConnell	August 1964–January 1965
Gen. William H. Blanchard	February 1965–May 1966
Gen. Bruce K. Holloway	August 1966–July 1968
Gen. John D. Ryan	August 1968–July 1969

Deputy Chiefs of Staff, Materiel

Lt. Gen. Clarence S. Irvine	April 1955–April 1959
Lt. Gen. Mark E. Bradley	June 1959–June 1961

Deputy Chiefs of Staff, Systems and Logistics

Lt. Gen. Mark E. Bradley	July 1961–June 1962
Lt. Gen. Thomas P. Gerrity	July 1962–July 1967
Lt. Gen. Robert G. Ruegg	August 1967–July 1969

Deputy Chief of Staff, Development

Lt. Gen. Roscoe C. Wilson	July 1958–June 1961

Deputy Chiefs of Staff, Research and Technology

Lt. Gen. Roscoe C. Wilson	July 1961–November 1961
Lt. Gen. James L. Ferguson	December 1961–January 1963

Deputy Chiefs of Staff, Research and Development

Lt. Gen. James L. Ferguson	February 1963–August 1966
Lt. Gen. Joseph R. Holzapple	September 1966–January 1969

Assistant Chiefs of Staff, Studies and Analysis

Maj. Gen. Howard A. Davis	February 1967–July 1968
Maj. Gen. Glenn A. Kent	August 1968–January 1972

Air Materiel Command

Gen. Samuel E. Anderson	March 1959–March 1961

Air Research and Development Command

Lt. Gen. Bernard A. Schriever	April 1959–April 1961

Air Force Systems Command

Gen. Bernard A. Schriever	April 1961–August 1966
Gen. James L. Ferguson	September 1966–August 1970

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List of Abbreviations

AAW	antiair warfare
ABMA	Army Ballistic Missile Agency
ACSFOR	assistant chief of staff for force development
ADCAP	Advanced Capabilities
ADL	Arthur D. Little, Inc.
AEC	Atomic Energy Commission
AFLC	Air Force Logistics Command
AFPRO	Air Force Plant Representative Office
AFSC	Air Force Systems Command
AGM	air-to-ground missile
AMC	Army Materiel Command (Army); Air Materiel Command (Air Force)
AMSA	Advanced Manned Strategic Aircraft
ARADMAC	Army Aeronautical Depot Maintenance Center
ARCOVE	Armament for Future Tanks or Similar Combat Vehicles
ARDC	Air Research and Development Command
ARGMA	Army Rocket and Guided Missile Agency
ARPA	Advanced Research Projects Agency
ASMS	Advanced Surface Missile System
ASPR	Armed Services Procurement Regulation
ASROC	antisubmarine rocket
ASW	antisubmarine warfare
BMD	Ballistic Missile Division
BNSP	Basic National Security Policy
CBU	cluster bomb unit
CDC	Combat Developments Command
CEP	circular error probable
CNO	chief of naval operations
CPFF	cost plus fixed fee
CPIF	cost plus incentive fee
CWAS	contractor's weighted average shares
CX–HLS	CX–Heavy Logistic Support

DASH	unmanned drone antisubmarine helicopter
DCAA	Defense Contract Audit Agency
DCAS	Defense Contract Administration Services
DCP	Development Concept Paper
DCSLOG	deputy chief of staff for logistics
DDR&E	director of defense research and engineering
DDT&E	design, development, and test and evaluation
DIAC	Defense Industrial Advisory Council
DPM	Draft Presidential Memorandum
DSA	Defense Supply Agency
DSB	Defense Science Board
DX	destroyer
DXG	guided-missile destroyer
ECM	electronic countermeasures
FAA	Federal Aviation Administration
FDL	Fast Deployment Logistics
FRAM	Fleet Rehabilitation and Modernization
FY	fiscal year
FYDP	Five-Year Defense Plan
GAO	General Accounting Office
H&R	Harrington & Richardson
HIBEX	High-G Boost Experiment
ICBM	intercontinental ballistic missile
IDA	Institute for Defense Analyses
IMR	Improved Military Round
IR&D	Independent Research and Development
IRBM	intermediate-range ballistic missile
JCS	Joint Chiefs of Staff
JDT	Joint Design Team
JEA	Joint Engineering Agency
JPL	Jet Propulsion Laboratory
JSOP	Joint Strategic Objectives Plan
LHA	amphibious assault ship
LMI	Logistics Management Institute
LOH	light observation helicopter
LORAN–C	Long-range Aid to Navigation
LPD	landing platform/dock
MATS	Military Air Transport Service
MBT	Main Battle Tank
MIPR	Military Interdepartmental Purchase Request
MIRV	multiple independently targetable reentry vehicle
MIT	Massachusetts Institute of Technology
MMRBM	mobile mid-range ballistic missile
MOL	Manned Orbiting Laboratory
MRV	multiple reentry vehicle
MTBF	mean time between failures

NASA	National Aeronautics and Space Administration
NM	nautical mile
NOTS	Naval Ordnance Test Station
NSC	National Security Council
NSIA	National Security Industrial Association
OPNAV	Office of the Chief of Naval Operations
ORL	Ordnance Research Laboratory
ORO	Operations Research Office
OSD	Office of the Secretary of Defense
OTAC	Ordnance Tank-Automotive Command
PBR	patrol boat river
PERT	Program Evaluation Review Technique
PL	Public Law
PPBS	Planning, Programming, and Budgeting System
R&D	research and development
RDT&E	research, development, and test and evaluation
RFP	request for proposal
ROAD	Reorganization Objective Army Division
RV	reentry vehicle
SABRE	Self-aligning Boost and Re-entry
SAGE	Semi-automatic Ground Environment
SAIMS	selected acquisition information and management system
SAM	surface-to-air missile
SAMSO	Space and Missile Systems Organization
SAR	Selected Acquisition Report
SIOP	Single Integrated Operational Plan
SLBM	submarine-launched ballistic missile
SOR	Specific Operational Requirement
SPIW	Special Purpose Individual Weapon
SPO	Special Projects Office (Navy), system program office (Air Force)
SRAM	short-range attack missile
STL	Space Technology Laboratories
SWIP	Super Weight Improvement Program
TAC	Tactical Air Command
TFX	Tactical Fighter Experimental
TI	Texas Instruments
TOW	tube-launched, optically tracked, wire-guided
TPP	total package procurement
TRW	Thompson Ramo Wooldridge
USSR	Union of Soviet Socialist Republics
VTOL	vertical takeoff and landing
WDD	Western Development Division
WSEG	Weapons Systems Evaluation Group

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Documents from several archival repositories in the Washington, DC, area were critical for reconstructing the history of weapons programs and gaining insight into decisionmaking in the Department of Defense. Most important were the records of the Office of the Secretary of Defense, Record Group (RG) 330, parts of which reside in three separate locations: the National Archives and Records Administration (NARA) in College Park, Maryland; NARA's Washington National Records Center in Suitland, Maryland; and the OSD Historical Office in Rosslyn, Virginia. In the OSD Historical Office, the papers of Henry E. Glass, particularly the documents pertaining to the OSD Comptroller, were vital to this study, as were the office's subject files, collection of the annual and semiannual reports of the secretary of defense, and DoD directives and instructions. In addition to Record Group 330, other collections at the National Archives in College Park contained key documents: the records of the Joint Chiefs of Staff (RG 218); the records of the Bureau of Aeronautics (RG 72); and the records of the Bureau of Naval Weapons (RG 402). The author also obtained significant primary source materials from the Air Force Historical Studies Office at Joint Base Anacostia-Bolling; the Library of Congress, notably the papers of Samuel C. Phillips; and the collections housed at Naval History and Heritage Command (formerly the Naval Historical Center) in the Washington Navy Yard, especially the files of the Chief of Naval Operations (Op-00).

Oral history interviews and direct communications with former DoD officials greatly enhanced the author's understanding of acquisition in the 1960s. The following graciously shared their wisdom and recollections: Charles A. Bowsher; Harold Brown; James N. Davis; Alain C. Enthoven; Brig. Gen. Alfred L. Esposito, USAF (Ret.); Robert A. Frosch; General Paul F. Gorman, USA (Ret.); Paul R. Ignatius; Robert S. McNamara; Tom Pelick; Dennis H. Trosch; and Rear Adm. Robert H. Wertheim, USN (Ret.). The author also made use of oral histories conducted by others, primarily historians from OSD, the Army, Navy, and Air Force.

Finally, the author made extensive use of published government documents. Particularly helpful were the records of congressional committees, including hearings, documents, and reports of the House committees on Armed Services, Appropriations, and Government Operations, and the Senate Committee on Government Operations, especially the latter's report on the TFX contract investigation. The author also relied heavily on executive branch publications and document collections, such as the OSD Historical Office's *Public Statements of the Secretary of Defense*, annual DoD fiscal year reports, the National Archives' *Public Papers of the Presidents of the United States*, and the Department of State's *Foreign Relations of the United States* series.

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