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"Big Five" Lessons for Today and Tomorrow

COL David C. Trybula, USA

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This work was conducted at the Institute for Defense Analyses by an active duty Army officer under terms of a Senior Service College Fellowship. The opinions, findings, and conclusions are the author's and should not be construed as representing the views of the United States Army or the Institute for Defense Analyses.

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USAWC CIVILIAN RESEARCH PROJECT

“Big Five” Lessons for Today and Tomorrow

by

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United States Army

MAY 29, 2012

Mr. James Kurtz

Project Advisor

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ABSTRACT

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America's preeminent ground combat capability is the result of the "Big Five" acquisition that produced the Abrams main battle tank, the Bradley fighting vehicle, the Apache attack helicopter, the Black Hawk utility helicopter, and the Patriot air defense missile system. The battle-proven capability of the "Big Five" systems—the mainstay of the Army's combat formations today—demonstrates the success of these programs both individually and collectively. Clearly, the "Big Five" acquisition is perceived as the gold standard.

Like most legends, the legend of the "Big Five" has its roots in actual events but also grows grander as memories of missteps, challenges, and problems fade in light of the final successes that continue to appear and reinforce their greatness. An examination of these programs demonstrates that while unequivocally successful in the end, each program would not have been described as successful at some point in its acquisition. They all had to overcome major challenges and morphed into what we know today. The salient points are then passed through the filter of environmental changes (threat, fiscal, industry, process, leadership, etc.) over the past decades to produce lessons learned and recommendations for current and future acquisitions.

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Executive Summary

The Army, indeed the Department of Defense, is repeatedly assailed by Congress and the press for a succession of less than stellar major acquisition programs. In many cases, these have been outright failures. A common thread behind this discourse is desire for the success that fashioned the Army's Big Five. This paper begins with the legend of the Big Five, followed by an examination of the history behind the legend. With a foundation in actual events, it then turns to understanding the environment that gave rise to the "Big Five" and juxtaposing it with today's environment. The salient points then can be filtered through the environmental changes to produce lessons learned and recommendations for today's acquisitions and future acquisitions.

This research into the "Big Five" suggests five recommendations.

1. First, lead—actively, continuously, and throughout. Continuity of leadership at all levels is important. The ability to maintain continuity at the most senior levels, given the changes from Goldwater-Nichols, mandates conscious forethought and redundancy at senior levels.

2. While prioritization and focus could be included under leadership, they are important enough to warrant their own recommendation. Prioritization and focus must be more than PowerPoint deep or simply decreed in a memo. They must be followed with the application of resources and senior leaders' time.

3. The next recommendation is to create flexibility and overcome linearity in the acquisition process with feedback mechanisms. This means the integration of users and engineers throughout the process, as well as continuously reevaluating assumptions and their implications.

4. Next, one of the reasons for the challenge of maintaining expertise is that until the 1960s acquisition programs fell right on top of each other. Lately there have been significant gaps in programs. Eliminating these gaps through heel-to-toe programs is one way to increase expertise and maintain it.

5. Finally, strategic communications must be compelling, pervasive, and updated regularly. These recommendations are purposely broad. Success requires a holistic approach and detailed lists as others have prescribed in the past are easy to be cherry picked or may solve specific problems being examined but are likely to result in other challenges, or risk falling to the tests of time.

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> *I am deeply concerned by the Army's inability to manage successfully its major defense acquisition programs; most prominently, the Future Combat System. With the arguable exception of Stryker, the Army has not successfully brought to—a major system from research and development, through full production since the so-called "big five," the Abrams tank, Bradley fighting vehicle, Patriot missile, and Black Hawk and Apache Helicopters, the late 1970s and early 1980s.*[1]
>
> —Senator John McCain

Introduction

The Army, indeed the Department of Defense, is repeatedly assailed by Congress and the Press for a succession of less than stellar—in many cases outright failures—major acquisition programs. A common thread behind this discourse is a desire for the success that fashioned the Army's "Big Five." This desire is the basis for this research project.

We will begin with the legend of the "Big Five" followed by an examination of the history behind the legend. As the details of each of the "Big Five" programs are uncovered, the missteps, challenges, and problems will be discussed. This will clarify the reality behind the legend. With a solid foundation in actual events, we can then turn to understanding the environment during the "Big Five" acquisition and juxtapose it with today's environment. The salient points are then passed through the filter of environmental changes over the past decades to produce lessons learned and recommendations for current and future acquisitions. The hope is to rationally use the "Big Five" lessons to enhance the probabilities for future successes.

[1] McCain, John, *Opening Statement at the Senate Armed Services Committee Hearing to Consider the Nomination of General Martin E. Dempsey, USA, for Reappointment to the grade of General and to be Chief of Staff, United States Army*, (Washington, DC: March 3, 2011).

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The Legend of the "Big Five"

America's preeminent ground combat capability is the result of the now famous "Big Five" acquisition that produced the Abrams main battle tank, the Bradley fighting vehicle, the Apache attack helicopter, the Black Hawk utility helicopter, and the Patriot air defense missile system. The overmatch and excellence of these systems was first proved in 1991 in the one hundred hours of ground combat in the First Gulf War that resoundingly defeated a numerically superior Iraqi army. Twelve years later these systems proved themselves again, defeating and toppling the Iraqi regime.

The Army's Leadership developed the "Big Five" systems as another means after Vietnam to ensure that the Army never fought another counterinsurgency war. The "Big Five" were based on the Israeli experience in the 1973 Yom Kippur War and in response to the Soviet and Warsaw Pact forces that threatened Western Europe with technologically superior weapon systems in numbers far greater than the US or NATO could supply.

Each of the "Big Five" systems was based on clear requirements and developed to be a leap forward technologically that would incorporate seamlessly with the other "Big Five" systems to provide superior capabilities. These capabilities would be more than sufficient to overcome the Soviet advantage in numbers. To integrate and fully utilize these cutting-edge weapon systems, the Army reorganized under Division 86 and rewrote its doctrine. First it established Active Defense and then AirLand Battle as the fully integrated means of defeating an enemy simultaneously in depth.

The Army completely overhauled how it trained by extensively integrating simulators and establishing centralized training centers for brigade-size operations at the National Training Center at Fort Irwin, California, the Combat Maneuver Training Center in Grafenwoehr, Germany, and the Joint Readiness Training Center at Fort Polk, Louisiana. In terms of personnel, there was recognition that smart soldiers are better soldiers and make the equipment they use more capable, and consequently the Army made a commitment to recruit and retain quality—a commitment that saved the fledgling All Volunteer Force.

The leadership and acquisition management of each of the "Big Five" programs successfully guided these systems through an environment of diminishing budget and increased oversight. Despite these challenges, the result was programs that delivered more capability, delivered before it was needed, and was produced in greater numbers than originally planned, all within the Army's budget. According to the Army's official history:

> To solve the problem of how to fight an enemy that would almost certainly be larger, the United States relied, in part, on technologically superior hardware that could defeat an enemy at ratios higher than 1:3. To achieve that end, the Army in the early 1970s began work on the "big five" equipment systems: a new tank, a new infantry

combat vehicle, a new attack helicopter, a new transport helicopter, and a new antiaircraft missile.[2]

The battle proven capability of the “Big Five” systems that are the mainstay of the Army’s combat formations and have been sold as part of the Foreign Military Sales program to numerous friends and allies demonstrates the success of these programs both individually and collectively. Clearly, the “Big Five” acquisition is the gold standard.

2 Schubert, Frank N. and Theresa L. Kraus, General Editors, *The Whirlwind War: The United States Army in Operations DESERT SHIELD and DESERT STORM*, (Washington, DC: Center for Military History, 1995), 28.

The History

Like most legends, the legend of the "Big Five" has its roots in actual events but also grows grander as memories of missteps, challenges, and problems fade in light of the final successes. Time and circumstance continue to reinforce the "Big Five's" greatness. At the time the "Big Five" were being developed, knowledge of the details of the programs was naturally limited to the programs themselves and necessary decision makers. Much of what was classified during the development of these programs is now, thirty plus years later, no longer classified.

With this declassification, even today there is a lack of knowledge of the "Big Five" and their history. Indeed, the "Big Five" are sometimes referred to as the Abrams tank, the Bradley, the Apache and Black Hawk helicopters, and the Multiple Launch Rocket System (MLRS), mistakenly omitting the Patriot and inserting the MLRS.[3] To gain a better understanding of the "Big Five" programs as they happened requires examining each one independently before assessing them collectively.

The individual chapters on the "Big Five" are intended to be stand alone chapters. This means that concepts and explanations introduced in the first chapter on the Abrams tank may be reintroduced in subsequent chapters nearly verbatim. While this repetitiveness may be slightly cumbersome for the reader who endeavors to read cover to cover, it is intended to eliminate the awkward need to constantly flip back and forth between chapters as these concepts reemerge.

There are many approaches that could be taken to the order of the examination of the "Big Five" programs individually. However, since the chapters are intended to stand alone, the order is not overly important. Therefore, the text will follow the order from the Army's official history quoted above: the Abrams main battle tank, the Bradley infantry fighting vehicle, the Apache attack helicopter, the Black Hawk utility transport helicopter, and the Patriot air defense system.

[3] Author's notes from October 20, 2011 Defense Business Board meeting, Pentagon.

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Figure 1. M1A1 Abrams Main Battle Tank[4]

Abrams Main Battle Tank

Understanding the Abrams main battle tank development, production and fielding is a critical part of this research. We will briefly look at the overall characteristics of the acquisition and deep dive on relevant points. There is a great deal of literature on the Abrams program for those who desire additional details: *King of the Killing Zone*, by Kelly Orr; *From Camp Colt to Desert Storm: The History of U.S. Armored Forces*, edited by George F. Hoffman and Donn A. Starry; *An Examination of the XM-1 Tank System Acquisition Program in a Peacetime Environment*, a thesis by Glen W. Williams; and *Bias in Weapon Development*, a dissertation by Daniel H. Else, III.

[4] Photo from US Army.

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The history of the Abrams main battle tank begins with the deployment of the M-60 tank[5] in 1960. While the M-60 was a marked improvement over the M-48 Patton, it was also the latest in a series of successive tank improvement programs that began before or during the fielding of the previous model. The U.S. Army recognized the need for the next generation and began working with the West Germans in 1963 on the Main Battle Tank—70 (MBT-70) program. The MBT-70 was a joint effort intended to produce vast improvements in lethality, survivability and mobility to be fielded in the early 1970s, hence the "-70" in its name. While the MBT-70 program started as a concerted effort by the two nations, cost overruns and competing priorities soon caused their views on the system to diverge.

Recognizing the challenges of the MBT-70 program, and perhaps contributing to them, the U.S. Army initiated the XM-803 tank program in 1969. In the XM-803 program the Army recognized both the need for a replacement for the M-60 and the likelihood that the MBT-70 program would not be able to produce the needed next generation. In 1970 Congress terminated the MBT-70 program. Notwithstanding its genesis from a recognition of the problems in the MBT-70 program, the XM-803 was also plagued with significant cost escalation despite limited improvements over the M-60. This led Congress to cancel the XM-803 in 1971.

Figure 2. M-60 Tank[5]

[5] Photo from US Army.
[6] Photo from US Army.

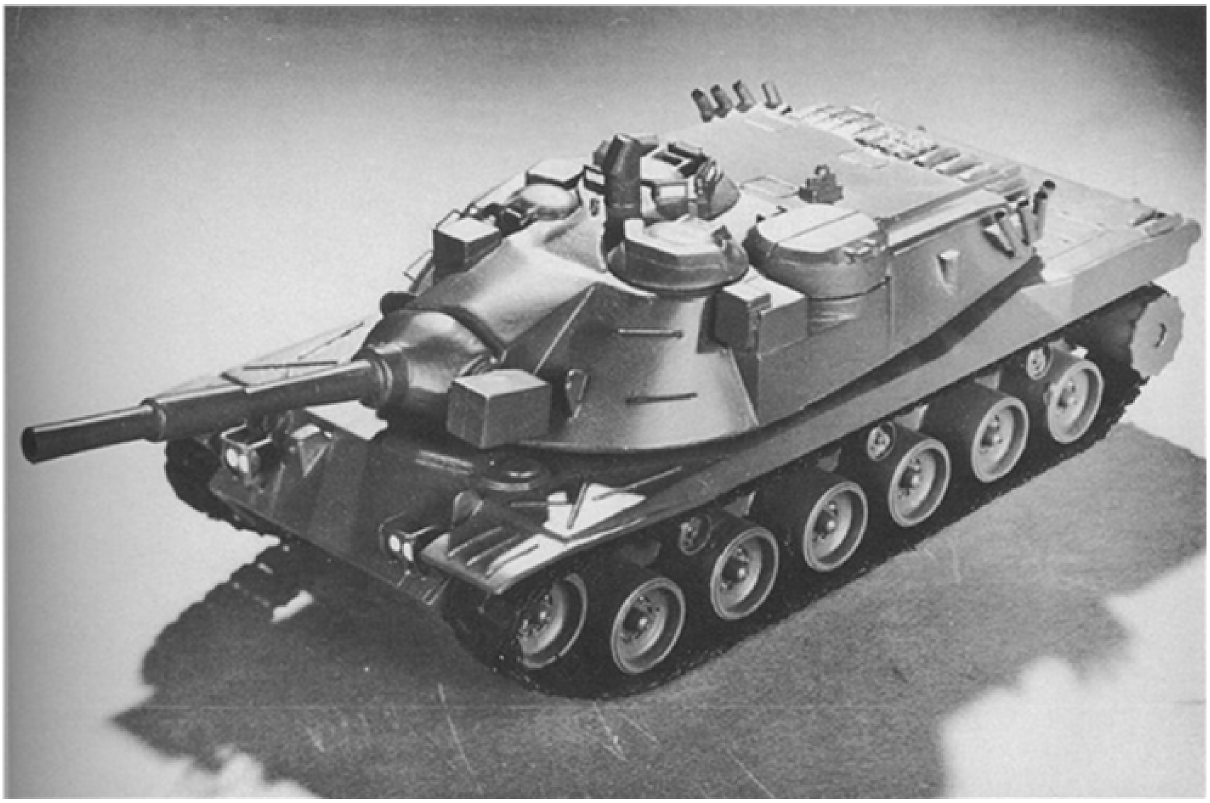

Figure 3. MBT-70 Model[6]

At the same time that Congress cancelled the XM-803 program, it recognized the need for a replacement for the M-60 and provided funds for the Army to conduct a study on the development of the next tank. The "Army established the Main Battle Task Force under the command of LTG John Norton, Commanding General, US Army Combat Developments Command, with representation and assistance from United Stated Continental Army Command, US Army Materiel Command and Army Staff elements.[7]" The Task Force was co-located at Fort Knox with the Armor Center, providing ready access to a multitude of experts. Additionally, the Task Force director, MG William R. Desobry, established a four-member committee to act as the "Task Force Devil's Advocate[9]" and to conduct "independent evaluations on certain key issues.[10]"

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7 US Army Combat Developments Command, *Main Battle Tank Task Force After Action Report*, (Fort Knox, KY, 1972), 1.

8 Photo from http://ookaboo.com/o/pictures/picture.large/21568158/XM_803_prototype.

9 US Army Combat Developments Command, *Main Battle Tank Task Force After Action Report*, (Fort Knox, KY, 1972), 1.

10 US Army Combat Developments Command, *Main Battle Tank Task Force After Action Report*, (Fort Knox, KY, 1972), 1.

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Figure 4. XM-803 Tank[8]

The Main Battle Task Force's 1972 report proposed requirements for a new tank that led to the initiation of the XM-1 tank program and the awarding of contracts to Chrysler and General Motors for prototypes. It is important to note that the program's charter included a direct, high-level, reporting chain: "The project manager reports directly to the Commanding General, U.S. Army Materiel Command (USAMC), since the XM-1 Tank System is one of the Army's 'Big Five'". [11]

During the development of the XM-1 tank—later redesignated the M-1 tank and named the Abrams tank after General Creighton Abrams[12]—there were significant technological enhancements made. The 2005 study, *Critical Technology Events in the Development of the Abrams Tank: Project Hindsight Revisited*, by Richard Chait, John Lyons, and Duncan Long of the National Defense University, specifically focused on what technologies were incorporated into the new tank. The study highlights 55 critical technology events (CTEs) that set the M-1 Abrams apart from the M-60. "CTEs are ideas, concepts, models, and analyses, including key technical and managerial decisions, that have had a major impact on the development of a specific weapons system. CTEs can occur at any point in the system's life cycle, from basic

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[11] Williams, Glen W., *An Examination of the XM-1 Tank System Acquisition Program in a Peacetime Environment*, (Fort Belvoir, VA: Defense Systems Management College, 1974), 23.

[12] Creighton Abrams was the most famous of Patton's armor battalion commanders in World War II, commander f the Military Assistance Command, Vietnam (MACV) from 1968 through 1972, and the Chief of Staff of the Army when the program began (he died in office in 1974)

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research, to advanced development, to testing and evaluation, to product improvements."[13] The M-1's CTEs are depicted in the Figure 6.

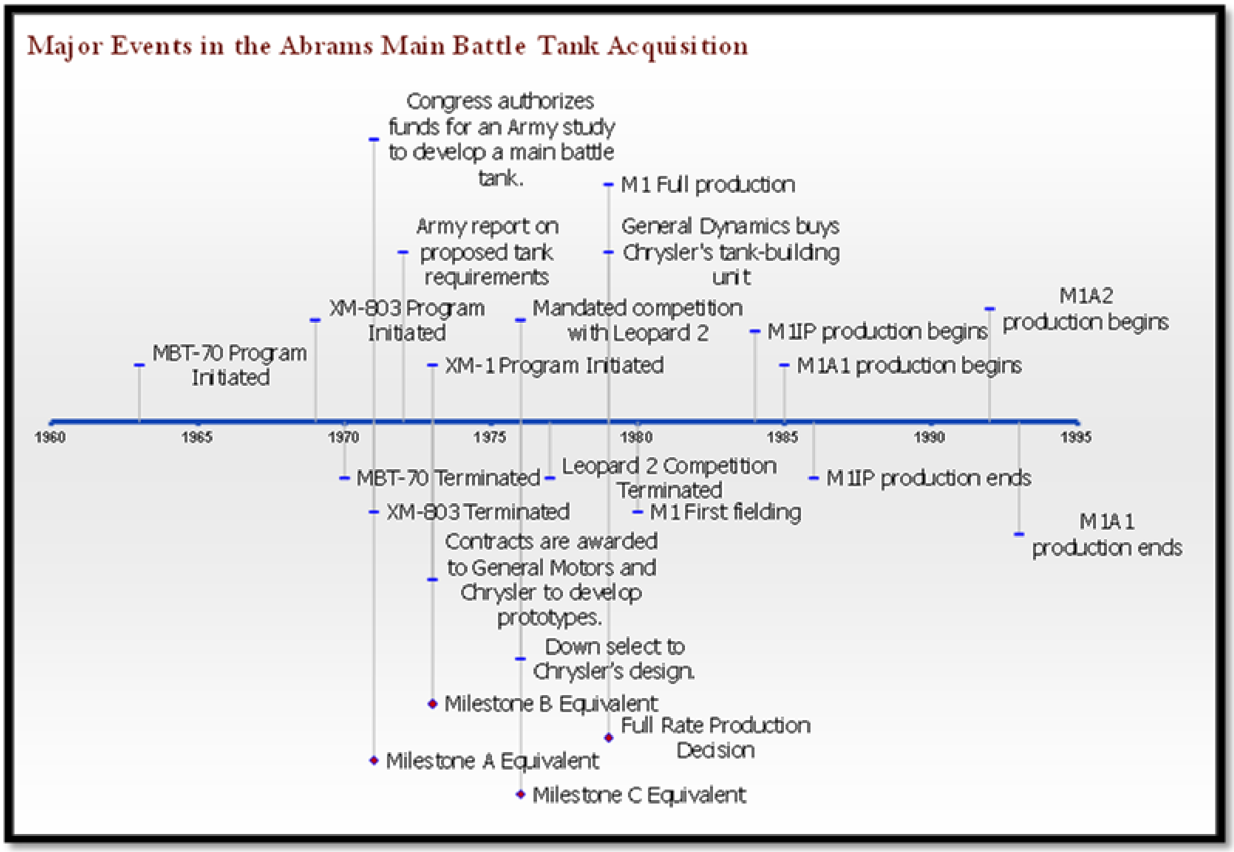

Figure 5. Abrams Main Battle Tank Development and Production Timeline.

The technological enhancements were pervasive throughout the entire new tank. The work in developing the MBT-70 and the XM-803 accelerated the incorporation of technologies into the M1. As with its predecessors, the M1 also had its technological critics. One of the most notorious technologies was the incorporation of a turbine engine. The turbine engine produced 1500 horsepower compared to the M-60's 750. This "new technology" was believed by many to be untested and unreliable and led to public concerns during Desert Shield and Desert Storm that the Abrams tank would not be able to survive the desert or be reliable over the vast distances that an attack required.[14] Despite beliefs to the contrary, the turbine technol-

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13 Chait, Richard, John Lyons, and Duncan Long, *Critical Technology Events in the Development of the Abrams Tank (Project Hindsight Revisited)*, (Washington, DC: Center for Technology and National Security Policy, National Defense University, 2005), 2.

14 Williams, Greg, *The Army's M1 Tank: Has It Lived Up To Expectations?* (Washington, DC: Project on Government Oversight, 1990), 1-12.

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ogy was not new—it was already in wide use in aircraft, away from dust and debris—only its incorporation into a tank was new.

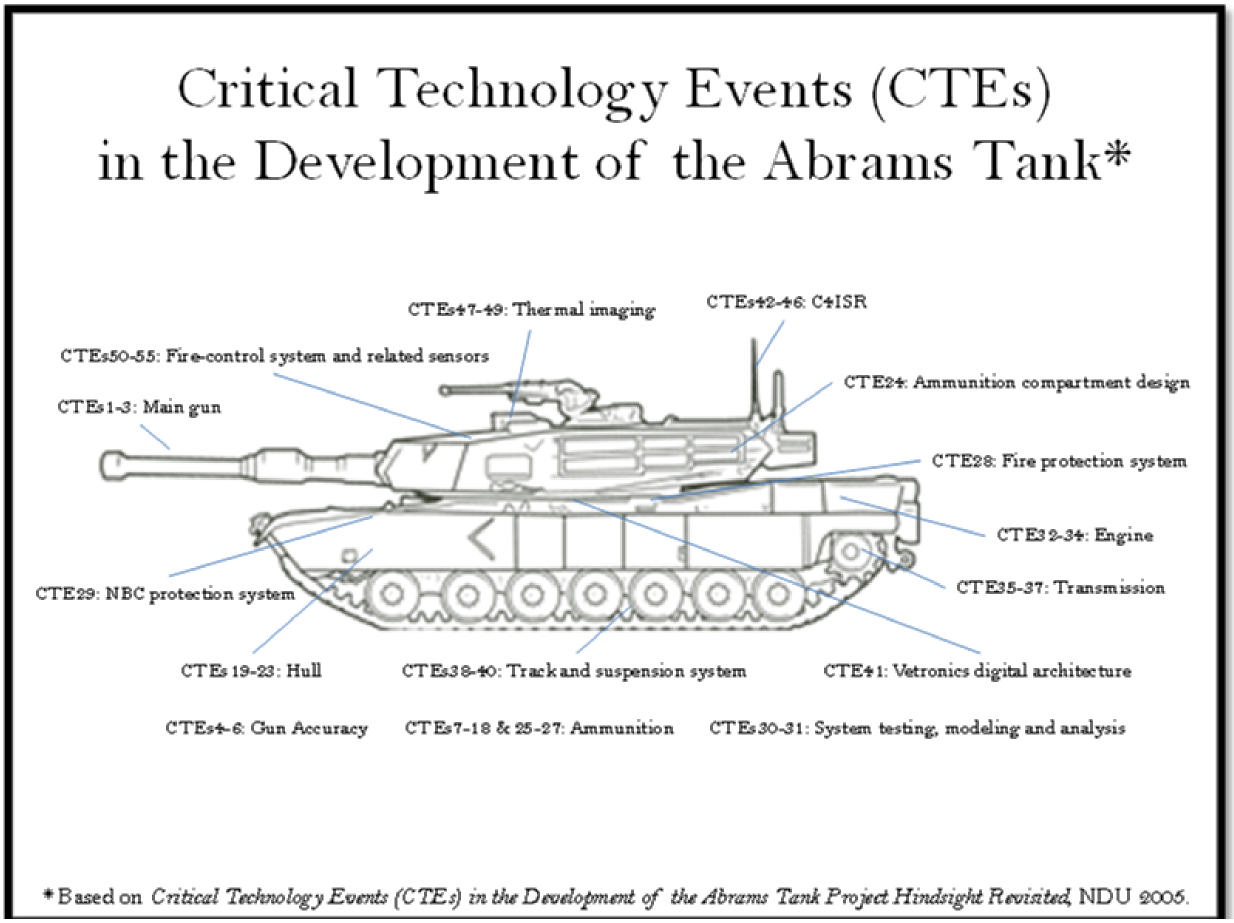

Figure 6. Critical Technology Events in the Development of the Abrams Tank

In July 1976, the Army selected the General Motors proposal and Secretary of the Army Martin Hoffman went to see Secretary of Defense Don Rumsfeld for approval. Prior to the meeting, the Army had already drafted a press release and distributed it to Congress. The Office of the Secretary of Defense, however, did not agree with the Army's decision and the Deputy Secretary of Defense made this clear to Secretary Rumsfeld during the meeting. Secretary Rumsfeld had not been previously briefed about any disagreements with the program and directed the Army to recall its press release while he examined the issues. In December 1976, over the Army's objections, Secretary Rumsfeld selected the Chrysler proposal primarily because of its ability to incorporate a 120mm cannon and the increased efficiency expected from the turbine engine.[15]

[15] Rumsfeld, Donald, *Known and Unknown: A Memoir*, (New York: Penguin Group, 2011), 219-21.

Notwithstanding the Secretary's decision, the tank decision continued to spark controversy inside and outside the Army. In a letter to the Army's Office of the Deputy Chief of Staff for Operations and Plans, MG Donn Starry, then the Commanding General of the Army's Armor Center and School at Fort Knox, expressed his concerns about the Abrams tank program, "The XM1 decision is a bloody disaster. But I wasn't consulted, and had I been I'd probably be retired by now for sounding off. Just wait until they start asking the Congress for money for their 'standardized' tank and try to explain how it costs about half again as much as the original design-to-cost prototype!"[16]

Despite the initial decision, Congress and staff elements of the Office of the Secretary of Defense were not convinced that the Chrysler tank was the right answer for the Army. This led to a mandate for a head-to-head competition with the German Leopard 2 tank. The Leopard 2 was the German follow on to the MBT-70 program and like the XM1 contained significant enhancements over the M-60 in mobility, survivability and lethality. The head-to-head competition took place at Aberdeen Proving Ground, Maryland but was cut short upon the discovery that the Leopard 2 being used for the mobility competition had been "hollowed out" to make it lighter and more maneuverable.[17] Secretary Rumsfeld's approval to proceed with limited production of the M1 included a concession to the Germans by mandating the use of the German designed 120mm smoothbore cannon which would also ensure interoperability and ease logistics with this key NATO ally.[18] The decision for full production followed in 1979 with the 105mm because the tank design was not ready for the 120mm cannon. Concurrently, General Dynamics purchased Chrysler's tank division.

By 1980, GEN Starry was the Commanding General of U.S. Army Training and Doctrine Command (TRADOC) and his views had changed, "The AGT-1500 turbine has experienced some growing pains; however, I do not feel that the problems have been abnormal and I am especially pleased with the latest test results. The reports of both the 4,000-mile three-tank test at Fort Knox and the 1,000-hour two-engine laboratory test show that tremendous improvements have been made through the identification of deficiencies and the timely development and application of fixes. As a result of these improvements we have now exceeded the … milestone in both the reliability requirement and durability threshold." [19]

First fielding occurred in 1980. Simultaneously, product improvement efforts were underway that would upgrade the M1. In 1984 the M1 Improved (M1IP) began production while the final integration was being completed to upgrade the main armament to a 120mm cannon

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16 Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 60.

17 Orr, Kelly, *King of the Killing Zone*, (New York: W W Norton and Company, 1989), 209.

18 Rumsfeld, Donald, *Known and Unknown: A Memoir*, (New York: Penguin Group, 2011), 219-21.

19 Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 80.

from the 105mm, as required by Secretary Rumsfeld in 1976. The M1A1 included the 120mm cannon and began production in 1985. While some units deployed to DESERT SHIELD in 1990 with M1IPs, these were replaced in theater with M1A1s prior to combat in DESERT STORM. In 1992, the M1A2 entered production. The M1A2 improved upon the M1A1 by providing an independent thermal sight for the tank commander. This allows the gunner and tank commander to independently search for and acquire targets. Integrated into the fire control system, this enhanced ability to acquire targets translates into reduced times to engage multiple targets. By the 1990s, the Abrams series of tank became the only tank in the Army's inventory with the exception of the M551 Sheridans in the 82nd Airborne Division; a feat that had never been accomplished since the first incorporation of armor into the Army.

Technically, the Abrams took only seven years to go from official program initiation in 1973 to its first fielding in 1980. An additional two years must be added if we define the start as the Congressional mandate, making the total nine years to first fielding. That is quick compared to most major defense acquisition programs (MDAPs), and even more so when compared to other developmental programs. This timeline, however, belies the fact that the M-1's success was built on two failed programs, the MBT-70 and the XM-803. A more appropriate start date is therefore 1963, making the time from program initiation to first fielding 17 years. This is consistent with the 15-20 years that MDAPs often take.[20]

In addition to schedule, cost is an important indicator of program management and performance. Figure 7 below is an historical look at total program costs for the XM-1 program. The data are taken from the Department of Defense's mandated reports to Congress on major defense acquisition programs called the Selected Acquisition Reports (SARs). While the format has changed over time, the data have been consistent across reports since the SARs were standardized in 1975. Although reports are submitted quarterly, the figure uses only the December reports to show how the program changed as it progressed. The blue bars in the chart are read from the left axis and represent the estimated total program cost at the time of the SAR. The number over the blue bar represents the planned procurement quantity. The red line is read from the right axis and represents the program acquisition unit cost (PAUC) which is calculated by dividing the total program cost by the quantity. Both total program cost and PAUC are reported in constant dollars, so the effects of inflation have been removed.

Figure 7 depicts significant fluctuations in quantity desired, starting with an objective of 3,323 tanks in 1973 and more than doubling in 1977 to 8,069. This was almost halved to 4,343 in 1980 and then reduced further to 3,216 in 1981. In 1984, the quantity more than doubled again, rising to 7,480 tanks. This rose to 7,857 in 1986 and further to 9,317 in 1988 before being

[20] Chait, Richard, John Lyons, and Duncan Long, *Critical Technology Events in the Development of the Abrams Tank (Project Hindsight Revisited)*, (Washington DC: Center for Technology and National Security Policy, National Defense University, December 2005), 7.

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reduced to 7,802 in 1989 and remaining in that vicinity. The SAR reports on the Abrams program ended in 1991, as the procurement reached more than 90 percent of its objective.

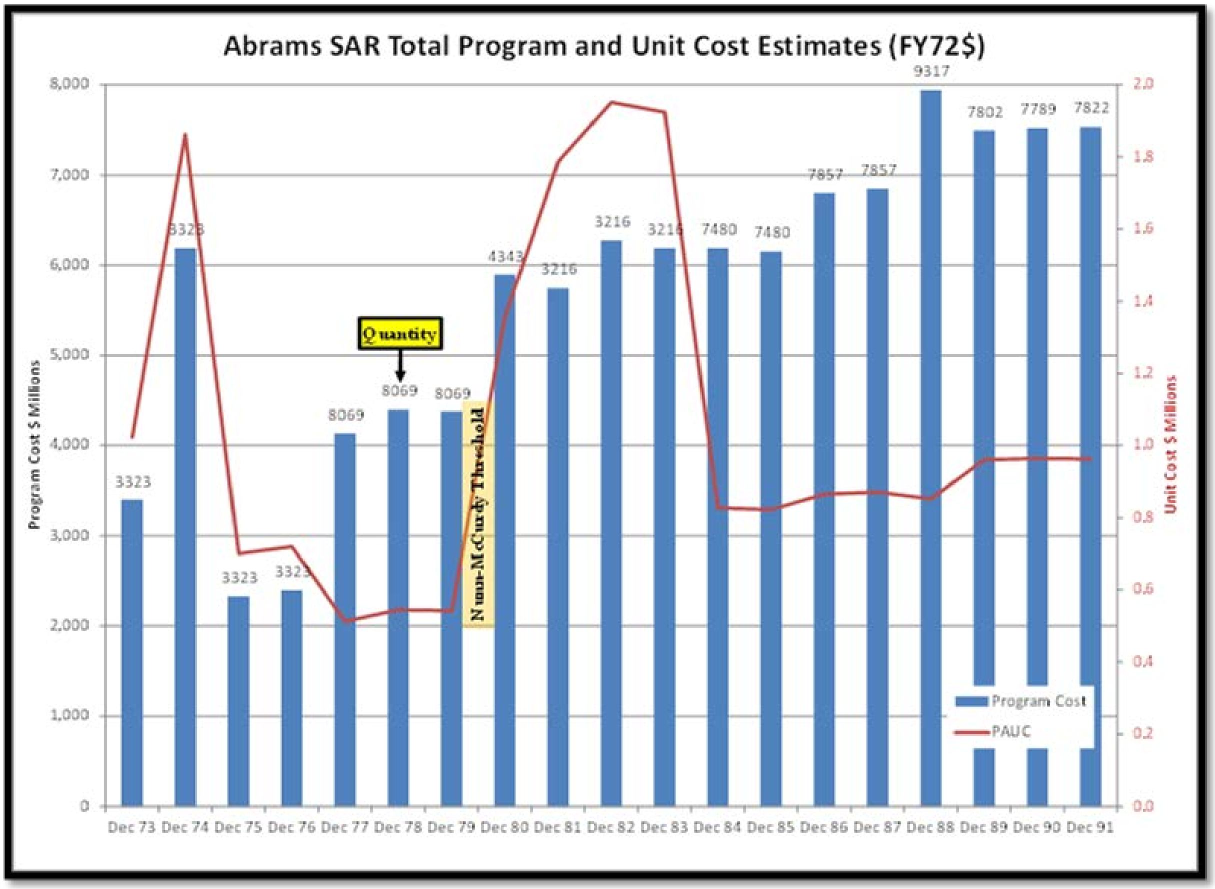

Figure 7. Abrams Selected Acquisition Report Total Program and Unit Cost Estimates

Program costs (blue bars) started at $3.5 billion in 1973 and rose to more than $6 billion the following year, but the consistency of these costs with the remainder of the data is questionable so it is better to start with the 1975 estimate of $2.3 billion for the total acquisition program. These estimates do not include the operations and maintenance costs to operate, maintain, and sustain the system over its lifetime. In 1976 the cost had risen to $2.4 billion before almost doubling to $4.1 billion the following year. The following two years saw modest increases until 1980, when the estimate soared to $5.9 billion. This was reduced in 1981 with a reduction in quantity to $5.7 billion but rose again the following year to $6.3 billion. Minor reductions in 1983 and 1985 followed. The increased quantity in 1986 led to estimates of $6.8 billion for the program, which rose to $7.9 billion by 1988 before dropping to $7.5 billion for the remainder of the program.

Program acquisition unit cost (PAUC), depicted by the red line, is simply the combination of program cost and quantity and represents the average cost of one tank including the research and development costs. Starting in 1975 when the SARs were standardized, the PAUC was $700 thousand. By 1977 this was reduced to $510 thousand and stayed relatively close until 1980 when the PAUC more than doubled to $1.4 million and continued rising to $2.0 million in 1982. With the drastic increase in quantity in 1984, the cost was reduced to $830 thousand per tank. This slowly rose, ending in 1991 at $960 thousand per tank in 1972 dollars, which equates to $3.2 million in 1991 dollars or $5.4 million in 2012 dollars.[21]

While the cost growth of the Abrams program was a concern at various times, there were no standardized thresholds for determining programs that were in trouble. This changed in 1982 with the passage of the Nunn-McCurdy Act. Moshe Schwartz of the Congressional Research Service succinctly explains the thresholds:

> A program that experiences cost growth exceeding any of the established thresholds is said to have a Nunn-McCurdy breach. There are two types of breaches: significant breaches and critical breaches. A "significant" breach is when the Program Acquisition Unit Cost (the total cost of development, procurement, and construction divided by the number of units procured) or the Procurement Unit Cost (the total procurement cost divided by the number of units to be procured) increases 15% or more over the current baseline estimate or 30% or more over the original baseline estimate. A "critical" breach occurs when the program acquisition or the procurement unit cost increases 25% or more over the current baseline estimate or 50% or more over the original baseline estimate.[22]

While both significant and critical breaches require Congressional notification, critical breaches require the Department of Defense to certify that the program is essential to national security, that there are no alternatives to the program, that new cost estimates are reasonable, and the that management structure of the program is adequate.

Under the Nunn-McCurdy criteria, the Abrams program would have experienced a critical breach in 1980. While the cost increases were reported to Congress as part of the SAR, they did not mandate the full program review to support recertification that would be required to continue such a program today. By the time the December 1980 SAR was provided to Congress, the M1 had already completed its initial fielding and was in full production. Given the recognized need to replace the M-60 tank—and for that matter the M-48, which was still in the National Guard and a few active units—it is unclear what impact a critical breach would have had at this juncture. It undoubtedly would have impacted the schedule, but whether or

[21] Author's calculations using tables from DoD's FY12 Green Book.

[22] Schwartz, Moshe, *The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress*, (Washington, DC: Congressional Research Service R41293, 2010), i.

not it would have reduced the quantity or removed planned upgrades to the M1IP and the M1A1 is unknowable.

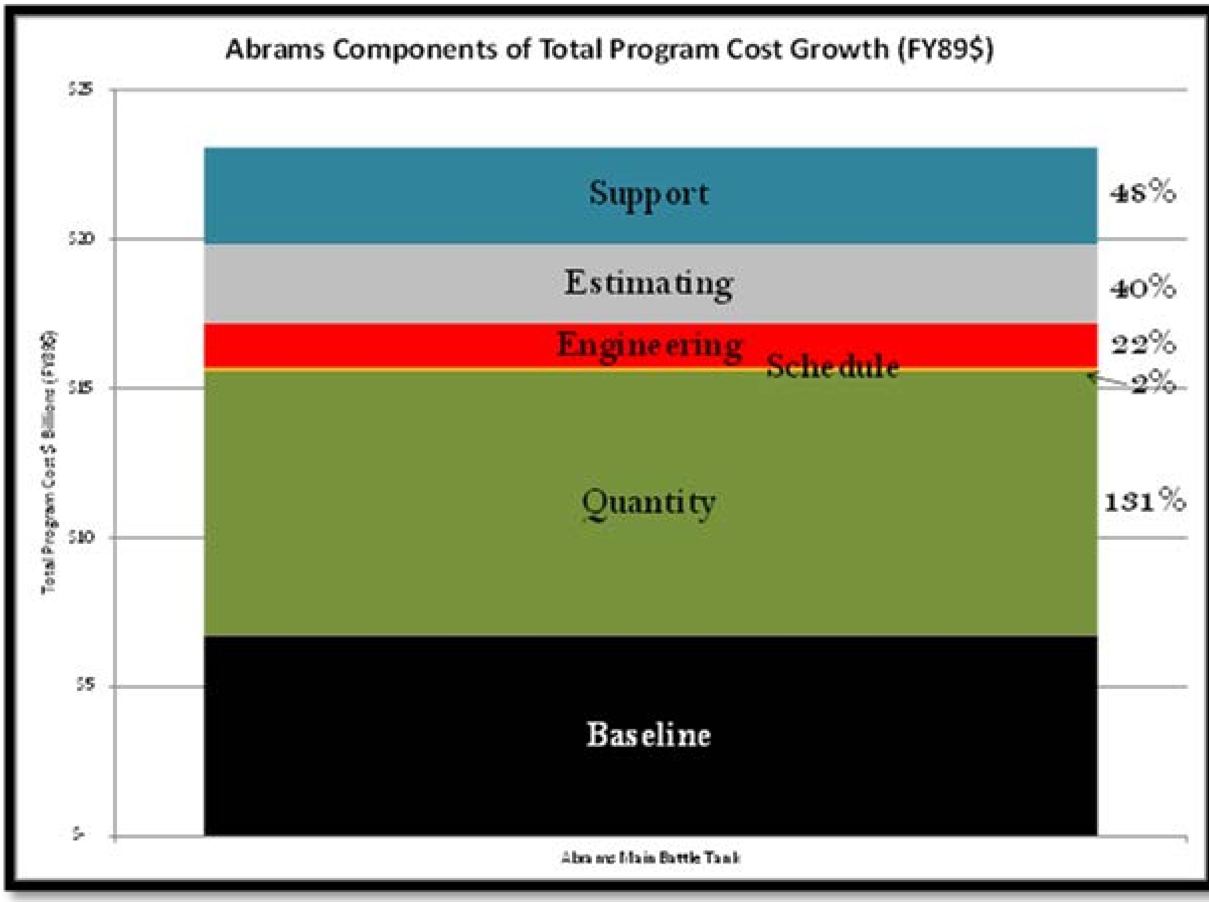

Figure 8. Abrams Components of Total Program Cost Growth

Program cost growth is broken down in the SARs into six categories: quantity, schedule, engineering, estimating, support, and other. While the categories are standardized, there are no universal definitions of the categories or clear delineations between them. Figure 8 represents the components of total program cost growth for the Abrams program as reported in its final SAR in a December 1991. The majority of the cost growth is due to increased quantity, accounting for an increase of 131 percent in the total program cost. Engineering generally reflects changes to the requirements and accounts for an increase of 22 percent. Schedule changes caused cost to grow only two percent. Estimating as a category includes non-inflation cost growth due to differences between the original estimate of costs and what actually happened. Support is an amorphous category and includes training devices and maintenance equipment added after the original estimate. Overall, the cost growth chart shows us that the

Abrams program began as a modest major defense acquisition program and grew, primarily through the desire for increased quantity, to a very large program.

As a testament to the success of the program, the Abrams main battle tank is used by both the Army and the Marine Corps in the United States and it has been sold to Australia, Iraq and Saudi Arabia, and licensed for production to Egypt.[23]

The Army's current description of the Abrams tank is found in Figure 9.

[23] *Jane's Armour and Artillery 2011-12*, (New York: Jane's Pub Inc., 2012).

U.S. ARMY FACTFILES

WEAPON SYSTEMS ALPHABETICAL LIST

TRACKED VEHICLES ABRAMS BRADLEY M88A2 M113

ABRAMS

MISSION

Provide heavy armor superiority on the battlefield.

ENTERED ARMY SERVICE

1980

ADDITIONAL MEDIA

DESCRIPTION AND SPECIFICATIONS

The Abrams tank closes with and destroys enemy forces on the integrated battlefield using mobility, firepower, and shock effect. There are three variants in service: M1, M1A1 and M1A2. The 120mm main gun on the M1A1 and M1A2, combined with the powerful 1,500 hp turbine engine and special armor, make the Abrams tank particularly suitable for attacking or defending against large concentrations of heavy armor forces on a highly lethal battlefield.

Features of the M1A1 modernization program include increased armor protection; suspension improvements; and a nuclear, biological and chemical (NBC) protection system that increases survivability in a contaminated environment. The M1A1D modification consists of an M1A1 with integrated appliqué computer and a far-target-designation capability.

The M1A2 modernization program includes a commander's independent thermal viewer, an improved commander's weapon station, position navigation equipment, a distributed data and power architecture, an embedded diagnostic system and improved fire control systems.

The M1A2 System Enhancement Program (SEP) adds second-generation thermal sensors and a thermal management system. The SEP includes upgrades to processors/memory that enable the M1A2 to use The Army's common command and control software, enabling the rapid transfer of digital situational data and overlays.

ABRAMS TANK INFORMATION

	M1/IPM1	M1A1	M1A2	M1A2 SEP
Length	32.04 ft	32.04 ft	32.04 ft	32.04 ft
Width	12 ft	12 ft	12 ft	12 ft
Height	7.79 ft	8 ft	8 ft	8 ft
Top Speed	45 mph	41.5 mph	41.5 mph	42 mph
Weight	61.4/62.8 tons	67.6 tons	68.4 tons	69.5 tons
Main Armament	105mm	120mm	120mm	120mm
Crew	4	4	4	4

MANUFACTURER

General Dynamics (Sterling Heights, MI; Warren, MI; Muskegon, MI; Scranton, PA; Lima, OH; Tallahassee, FL)

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Figure 9. Description of the Abrams Main Battle Tank[24]

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Figure 10. Bradley Fighting Vehicle[25]

Bradley Fighting Vehicle

Understanding the development, production and fielding of the Bradley Fighting Vehicle is a critical part of this research. We will briefly look at the overall characteristics of the acquisition and deep dive on relevant points. There is a great deal of literature on the Bradley program for those who desire additional details: *The Bradley and how it got that way: technology, institutions, and the problem of mechanized infantry in the United States Army* by W. Blair Haworth, Jr.; *The Pentagon Wars: Reformers Challenge the Old Guard* by James G. Burton; and *From Camp Colt to Desert Storm: The History of U.S. Armored Forces*, edited by George F. Hoffman and Donn A. Starry.

[24] Photo from US Army.

Figure 11. XM-701 MICV-65 Prototype[26]

The Bradley began as the Mechanized Infantry Combat Vehicle–65 (MICV-65) in 1963. The Army recognized the need to replace the M113 Armored Personnel Carrier (APC) with an infantry fighting vehicle. Instead of having an armored transport vehicle, the requirement was for a squad to be able to fight from the vehicle and for the vehicle to provide fire support for the squad once it dismounted. This requirement was reinforced with the development of the Soviet BMP in the early 1960s, with BMP prototypes developed by 1964 and fielding beginning in 1966. Nevertheless, in contrast to the M1 having replaced all other tanks in the Army inventory, the M113 has not been totally replaced by the Bradley.

The M113 APC had been designed in the 1950s to transport infantrymen to the battlefield. It was lightly armored, carried a crew of two and eleven infantrymen—a full squad—and mounted the M2 .50-caliber machine gun. The M113 was produced by Food Machinery Corporation (FMC) and initially delivered to the Army in 1960. It first saw use in Vietnam in 1962 as it was provided to Army of the Republic of Vietnam (ARVN) forces. The M113 was well known for its mobility, to include an ability to swim, and for its deployability, being able to deploy on both C-130 and C-141 aircraft.

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[25] Photo from US Army.

Figure 12. M113 Armored Personnel Carrier[27]

In 1965, the Pacific Car and Foundry Company delivered the XM-701 prototype. The XM-701 carried a three-man crew and eight or nine infantrymen (depending on the information source). There was a two-man turret with a 20mm gun and a 7.62mm machine gun. There were firing ports for infantrymen in the back, and even a toilet! Armor was supposed to be able to stop 14.5mm machine gun fire. The vehicle was amphibious as well as over-pressurized for nuclear, biological, and chemical protection. Prototypes were offered in both steel and aluminum armor resulting in a weight of 25–27 tons.[28]

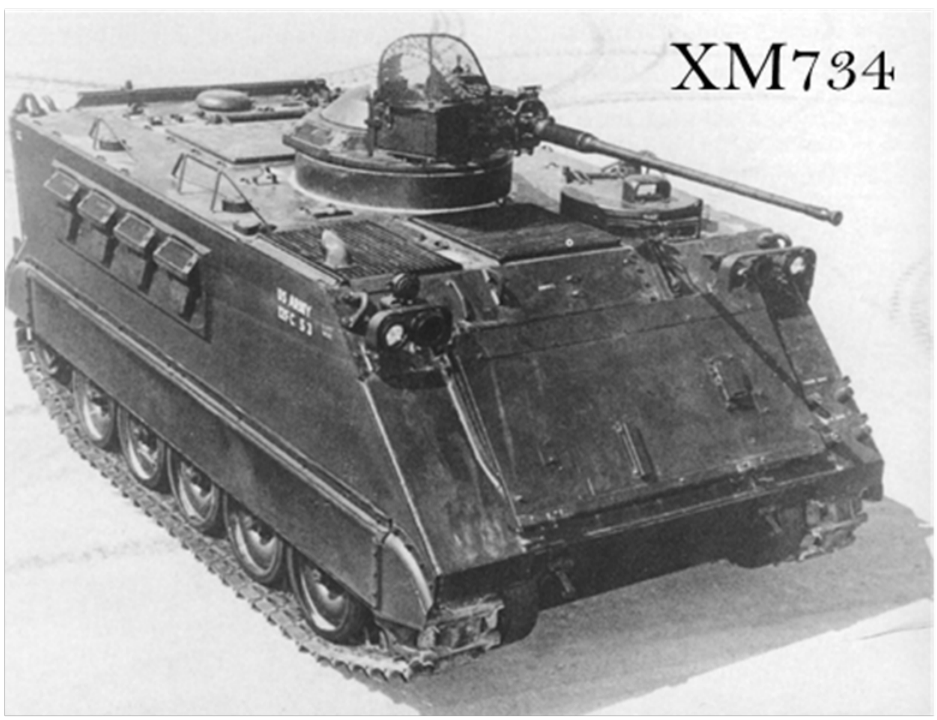

Figure 13. XM-734 MICV-65 Prototype[27]

[26] Photo from US Army.
[27] Photo from US Army.
[28] Green, Michael and James D. Brown, *M2/M3 Bradley at War*, (St. Paul, MN: Zenith Press, 2007), 21-25.

FMC provided two modified versions of the M113, dubbed the XM-734 and the XM-765, for the MICV-65 program. The XM-734 was deployed to Vietnam and appears to have served in various units from 1967 through 1972.[29] The XM-734 reconfigured the infantry seating in the M113 so that there was a bench in the center of the vehicle. Infantrymen would sit facing outward with four firing ports with vision blocks on each side, providing the ability to fire while under armor protection. The track commander's position was changed into a turret to afford protection for the track commander while firing the M2 .50-caliber machine gun.[30]

The XM-765, also based on the M113, and also included upgrades for firing ports and a turret. The XM-765 turret included the same M2 .50-caliber machine gun but it allowed the track commander to fire the weapon remotely from within the vehicle, under armor protection. Visibility was achieved through vision blocks. [32] It is interesting to note that the XM-765 became FMC's Armored Infantry Fighting Vehicle, which has been purchased by the military in Bahrain, Belgium, Chile, Egypt, Jordan, Malaysia, Netherlands, Philippines, Turkey, and the United Arab Emirates.[33]

Figure 14. XM-765 MICV-65 Prototype[28]

[29] Doyle, David, *Standard Catalog of US Military Vehicles*, (Iola, WI: Krause Publications, 2003), 322.
[30] *Jane's Armour and Artillery 1979-80*, (New York: Jane's Pub Inc., 1980).
[31] Photo from US Army.
[32] *Jane's Armour and Artillery 1979-80*, (New York: Jane's Pub Inc., 1980), 269.
[33] *Jane's Armour and Artillery 2011-12*, (New York: Jane's Pub Inc., 2012), 467.

In 1968, the Army rejected all proposals, primarily based on their inability to deploy via C-130 aircraft. It is not clear why this requirement was added during the assessment of the prototypes and not included in the request for proposals (RFP). With the BMP being widely fielded by the Soviets, the Army was concerned it might not have defined the requirement for the MICV-65 correctly. MG George Casey[34] was directed to review the requirement and report out. The Casey Board, as it became known, revalidated the need for a mechanized infantry combat vehicle.

Figure 15. XM-723 MICV-70 Prototype[32]

Based on MG Casey's recommendations, the MICV-70 program was initiated in 1969. An RFP was released in 1972. Chrysler, FMC, and Pacific Car and Foundry were leading candidates. By the end of 1972, FMC was selected to develop and produce an MICV-70 prototype. The XM-723 was the result, delivered to the Army in 1975. The XM-723 had a crew of three and carried eight infantrymen. The driver sat in the front left of the vehicle hull, and immediately behind him sat the track commander, also in the hull. The gunner occupied a one-man turret with a 20mm gun. Because the track commander was in the hull, his visibility was impaired by the turret. The eight infantrymen had firing ports so they could engage targets from within the armor protection of the vehicle.[35]

[34] MG Casey went on to die in command of the 1st Cavalry Division in Vietnam and is the father of the recent CSA, GEN George Casey, Jr.

[35] *Jane's Armour and Artillery 1979-80*, (New York: Jane's Pub Inc., 1980), 267.

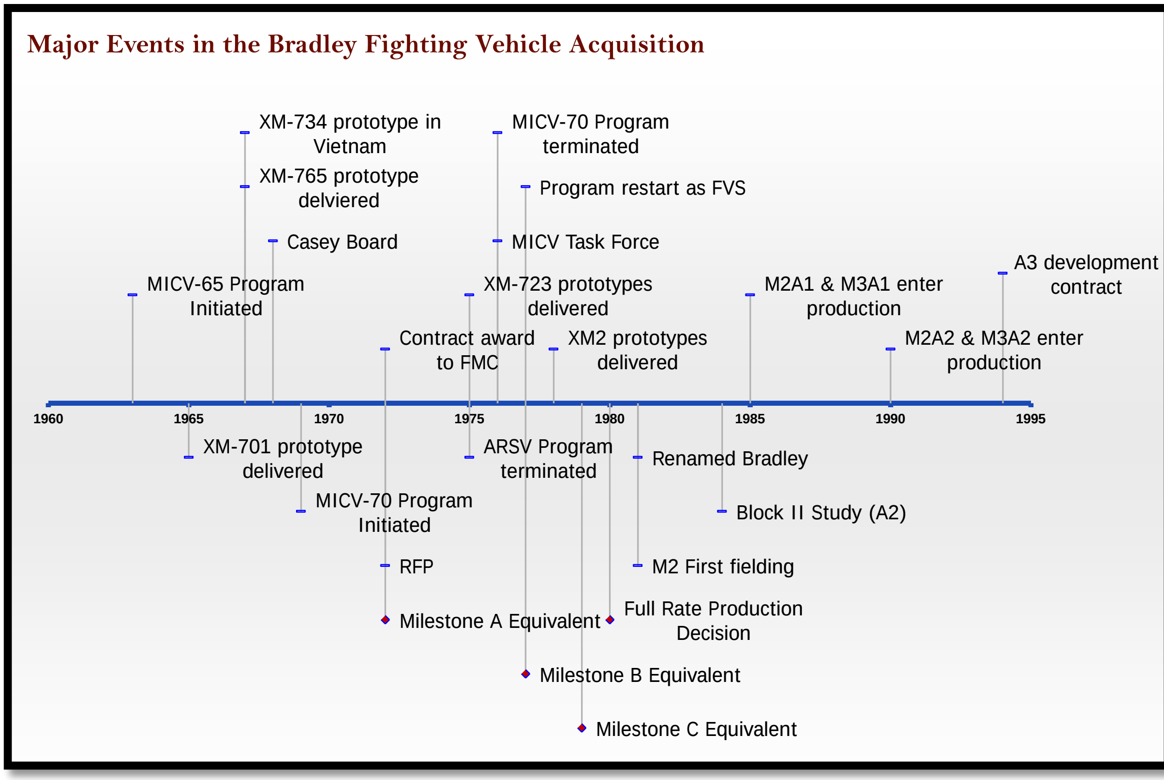

Figure 16. Bradley Fighting Vehicle Development and Production Timeline

In a parallel development, the Army was looking at acquiring an Armored Reconnaissance Scout Vehicle (ARSV). In 1973, prototypes were delivered for testing. GEN Starry's recollection[36] is succinct:

> There were two candidates, one full tracked and one wheeled. One look was sufficient to suggest that both were wide of the requirement, by then some ten years old. Having just forced a decision to take the unsatisfactory M114 scout vehicle, and the equally deficient M551 Sheridan airborne assault/armored reconnaissance vehicle, out of the inventory, I was extremely reluctant to buy into another uncertain program. We tested the candidates at Fort Knox and recommended the program's termination.[37]

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36 GEN Starry was the two-star commanding the Armor Center and School at Fort Knox at this time.

37 Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 29.

As recommended by MG Starry, the Army cancelled the ARSV program in 1975. At the same time the XM-723 was undergoing testing. Again GEN Starry summarized:

> Not long thereafter the MICV prototype was delivered for testing—again ten years after the requirements documentation was written. Just on observation it was worse than the ARSV. However, having just terminated ARSV, we feared cancellation of another major program would eliminate TRADOC as well. So it was decided to 'fix' the MICV … To help hold down rising costs we added the ARSV acquisition objective numbers to the IFV numbers to help reduce unit cost. Hence the Army eventually fielded two versions of the Bradley fighting vehicle, one for infantry and one for cavalry scouts. However, neither model met requirements.[38]

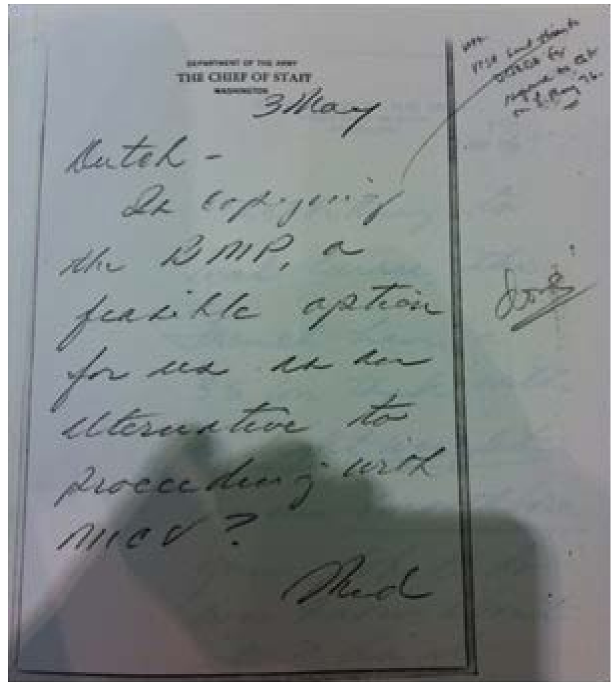

Figure 17. Note from CSA to VCSA on MICV[40]

In 1975, Congress also asked the General Accounting Office (GAO) to look at the MICV-70 program, the Army established a MICV Task Force with representation from the Infantry school at Fort Benning, Georgia and the Armor school at Fort Knox, Kentucky. The Office of Management and Budget (OMB) also zeroed out the program, removing all funding in the President's budget request and essentially cancelling the program.

Understanding the requirement for an infantry combat vehicle and the problems of the MICV-70 program, on May 3, 1976, the Army Chief of Staff, GEN Fred Weyand wrote to Army Vice Chief of Staff, GEN Walter "Dutch" Kerwin, asking "Is copying the BMP, a feasible option for us as an alternative to proceeding with MICV?"[39] The answer was no, although it is unclear how thoroughly this option was pursued.

The MICV Task Force re-validated the requirement for a combat infantry vehicle and made several recommendations. First, the program should be combined with the recently ter-

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38 Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 29.

39 Weyand, Fred C., *Frederick C. Weyand papers, 1972-1999*, (maintained at United States Military History Institute, Carlisle Barracks, PA, 1972-1999), intra-office memo.

minated ARSV program. This was to artificially reduce unit costs but also to ensure that cavalry units would have the same equipment as other combat units so that they could not easily be distinguished by an enemy. The requirement to provide supporting fire for dismounted infantry resulted in a recommendation to up-gun the vehicle to a 25mm chain gun. Recognition that movement on the battlefield with the XM1 tank would make it a likely tank target led to recommendation to add a twin TOW launcher to the turret as well. Finally, the Task Force recommended that the vehicle be amphibious capable.[40] The program was restarted in 1977 as the Fighting Vehicle System (FVS) with two component systems, the Infantry Fighting Vehicle (IFV) and the Cavalry Fighting Vehicle (CFV).

With the start of the FVS program the Army needed to reverse the momentum against the program and gain support from key stakeholders in the Office of the Secretary of Defense (OSD), the Office of Management and Budget (OMB), and Congress. GEN Starry, as the commanding general of TRADOC, was not impressed with the initial attempts at strategic communications. On January 9, 1978 he wrote:

> 1. I have reviewed the briefing … It falls well short of the mark. In fact it's horrible. If we are to satisfy our critics in OSD, the Congress, and elsewhere of the need for the IFV/CFV, then we must put together a very convincing case, which this briefing does not do. We must describe operational concepts which generate the requirement for an IFV with the capabilities we have said we require, e.g., kill BMPs, XM1-like mobility, etc.
>
> 2. … One of the reasons we have not been successful in articulating our case for the IFV is because our critics view it as just a product-improved 113, which it is not. The 113 is a carrier; the IFV is a fighting vehicle. It is the difference between the two, and why a fighting vehicle is needed, that we have not clearly articulated to our critics. To make the case, we must first describe how tanks, long-range infantry and short-range infantry must fight together on the battlefield, clearly describing the complementary roles of each. Structuring the battlefield by infantry as described in the briefing certainly is not one of them. Then we must show why the M113 is inadequate for operations with the M60 series tanks, given its limited armor protection and limited firepower. When we go to the XM1 the situation just gets worse. Here we must clearly describe the stress on the tank due to the 113's inability to operate with our current and future tanks. Having done all this, the operational concept for employment of the IFV with the XM1 must be shown. But, again, not described as simply a product-improved 113 nor, on the other hand,

[40] *Jane's Armour and Artillery 1979-80*, (New York: Jane's Pub Inc., 1980), 267.

> should it be made to appear as a light tank. It must be shown as a fighting vehicle that can unstress the tank and also carry infantry.[41]

GEN Starry did his part to rally support for the program but it was not without frustrations. In a message to the U.S. Army attaché in Israel he stated, “We’re having a hell of a time trying to save the infantry fighting vehicle. All R&D and procurement was cut by OMB in budget process. If he hears of it, tell him [Musa Peled] I haven’t lost my mind—just surrounded by people who haven’t fought a war and whom we can’t make understand the battle equation.”[42]

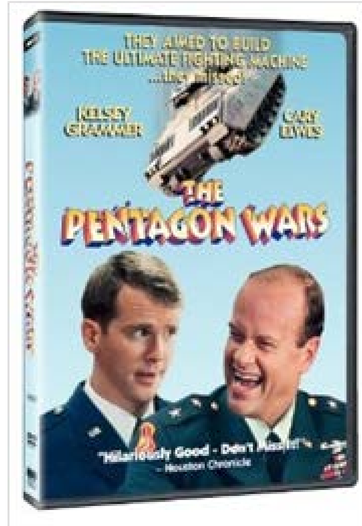

Figure 18. The Pentagon Wars HBO Movie

In 1978 FMC delivered prototypes that were whisked through testing. The approval for limited rate production was provided in 1979 and full production the following year. 1981 saw the first fielding of the M2 and its naming as the Bradley in honor of General of the Armies Omar Bradley. As the Bradley was being fielded throughout the Army, the Joint Live Fire Testing program began in 1984. The result of the contentious interaction between the Army and the officer assigned to oversee the tests for the Bradley, COL James Burton, led to COL Burton’s book, *The Pentagon Wars*, a Home Box Office (HBO) movie of the same name, and Congressional hearings. The movie sarcastically summarized the capabilities of the Bradley as well as the debates over its development in the following conversation:

> Col. Robert Laurel Smith: In summation, what you have before you is...
>
> Sgt. Fanning: A troop transport that can’t carry troops, a reconnaissance vehicle that’s too conspicuous to do reconnaissance...
>
> Lt. Colonel James Burton: And a quasi-tank that has less armor than a snow-blower, but carries enough ammo to take out half of D.C. THIS is what we’re building?[43]

The ensuing Congressional hearings threatened to halt Bradley production and fielding but the Army recognized the precarious situation and went all out to ensure the program continued. The Army successfully engaged the Chairman of the Joint Chiefs of Staff, ADM Wil-

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41 Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 240.

42 Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 242.

43 http://www.imdb.com/title/tt0144550/quotes?qt=qt0457234.

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liam Crowe, as an advocate for the program. On June 5, 1986, he wrote the House Armed Services Committee Chairman, Congressman Les Aspin, in support of the Bradley:

> … I wish to reaffirm the importance and contribution of the Bradley Fighting Vehicle to our nation's combat capability. Future land warfare will be faster paced than ever in history; the Bradley enables our infantry to get there quicker with more firepower than ever before. The requirement for this vehicle is clear and unequivocal. … I urge your support in continuing to field the Bradley which is a critical component of the Army modernization program.[44]

Similar letters were sent to the chairmen of the House Appropriations, Senate Appropriations, and Senate Armed Services Committees. On July 2, 1986, the Army Chief of Staff, GEN John Wickham, responded to concerns about the Bradley from Congressman Charles E. Bennett by writing him, "Even though there appears to be disagreement between honest people concerning the test results and shot selections, we should not allow this disagreement to stop the production of a fielded system which has met its original design specifications. The Army and our soldiers need this vehicle. Your support is needed."[45] The strategic communications campaign was successful and the Bradley continued to be produced and fielded.

Even with the FVS program, the design continued to change to meet requirements. On October 7, 1986 MG Ed Burba updated the Army Chief of Staff, GEN John Wickham, on Bradley weight evolution: "The original design of the Bradley fully combat loaded (FCL) was to be 40,000 pounds. However, when the materiel needs requirement was formalized in 1978 the weight had crept up to 47,000 pounds (FCL). When the vehicle was finally fielded it came in at 50,259 pounds (FCL). Two up-Armor versions being considered at this time would raise the weight to 55,000 and 60,000 pounds (FCL), respectively."[46] Clearly this would impact schedule and cost as well.

Cost is an important indicator of program management and performance. Figure 19 below is an historical look at total program costs for the MICV program that produced and fielded the Bradley infantry and cavalry fighting vehicles. The data are taken from the Department of Defense's mandated reports to Congress on major defense acquisition programs called the Selected Acquisition Reports (SARs). While the format has changed over time, the data have been consistent across reports since the SARs were standardized in 1975. Although reports are submitted quarterly, the figure uses only the December reports to show how the program changed as it progressed. The blue bars in the chart are read from the left axis and

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44 Wickham, John Adams, *John A. Wickham Jr. papers, 1946-1991*, (maintained at United States Military History Institute, Carlisle Barracks, PA, 1946-1991), Crowe letter.

45 Wickham, John Adams, *John A. Wickham Jr. papers, 1946-1991*, (maintained at United States Military History Institute, Carlisle Barracks, PA, 1946-1991), Wickham letter.

46 Wickham, John Adams, *John A. Wickham Jr. papers, 1946-1991*, (maintained at United States Military History Institute, Carlisle Barracks, PA, 1946-1991), Burba letter.

represent the estimated total program cost at the time of the SAR. The number over the blue bar represents the planned procurement quantity. The red line is read from the right axis and represents the program acquisition unit cost (PAUC), which is calculated by dividing the total program cost by the quantity. Both total program cost and PAUC are reported in constant dollars, so the effects of inflation have been removed.

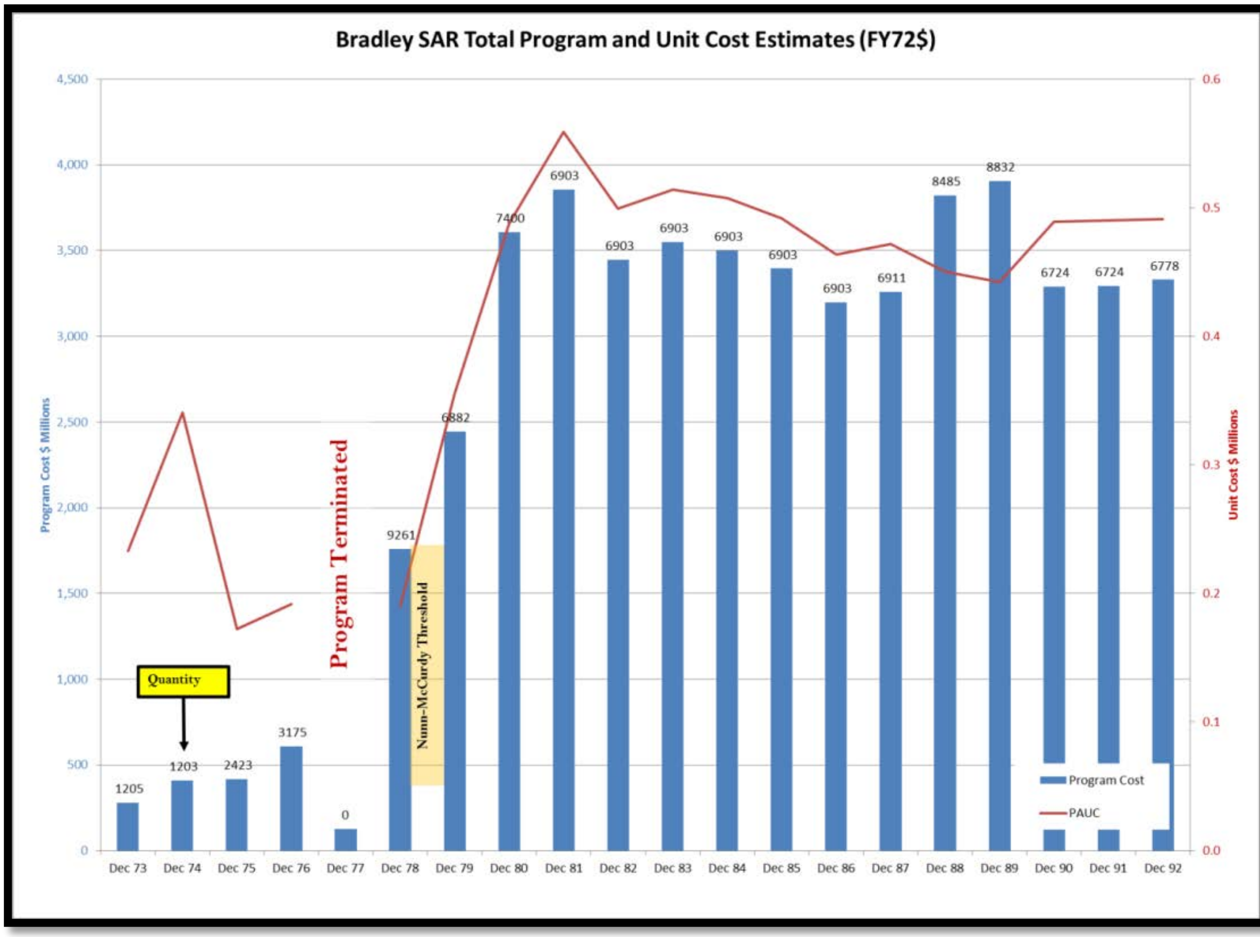

Figure 19. Bradley Selected Acquisition Report Total Program and Unit Cost Estimates

Figure 19 depicts significant fluctuations in quantity desired, starting with an objective of 1,205 vehicles in 1973, which went down slightly the next year to 1,203 before more than doubling in 1975 to 2,423. This increased again the following year to 3,175. In 1977 this was reduced to zero. The Bradley is the only program among the “Big Five” that was officially terminated during development. Resurrected in 1978, the projected quantity was 9,261 vehicles. In 1979 this was reduced to 6,882. In 1980 it rose to 7,400 before settling at around 6,900 vehicles from 1981 through 1987. In 1988 and 1989, quantity jumped to 8,485 and then 8,832 vehicles before falling in 1990 to 6,724. The SAR reports on the Bradley program ended in 1992, with an objective of 6,778 vehicles, as the procurement reached more than 90 percent of its objective.

Program costs (blue bars) started at $281 million in 1973 and rose to $410 million the following year, but the consistency of these costs with the remainder of the data is questionable so it is better to start with the 1975 estimate of $418 million for the total acquisition program. These estimates do not include the operations and maintenance costs to operate, maintain, and sustain the system over its lifetime. By 1976 the cost had risen to $609 million before the program's cancellation the following year. With the program in a terminated status, the $125 million total program cost reflected in 1977 reflects the sunk costs to date and includes no future costs. In 1978 the revived program projected a $1.8 billion program cost that rose the following year to $2.4 billion before skyrocketing to $3.6 billion in 1980. Costs peaked in 1981 at $3.9 billion. In 1982 they dropped to slightly less than $3.4 billion and in the $3.2 to $3.6 billion range through 1987. The following year saw a sharp increase to $3.8 billion, followed in 1989 with an increase to $3.9 billion. In 1990 program costs were reduced to $3.3 billion for the remainder of the program. To add some perspective, the total program cost of $3.3 billion dollars in 1972 constant dollars equates to $18.6 billion dollars in 2012.

Program acquisition unit cost (PAUC), depicted by the red line, is simply the combination of program cost and quantity and represents the average cost of one vehicle, including the research and development costs. Starting in 1975, for the reasons mentioned above, the PAUC was $170 thousand. In 1976 this increased to $190 thousand, which is where it was when the program restarted in 1978. In 1979, however, the PAUC almost doubled to $360 thousand and continued rising to $560 thousand in 1981. From 1981 through 1989 the cost trended downward until it was reduced to $440 thousand per vehicle. In 1990 this rose to $490 thousand, where it remained for the rest of the program. The $490 thousand per vehicle is expressed in 1972 dollars, which equates to $1.7 million in 1991 dollars, or $2.8 million in 2012 dollars.[47]

While the cost growth of the Bradley program was a concern at various times, there were no standardized thresholds for determining programs that were in trouble. This changed in 1982 with the passage of the Nunn-McCurdy Act. Under the Nunn-McCurdy criteria, the Bradley program would have experienced a critical breach in 1979. While the cost increases were reported to Congress as part of the SAR, they did not mandate a full program review to support recertification, as would be required to continue the program today. Coming immediately on the heels of the termination and restart, one is left wondering whether the Bradley could have survived. Given that it made it past COL Burton and related Congressional hearings, it seems likely it would have survived. A compelling case had been made and even detractors saw no alternative, as expressed by GEN Starry:

[47] Author's calculations using tables from DoD's FY12 Green Book.

> … I was a critic of the Bradley from the beginning because it couldn't fight with the tanks out there. It didn't meet the requirements for an infantry fighting vehicle. I was responsible for getting the Bradley adopted as a scout vehicle. It was an unsatisfactory decision at the time and I knew it, but the alternative was to put the scouts back in jeeps. So going ahead with the Bradley was less unsatisfactory, if that's a good phrase—I don't like it—than the alternative, which was to put the scouts back in jeeps, just as the decision to put the mech infantry in the Bradley itself was a less unpleasant alternative to putting them back in 113s.[48]

Thus, it is reasonable to suggest that the Bradley still would have been fielded even if it had needed recertification by the Secretary of Defense.

The Bradley Fighting Vehicle is used by the U.S. Army and has been sold to Saudi Arabia.[49]

The Army's current description of the Bradley Fighting Vehicle is found in Figure 20.

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48 Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 1120.

49 *Jane's Armour and Artillery 2011-12*, (New York: Jane's Pub Inc., 2012).

50 http://www.army.mil/factfiles/equipment/tracked/bradley.html.

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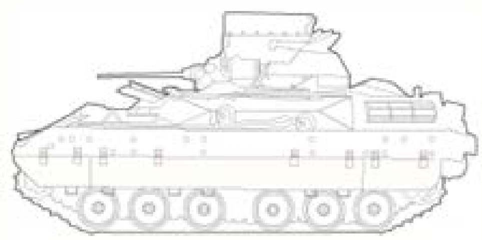
WEAPON SYSTEMS | ALPHABETICAL LIST

TRACKED VEHICLES | ABRAMS | BRADLEY | M88A2 | M113

BRADLEY

MISSION

Provides protected transport of an infantry squad on the battlefield and overwatching fires to support the dismounted infantry; is employed to suppress and defeat enemy tanks, reconnaissance vehicles, infantry fighting vehicles, armored personnel carriers, bunkers, dismounted infantry and attack helicopters; and performs cavalry scout and other essential (Bradley-equipped fire support and Stinger teams) missions in the 21st century. The infantry version (M2) is used most often to close with the enemy by means of fire and maneuver. The primary tasks performed by the cavalry version (M3) as part of a troop and/or squadron are reconnaissance, security and flank guard missions.



ADDITIONAL MEDIA

ENTERED ARMY SERVICE

1981

DESCRIPTION AND SPECIFICATIONS

The Bradley M2A3 Infantry / M3A3 Cavalry Fighting Vehicle is configured as follows:

LENGTH: 21 ft 2 in
WIDTH: 11.83 ft with armor tiles; 10.75 ft without armor tiles
HEIGHT: 11.8 ft
WEIGHT: 50,000 lbs unloaded; 67,000 lbs combat loaded
POWER TRAIN: 600 hp Cummins VTA-903T diesel engine with GM-Allison HMPT-500-3SEC hydro-mechanical automatic transmission
CRUISING RANGE: 250 miles
CREW: M2A3: 9 (3 crew; 6 dismounts); M3A3: 5 (3 crew; 2 dismounts)
ARMAMENT: 25-mm M242 Bushmaster cannon, TOW II missile system, 7.62 mm M240C machine gun

Vehicle features: Two second generation forward looking infrared (FLIR) sensors in the Improved Bradley Acquisition System (IBAS) and Commander's Independent Sight (CIV) provide "Hunter-Killer target handoff" capability with a ballistic fire control system; embedded diagnostics; integrated combat command and control (IC3) digital communications suite hosting Force XXI Battle Command Brigade-and-Below package with digital maps, messages and friend/foe situational awareness; position navigation system with GPS and inertial navigation system; and enhanced squad situational awareness with squad leader display integrated into vehicle digital images and Ic#.

MANUFACTURER

United Defense, L.P. (San Jose, CA; Fayette, PA; York, PA; Arlington, VA)

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Figure 20. Description of the Bradley Fighting Vehicle[51]

Figure 21. AH-64 Apache Attack Helicopter[52]

Apache Helicopter

Understanding the Apache Attack Helicopter development, production and fielding is a critical part of this research. We will briefly look at the overall characteristics of the acquisition and examine the relevant points more closely. There is literature on the Apache program for those who desire additional details: *Case Study of the Development of the Apache Attack Helicopter (AH-64)*, a thesis by Edward W. Ference; *An Abridged History of the Army Attack Helicopter Program*, by the Office of the Assistant Vice Chief of Staff of the Army; *The Evolution of the Advanced Attack Helicopter*, by Dante A. Camia; and *Materiel Acquisition Management of U.S. Army Attack Helicopters*, a thesis by Patrick J. Becker.

[51] Photo from US Army.

Figure 22. Sikorsky S-66 AAFSS Design[52]

To understand the story of the Apache we must go back to the U.S. Army's Advanced Aerial Fire Support System (AAFSS) program. Officially begun in March 1963,[53] this was the first helicopter designed from inception as an armed aircraft. This was the result of a decision by Secretary of the Army Cyrus R. Vance to reject the recommendation of senior general officers to pursue a derivative aircraft as an interim solution. Secretary Vance "directed the Army 'to lift its sights' to a more advanced system."[54]

Problems started immediately with the AAFSS program. The program management office took eight months to receive adequate personnel. The request for proposals (RFP) for project definition contracts was released in August 1964. In February 1965, Lockheed and Sikorsky were selected and provided a revised RFP incorporating Qualitative Materiel Development Objective (QMDO) and Qualitative Materiel Requirement (QMR) updates. In November 1965 Lockheed was announced as the winner despite the lack of an approved QMR. This caused delays in final contract negotiation as the QMR worked its way to approval. The Chief of Staff of the Army returned the QMR, directing that it incorporate a clearly defined need for the aircraft to ensure it would receive funding. This generated cost effective-

52 Photo courtesy of Igor I. Sikorsky Historical Archives, Inc.

53 Camia, Dante A., *The Evolution of the Advanced Attack Helicopter*, (Fort Leavenworth, KS: US Army Command and General Staff College, 1975), 258.

54 Office of the Assistant Vice Chief of Staff of the Army, *An Abridged History of the Army Attack Helicopter Program*, (Washington, DC, circa 1975), 1.

55 Photo from US Army.

ness analyses by Army Materiel Command and the Ballistic Research Laboratory (BRL) which resulted in BRL initially finding the AAFSS program the least cost-effective until the program office could engage BRL. When the QMR was approved in December 1965, there were fourteen additional requirements that had not been included in the Lockheed bid.[56]

Figure 23. AH-1 Cobra Helicopter[56]

Meanwhile, the Army recognized the need for an interim solution for immediate use in Vietnam. Bell began internal development for this need in March 1965, producing the first prototype in September, which it delivered for evaluation to the Army in December of the same year.[57] In April 1966, Bell's Huey Cobra was selected as the interim armed helicopter and by August 1967 was deployed for use in Vietnam. "While the Cobra served well in SEA [South East Asia] and confirmed the value of attack helicopters, performance limitations highlighted the need for an improved aircraft and emphasized the existing concern of vulnerability in a mid-intensity environment."[58] The Army ordered hundreds of Cobra helicopters for employment in Vietnam. "Although the Army obtained a gunship of great utility, the AH-1 [Cobra] still did not fulfill the requirements specified in the AAFSS program … it could not keep

[56] Office of the Assistant Vice Chief of Staff of the Army, *An Abridged History of the Army Attack Helicopter Program*, (Washington, DC, circa 1975), 4-5.

[57] Becker, Patrick J., *Materiel Acquisition Management of US Army Attack Helicopters*, (Fort Leavenworth, KS: US Army Command and General Staff College, 1989), 54.

[58] Office of the Assistant Vice Chief of Staff of the Army, *An Abridged History of the Army Attack Helicopter Program*, (Washington, DC, circa 1975), 3.

pace with the CH-47 when fully armed, operate in the meteorlogical [sic] environment defined … nor possess the navigational or armament capability identified."[59]

Lockheed's AAFSS prototype was named the AH-56 Cheyenne, and was ready for flight tests in September 1967. In January 1968 the Secretary of Defense approved the contract for 375 aircraft even though the system had not proven itself. Concurrently, flight testing continued. As the Cheyenne flew faster than any helicopter had before, it broke new ground. This did not happen without unforeseen challenges. One of the prototypes crashed and another was destroyed in follow-on wind tunnel testing.[61] In 1969 this led the Army to terminate the production part of its contract with Lockheed. The Army and Lockheed continued to work with the prototypes and by November 1970 development was complete.

Figure 24. AH-56 Cheyenne Prototype[61]

[59] Becker, Patrick J., *Materiel Acquisition Management of US Army Attack Helicopters*, (Fort Leavenworth, KS: US Army Command and General Staff College, 1989), 54-5.

[60] Photo from US Army.

[61] Becker, Patrick J., *Materiel Acquisition Management of US Army Attack Helicopters*, (Fort Leavenworth, KS: US Army Command and General Staff College, 1989), 63.

Figure 25. Sikorsky S-67 Blackhawk Prototype[62]

At this time several external factors started to impact the program. There was concern from the Air Force that the Army was encroaching on its territory, and concern from the Congress that AAFSS and the Air Force's A-X, later designated the A-10 and named the Thunderbolt II but widely called the Warthog, close air support program, were duplicative. Industry came up with two potential competitors, the Bell King Cobra and the Sikorsky Black Hawk. Given the cost escalation of the Cheyenne, the Army decided in early 1972 that it would be best to conduct flight evaluations of the Cheyenne, King Cobra, and Black Hawk prototypes. To evaluate the three aircraft, the Army established a task force headed by MG Sidney M. Marks. Flight testing occurred at Fort Hunter Liggett, California with "intense Congressional, military and industry interest."[63] MG Marks submitted the task force's evaluation on August 7, 1972 and the Secretary of the Army terminated the AAFSS program two days later. There are suggestions that the fiscal austerity of the time influenced the decision so that the A-10 could be fully funded and its mission not duplicated;[64] however, evidence of this line of reasoning is lacking.

[62] Photo courtesy of Igor I. Sikorsky Historical Archives, Inc.

[63] Camia, Dante A., *The Evolution of the Advanced Attack Helicopter*, (Fort Leavenworth, KS: US Army Command and General Staff College, 1975), 189.

[64] Tate, Frank W., *Army Aviation as a Branch, Eighteen Years After the Decision*, (Fort Leavenworth, KS: School of Advanced Military Studies, US Army Command and General Staff College, 2001), 14.

Figure 26. Bell King Cobra Prototype[65]

Within two weeks, the Army started a new program, the Advanced Attack Helicopter (AAH). The new aircraft "was to be smaller, less complex and cost less to procure, operate and maintain … These attributes were achieved by reducing the requirements for airspeed, payload, navigation accuracies, and weapons sophistication."[66] The AAH was to be focused on the Soviet threat in Europe as a "stand-off tank killer, an aircraft that could be effective against Warsaw Pact armor while keeping its distance from a majority of ground-fire threats."[67] The Deputy Secretary of Defense approved the release of an RFP in November 1972. Bell, Boeing-Vertol, Hughes, Lockheed, and Sikorsky submitted proposals in February 1973.

[65] Photo courtesy of Textron.

[66] Office of the Assistant Vice Chief of Staff of the Army, *An Abridged History of the Army Attack Helicopter Program*, (Washington, DC, circa 1975), 10.

[67] Chait, Richard, John Lyons, and Duncan Long, *Critical Technology Events in the Development of the Apache Helicopter (Project Hindsight Revisited)*, (Washington, DC: Center for Technology and National Security Policy, National Defense University, February 2006), 5-6.

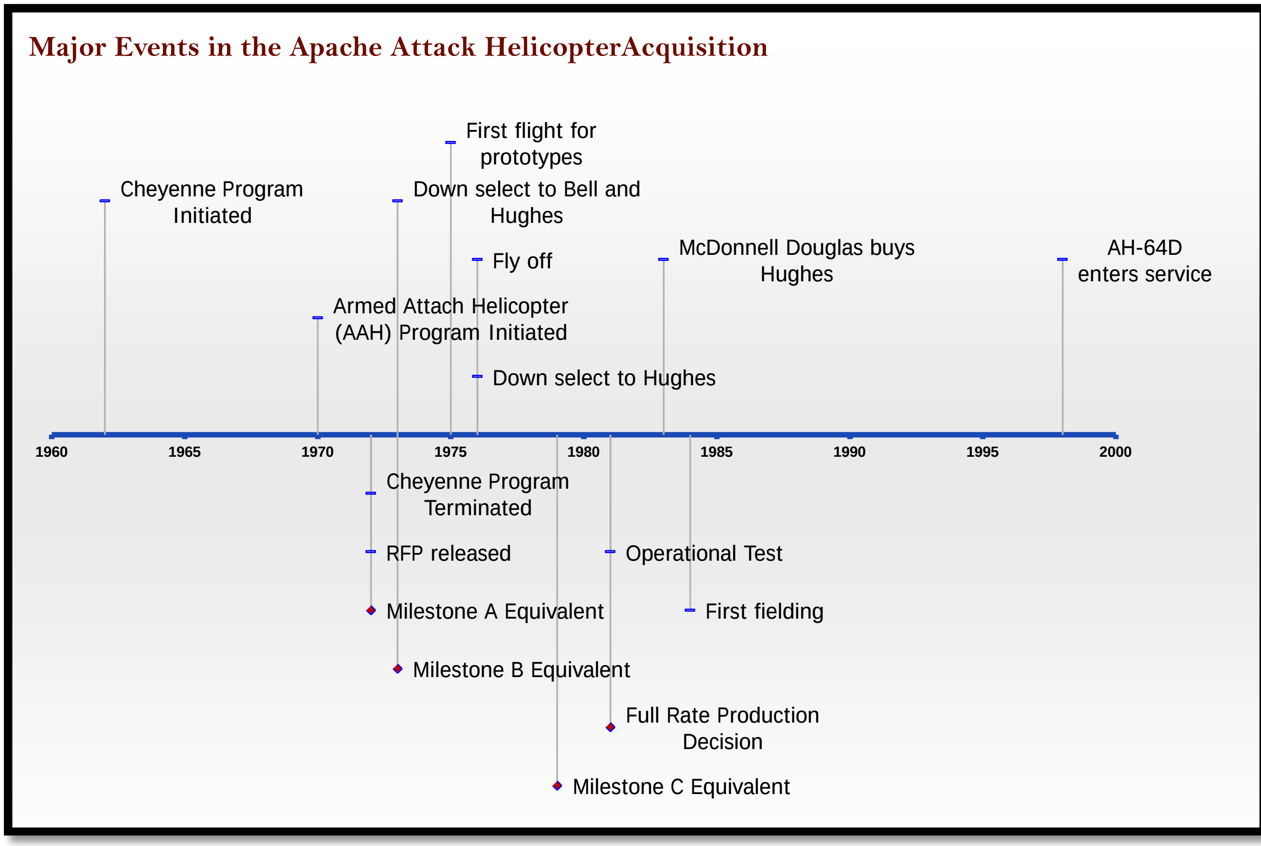

Figure 27. Apache Attack Helicopter Development and Production Timeline

In June 1973, engineering development contracts were awarded to Bell and Hughes. However, the Deputy Secretary of Defense mandated a thirty-day wait pending "1) Army/ OSD CAIG intensive review of projected unit costs, 2) OSD/CAIG clarification of Design-to-Cost consistent with other cost reporting procedures, and 3) revalidation of cost data and design trade-off determinations to identify cost reduction possibilities to assure maintenance of the Design-to-Cost goal."[68]

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[68] Office of the Assistant Vice Chief of Staff of the Army, *An Abridged History of the Army Attack Helicopter Program*, (Washington, DC, circa 1975), 11.

Figure 28. Sikorsky YAH-63 AAH Prototype[69]

Figure 29. Hughes YAH-64 AAH Prototype[70]

Ground test vehicles were operational by June 1975 and a first flight quickly followed in September. The Bell prototype was designated the YAH-63 and the Hughes prototype was called the YAH-64. A competitive fly-off was conducted from June through September 1976.

[69] Photo courtesy of Igor I. Sikorsky Historical Archives, Inc.

[70] Photo courtesy of the Department of Defense.

The source selection evaluation board recommended the Hughes aircraft. In November this recommendation was approved and a full development contract was awarded.[71]

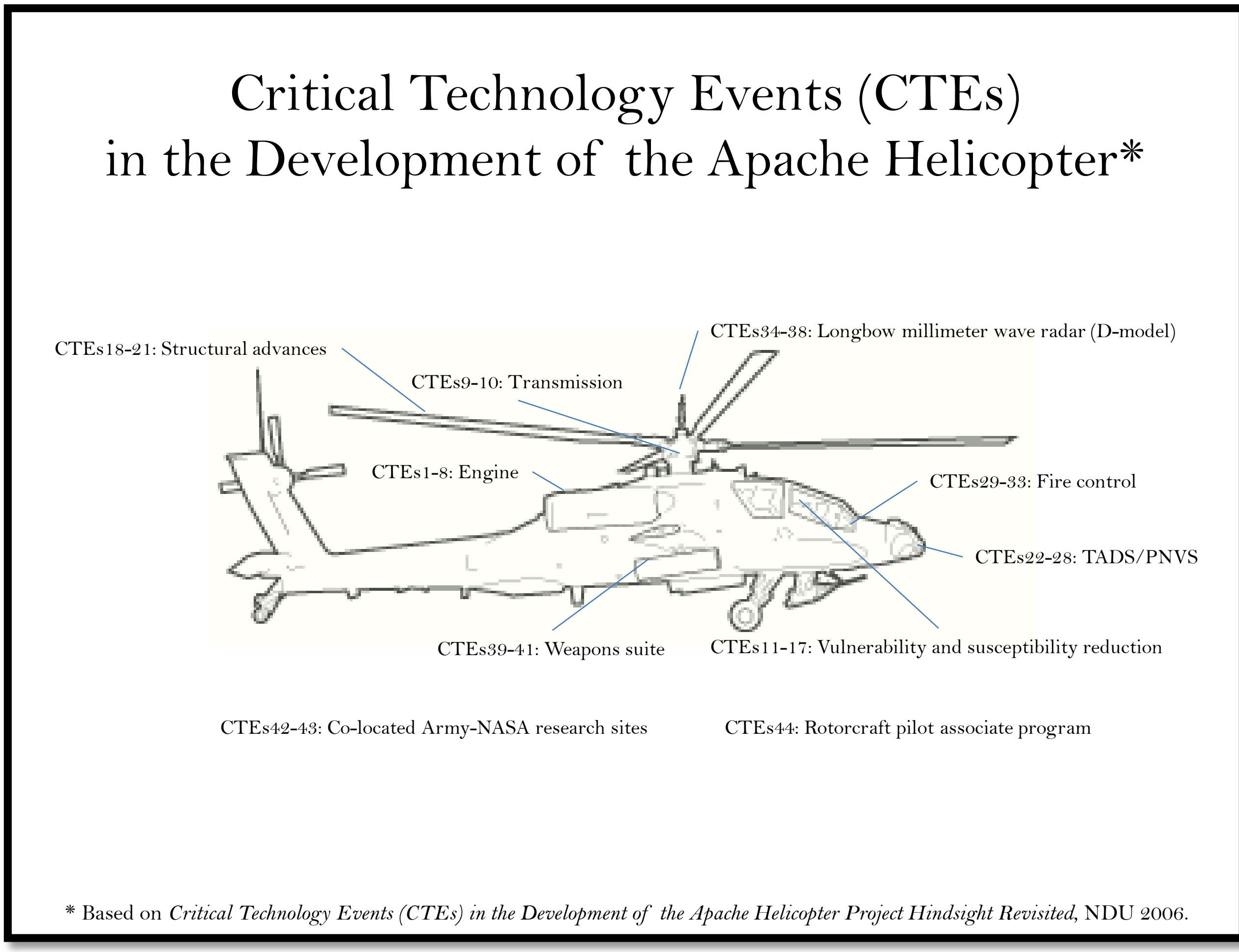

Figure 30. Critical Technology Events in the Development of the Apache Attack Helicopter

During the development of the Advanced Attack Helicopter—later redesignated the AH-64 and named the Apache—there were significant technological enhancements made. The 2006 study, *Critical Technology Events in the Development of the Apache Helicopter: Project Hindsight Revisited*, by Richard Chait, John Lyons, and Duncan Long of the National Defense University specifically focused on what technologies were incorporated into the new helicopter. The study highlights 44 critical technology events that set the Apache apart from earlier aircraft. These are depicted in figure 30.

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[71] Camia, Dante A., *The Evolution of the Advanced Attack Helicopter*, (Fort Leavenworth, KS: US Army Command and General Staff College, 1975), 190.

Technological enhancements were pervasive throughout the entire new aircraft. The engine was a significant improvement over the Cobra, and the Apache had two instead of one. The same engine was used in the UH-60 Black Hawk. Chait attributes the success of the technological enhancements to "the expertise of the Army in-house scientists and engineers" although "competence and dedication of industrial partners was also crucial."[72] In the case of the Apache, a considerable amount of innovation was made possible by parallel basic research at Army labs and in conjunction with NASA, but this required significant integration managed by the program office.

In August 1979, approval was provided for low-rate initial production with the first production aircraft delivered in August 1981. Operational testing followed and the go-ahead for full-rate production was given. In 1983 Hughes Aircraft was sold to McDonnell Douglas and initial fielding of the Apache followed in 1984. The AH-64D Apache Longbow with a glass cockpit, millimeter wave radar mounted in the mast, and improved engines was fielded in 1998.[73]

Cost is an important indicator of program management and performance. Figure 31 is an historical look at total program costs for the AAH program that produced and fielded the Apache attack helicopter. The data are taken from the Department of Defense's mandated reports to Congress on major defense acquisition programs called the Selected Acquisition Reports (SARs). While the format has changed over time, the data have been consistent across reports since the SARs were standardized in 1975. Although reports are submitted quarterly, the figure uses only the December reports to show how the program changed as it progressed. The blue bars in the chart are read from the left axis and represent the estimated total program cost at the time of the SAR. The number over the blue bar represents the planned procurement quantity. The red line is read from the right axis and represents the program acquisition unit cost (PAUC), which is calculated by dividing the total program cost by the quantity. Both total program cost and PAUC are reported in constant dollars, so the effects of inflation have been removed.

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[72] Chait, Richard, John Lyons, and Duncan Long, *Critical Technology Events in the Development of the Apache Helicopter (Project Hindsight Revisited)*, (Washington, DC: Center for Technology and National Security Policy, National Defense University, February 2006), 35.

[73] *Jane's All the World's Aircraft 2011*, (New York: Jane's Pub Inc., 2012).

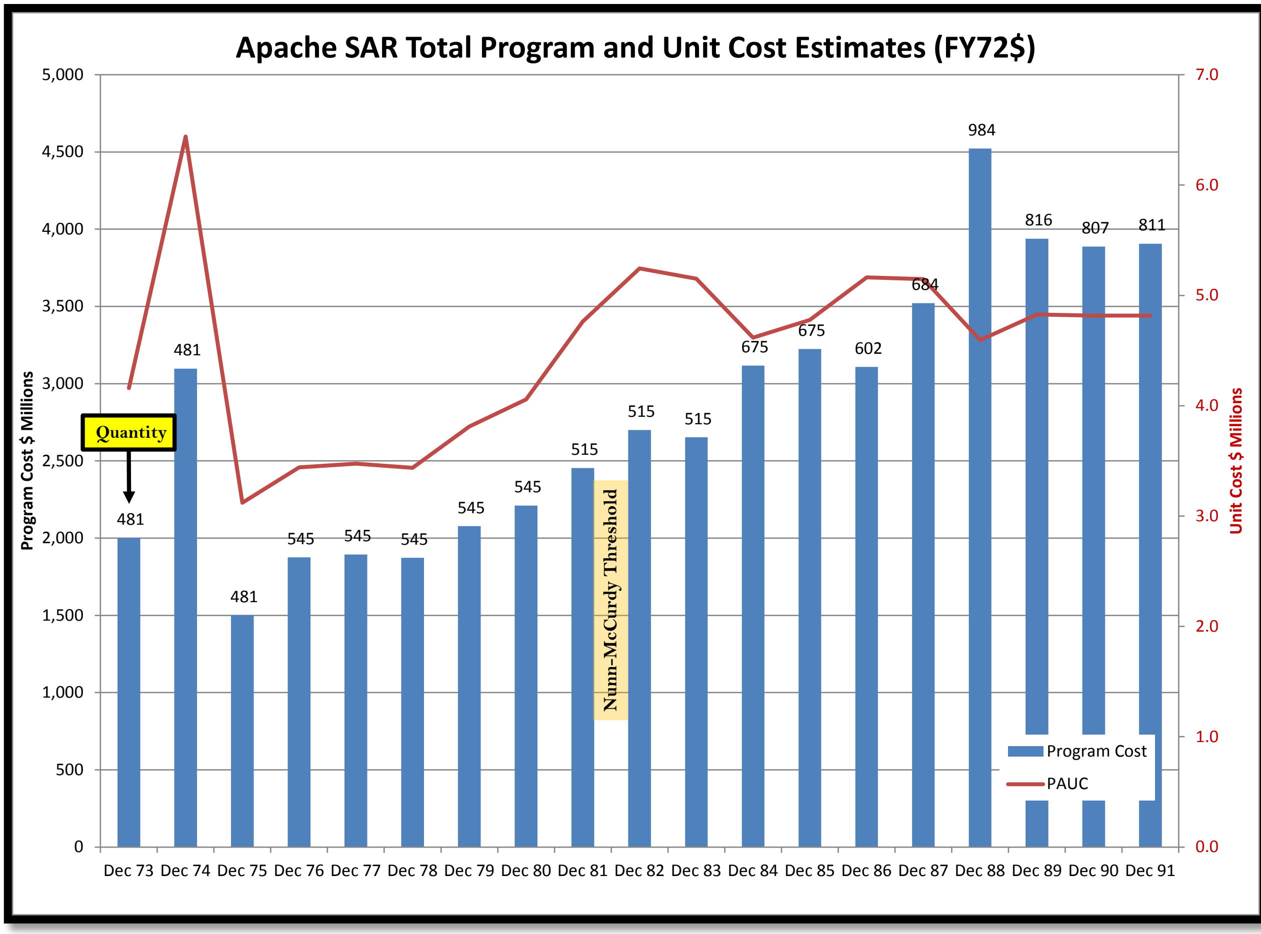

Figure 31. Apache Selected Acquisition Report Total Program and Unit Cost Estimates

Figure 31 depicts significant fluctuations in quantity desired over the duration of the Apache program, starting with an objective of 481 aircraft in 1973. In 1976 this was increased to 545 aircraft before being reduced to 515 in 1981. 1984 saw an increase in quantity to 675, which went down in 1986 to 602 aircraft. In 1987 the quantity was increased to 684 and then again the following year to 984. This decreased the following year to 816 aircraft. In 1990 this was reduced to 807. The SAR reports on the Apache program ended in 1991, with an objective of 811 aircraft, as the procurement reached more than 90 percent of its objective.

Program costs (blue bars) started at $2.0 billion in 1973 and rose to $3.1 billion the following year, but the consistency of these costs with the remainder of the data is questionable so it is better to start with the 1975 estimate of $1.5 billion for the total acquisition program. These estimates do not include the operations and maintenance costs to operate, maintain, and sustain the system over its lifetime. In 1976 the cost rose to $1.9 billion, where it stayed for three years. In 1979 the estimated cost rose to $2.1 billion and continued to rise until reaching $2.7 billion in 1982. This was reduced slightly in 1983 before rising to $3.1 billion in 1984 and again in 1985 to $3.2 billion. Costs fell in 1986 back to $3.1 billion but rose the following year to $3.6 billion. In 1988 the estimated total program cost reached its apex, exceeding $4.5 billion. In 1989 program costs were reduced to $3.9 billion for the remainder of the program. To add some perspective, the total program cost of $3.9 billion dollars in 1972 constant dollars equates to $22.0 billion dollars in 2012.

Program acquisition unit cost (PAUC), depicted by the red line, is simply the combination of program cost and quantity and represents the average cost of one helicopter including the research and development costs. Starting in 1975, for the reasons mentioned above, the PAUC was $3.1 million. In 1976 this increased to $3.4 million is where it stayed for three years. In 1979, however, the PAUC began a steady increase through 1982 when it reached its zenith at $5.2 million per aircraft. Over the next several years, the PAUC had its ups and downs but remained in the $4.6 to $5.2 million range with a final dip in 1988 to $4.6 million. In 1989 this rose to $4.8 million per aircraft, where it remained for the rest of the program. The $4.8 million per aircraft is expressed in 1972 dollars, which equates to $16.0 million in 1991 dollars or $27.0 million in 2012 dollars.[74]

While the cost growth of the Apache program was a concern at various times, there were no standardized thresholds for determining programs that were in trouble. This changed in 1982 with the passage of the Nunn-McCurdy Act. Under the Nunn-McCurdy criteria, the Apache program would have experienced a critical breach in 1982. While the cost increases were reported to Congress as part of the SAR, they did not mandate a full program review to support recertification as would be required to continue the program today. By the time the December 1982 SAR was provided to Congress, the Apache had already been approved for full production. The delays inherent in a program going through a Nunn-McCurdy recertification could have impacted the ability to send Apache units in the numbers provided for DESERT SHIELD and DESERT STORM. Given the recognized need for an anti-armor aircraft, the Army undoubtedly would have pressed hard to see the Apache program through to its full conclusion but the impact on timing, quantity, and cost are unknowable.

The Apache attack helicopter has been sold to Egypt, Greece, Israel, Japan, Kuwait, Saudi Arabia, Singapore, and the United Kingdom.[75]

The Army's current description of the Apache attack helicopter is found in Figure 32.

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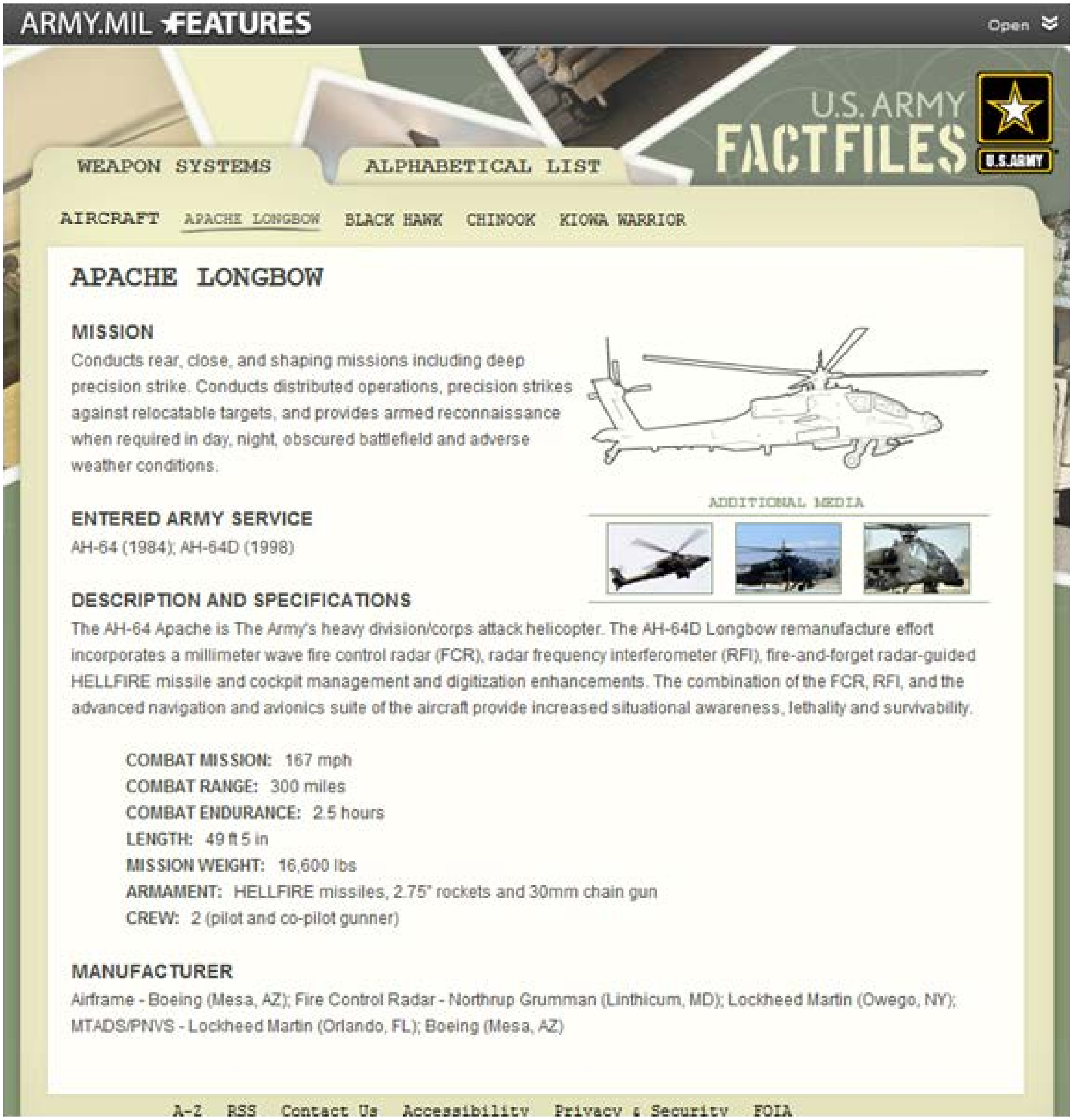
[74] Author's calculations using tables from DoD's FY12 Green Book.

[75] *Jane's All the World's Aircraft 2011*, (New York: Jane's Pub Inc., 2012).

[76] Image from http://www.army.mil/factfiles/equipment/aircraft/apache.html.



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WEAPON SYSTEMS | ALPHABETICAL LIST

AIRCRAFT | APACHE LONGBOW | BLACK HAWK | CHINOOK | KIOWA WARRIOR

APACHE LONGBOW

MISSION

Conducts rear, close, and shaping missions including deep precision strike. Conducts distributed operations, precision strikes against relocatable targets, and provides armed reconnaissance when required in day, night, obscured battlefield and adverse weather conditions.

ADDITIONAL MEDIA

ENTERED ARMY SERVICE

AH-64 (1984); AH-64D (1998)

DESCRIPTION AND SPECIFICATIONS

The AH-64 Apache is The Army's heavy division/corps attack helicopter. The AH-64D Longbow remanufacture effort incorporates a millimeter wave fire control radar (FCR), radar frequency interferometer (RFI), fire-and-forget radar-guided HELLFIRE missile and cockpit management and digitization enhancements. The combination of the FCR, RFI, and the advanced navigation and avionics suite of the aircraft provide increased situational awareness, lethality and survivability.

COMBAT MISSION: 167 mph
COMBAT RANGE: 300 miles
COMBAT ENDURANCE: 2.5 hours
LENGTH: 49 ft 5 in
MISSION WEIGHT: 16,600 lbs
ARMAMENT: HELLFIRE missiles, 2.75" rockets and 30mm chain gun
CREW: 2 (pilot and co-pilot gunner)

MANUFACTURER

Airframe - Boeing (Mesa, AZ); Fire Control Radar - Northrup Grumman (Linthicum, MD); Lockheed Martin (Owego, NY); MTADS/PNVS - Lockheed Martin (Orlando, FL); Boeing (Mesa, AZ)

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Figure 32. Description of the Apache Attack Helicopter[77]

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Figure 33. UH-60 Black Hawk Helicopter[78]

Black Hawk Helicopter

Understanding the Black Hawk Utility Helicopter development, production and fielding is a critical part of this research. We will briefly look at the overall characteristics of the acquisition and explore relevant points in depth. There is some literature on the Black Hawk program for those who desire additional details: *Black Hawk, The Story of a World Class Helicopter*, by Ray D. Leoni; *The Decision to Develop The UTTAS*, a thesis by Clarence A. Patnode, Jr.; *Government Competitive Test Utility Tactical Transport Aircraft System (UTTAS). Sikorsky YUH-60A Helicopter*, by John I. Nagata et al; and *Should the United States Army Procure the Total Quantity of Black Hawk Helicopters it Requires?*, a thesis by Robert W. Kenneally.

[77] Photo from US Army.

Figure 34. UH-1 Huey Helicopter[79]

The story of the Black Hawk helicopter must begin with the UH-1 Huey helicopter. In 1952 the Army identified the requirement for a medical evacuation and utility helicopter that would become the "Huey", officially known as the Iroquois. By 1955 the Army had selected Bell to build prototypes for testing. The prototypes began flying in 1956 and in 1960 the Army ordered 100 aircraft. Fielding began in 1961 and in 1962 the Huey deployed to Vietnam as part of a medical evacuation unit. The Hueys in Vietnam were soon modified to mount weapons and were also used in a troop assault, or air-mobility, role.[79]

Since the Huey was not designed for the air-mobility mission, it had "serious operational shortcomings."[80] In 1965, the Army began the work to identify the requirements for a system to replace the Huey helicopter and developed a Qualitative Materiel Development Objective (QMDO) for the Utility Tactical Transport Aircraft System (UTTAS), which was approved in October 1965. In January 1966 the Army extended production of the Huey to meet requirements in Vietnam, so U.S. Army Combat Developments Command (USACDC) reviewed the QMDO for the UTTAS. In October 1966 USACDC recommended slipping the initial operating capability to the mid-1970s and conducting a new study to review the requirements for UTTAS.[81]

As the study began, it focused on determining operational capabilities needed in the future threat environment of 1975-1985. The team quickly determined that they could not focus on the UTTAS in isolation but needed to look at the lift needs of the Army and the corresponding fleet of helicopters. This entailed more work than originally anticipated.

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78 Photo from US Army.

79 *Jane's All the World's Aircraft 1964-65*, (New York: Jane's Pub Inc., 1965), 182-3.

80 Patnode, Clarence A., Jr., *The Decision to Develop The UTTAS*, (Carlisle Barracks, PA: Army War College, 1972), 8.

81 Patnode, Clarence A., Jr., *The Decision to Develop The UTTAS*, (Carlisle Barracks, PA: Army War College, 1972), 10.

At this time critics of the program made the assertion that to meet the requirements of UTTAS, the Army had focused solely on a new development to the peril of potential improvements to the Huey. The Army stood up the Buelow Committee under Colonel Wallace R. Buelow to evaluate the cost effectiveness of the UTTAS and potential improvements to the Huey. Concurrently, budgets were tightening and the Army decided to prioritize the developmental effort for a new heavy lift helicopter (HLH). On May 19, 1970, this changed with the Army's acknowledgement that the HLH needed to be preceded by other developmental work. Soon after, the Vice Chief of Staff of the Army, GEN Bruce Palmer, directed that the UTTAS program be renamed The Improved Lift Ship (TILS) to ensure that analysis would be impartial between an upgraded Huey and the UTTAS. After senior level briefings, GEN Palmer approved the UTTAS QMR on February 10, 1971. En route to securing OSD approval, the Army took the unusual step of briefing the Defense Science Board in April 1971. OSD approval followed in June.[82]

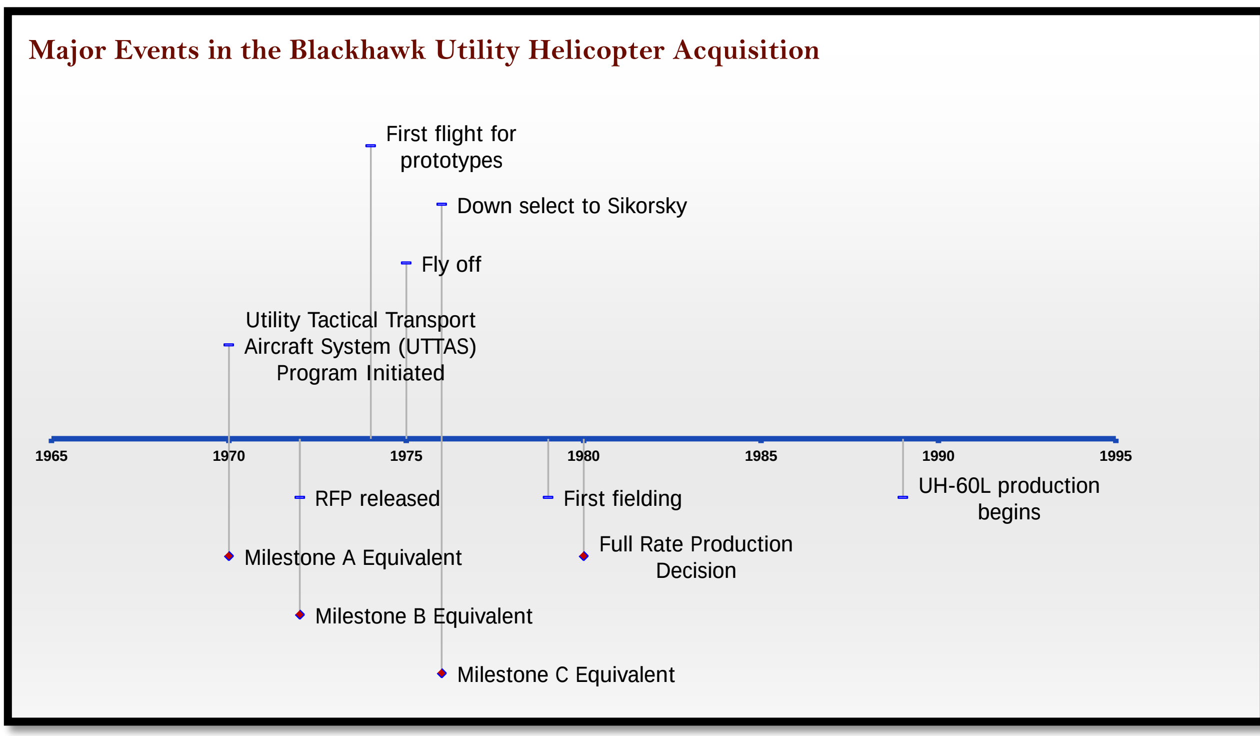

Figure 35. Black Hawk Utility Helicopter Development and Production Timeline.

In January 1972, the Army issued its requests for proposals (RFP). Boeing-Vertol and Sikorsky were awarded contracts for development and production of prototypes. The prototypes began flying in October 1974 and were delivered to the Army in March 1976 for a fly-

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[82] Patnode, Clarence A., Jr., *The Decision to Develop The UTTAS*, (Carlisle Barracks, PA: Army War College, 1972), 21–36.

off competition. In December 1976, the Sikorsky aircraft was selected. A contract was let for limited rate production, resulting in initial fielding in 1979 and the approval for full production in 1980.[83]

Cost is an important indicator of program management and performance. Figure 36 is an historical look at total program costs for the UTTAS program that produced and fielded the Black Hawk utility helicopter. The data are taken from the Department of Defense's mandated reports to Congress on major defense acquisition programs called the Selected Acquisition Reports (SARs). While the format has changed over time, the data have been consistent across reports since the SARs were standardized in 1975. Although reports are submitted quarterly, the figure uses only the December reports to show how the program changed as it progressed. The blue bars in the chart are read from the left axis and represent the estimated total program cost at the time of the SAR. The number over the blue bar represents the planned procurement quantity. The red line is read from the right axis and represents the program acquisition unit cost (PAUC), which is calculated by dividing the total program cost by the quantity. Both total program cost and PAUC are reported in constant dollars, so the effects of inflation have been removed.

Figure 36 depicts a generally stable program in terms of quantity desired, starting with an objective of 1,123 aircraft in 1971, which was reduced to 1,117 in 1973. That objective stayed constant from 1973 through 1985. In 1986 it rose to 1,121, rising again in 1988 to 1,337 before almost doubling in 1989 to 2,267. In 1990 this was reduced to 1,447 but in 1992 the quantity was up to 2,248 aircraft. The SAR reports on the Black Hawk program ended in 1993, with an objective of 2,127 aircraft, as the procurement reached more than 90 percent of its objective.

83 Leoni, Ray D., Black Hawk, *The Story of a World Class Helicopter*, (Reston, VA: American Institute of Aeronautics and Astronautics, 2007), 8-48.

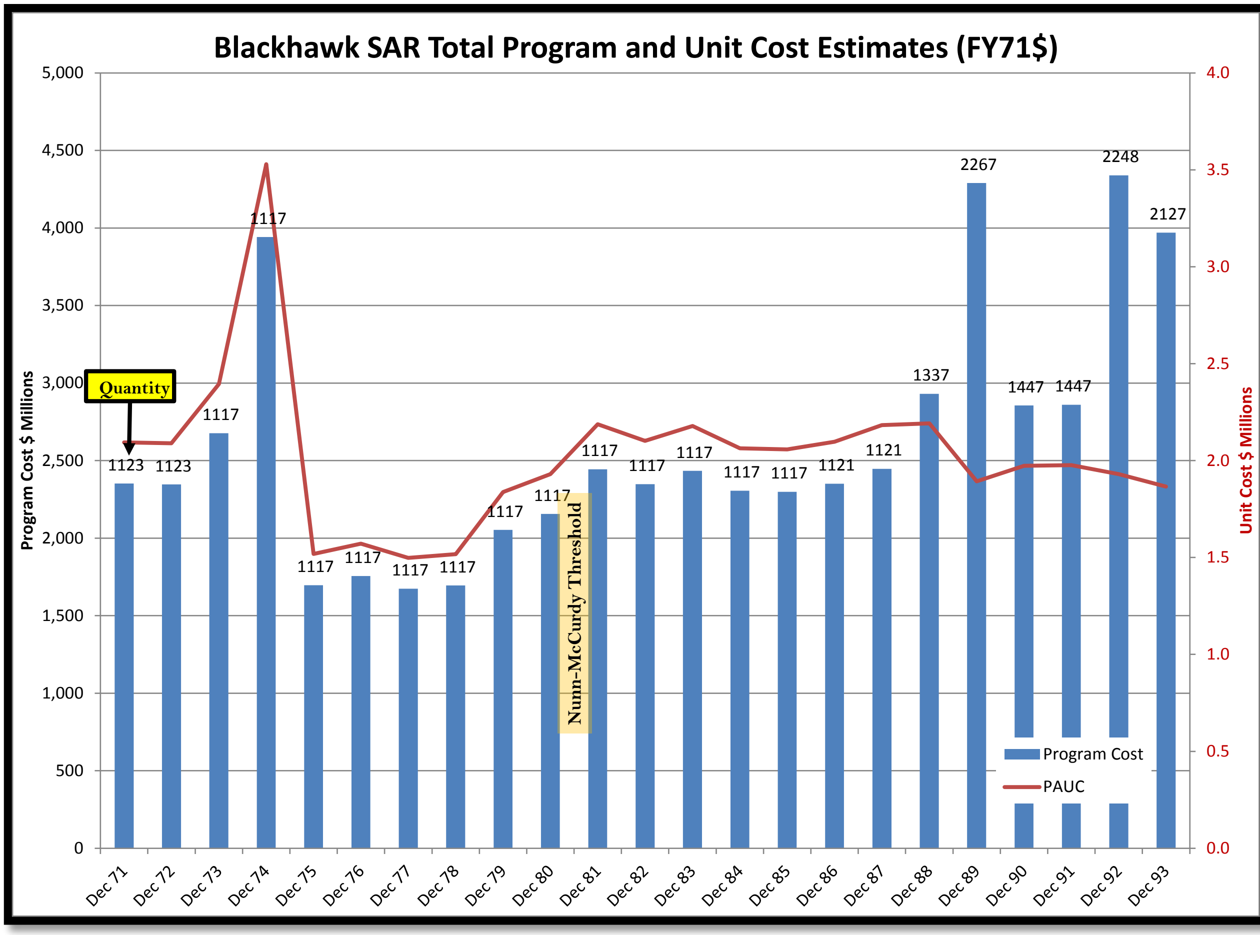


Figure 36. Black Hawk Selected Acquisition Report Total Program and Unit Cost Estimates

Program costs (blue bars) started at $2.4 billion in 1971 and did not change the following year. In 1973 they rose to $2.7 billion and then again in 1974 to $3.9 billion, but the consistency of these costs with the remainder of the data is questionable so it is better to start with the 1975 estimate of $1.7 billion for the total acquisition program. These estimates do not include the operations and maintenance costs to operate, maintain, and sustain the system over its lifetime. The estimated costs were relatively stable through 1978. In 1979, the cost rose to $2.1 billion, followed by an increase to $2.2 billion in 1980 and $2.4 billion in 1981. The program stayed between $2.3 and $2.5 billion until 1988 when the cost rose to $2.9 billion. The following year it was $4.3 billion before falling to $2.9 billion in 1990 and 1991. In 1992 program costs jumped with the increase in quantity back to $4.3 billion. The program ended with a cost estimate of $4.0 billion.

Program acquisition unit cost (PAUC), depicted by the red line, is simply the combination of program cost and quantity and represents the average cost of one aircraft including the research and development costs. Starting in 1975 for the reasons mentioned above, the PAUC was $1.5 million and stayed there until rising to $1.8 million in 1979 and continuing to rise to

$2.2 million in 1981. From 1981 through 1988 the average cost remained in the $2.0 to $2.2 million range. In 1989 this fell to $1.9 million per aircraft, rising to $2.0 million in 1990 before falling to $1.9 million at the end of the program in 1993. The $1.9 million per aircraft is expressed in 1971 dollars, which equates to $11.7 million in 2012 dollars.[84]

While the cost growth of the Black Hawk program was a concern at various times, there were no standardized thresholds for determining programs that were in trouble. This changed in 1982 with the passage of the Nunn-McCurdy Act. Under the Nunn-McCurdy criteria, the Black Hawk program would have experienced a critical breach in 1981. While the cost increases were reported to Congress as part of the SAR, they did not mandate a full program review to support recertification, as would be required to continue the program today. By the time the December 1981 SAR was provided to Congress, the Black Hawk had already completed its initial fielding and was in full production. Given the recognized need to replace the UH-1 Huey, it is unclear what impact a critical breach would have had at this juncture. It undoubtedly would have impacted the schedule and thereby cost, but the Black Hawk was in high demand with variants already being designed for the Navy, Air Force, and special operations. Therefore, it is difficult to see how a Nunn-McCurdy breech would have led to anything other than recertification for the Black Hawk program.

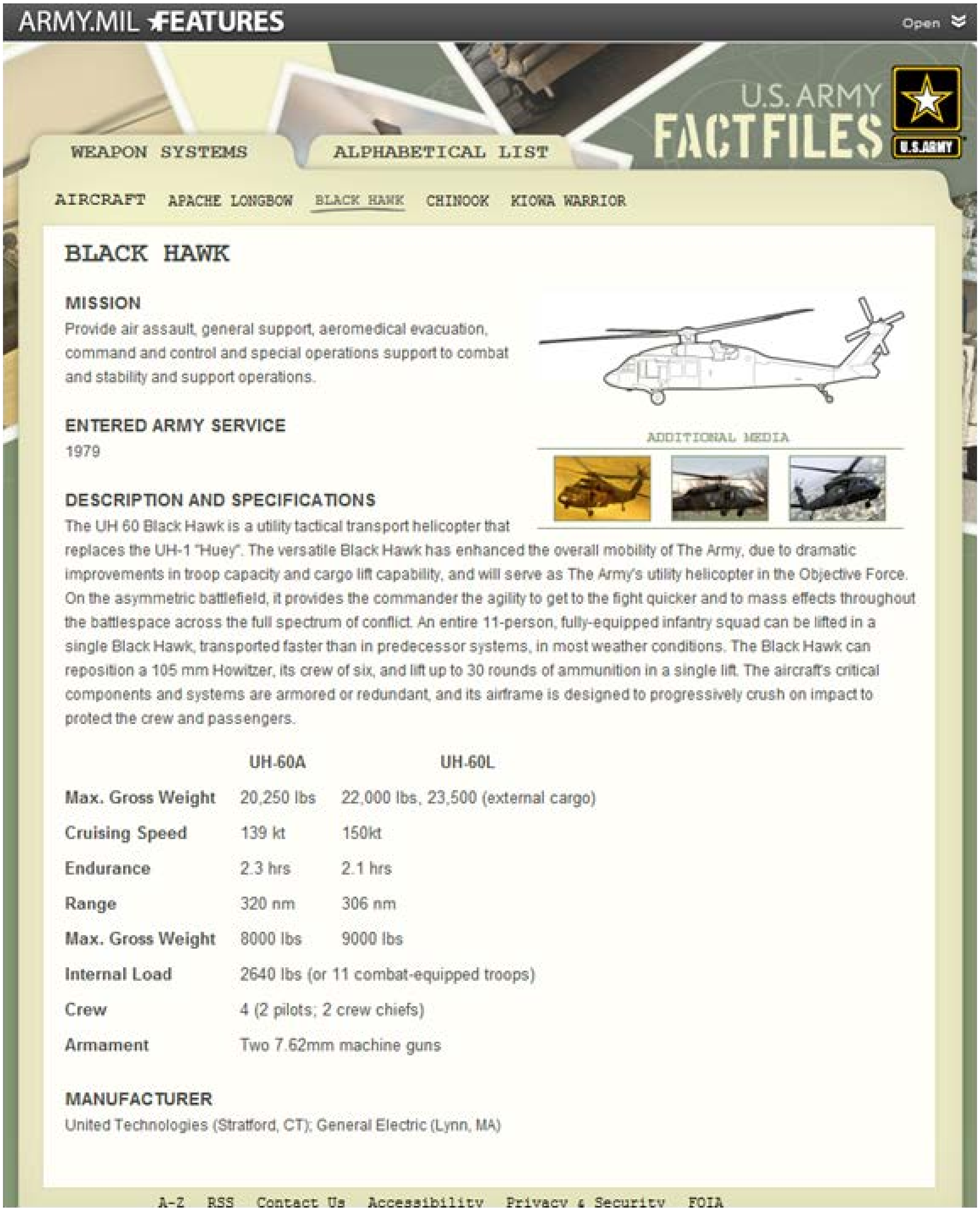
The Black Hawk helicopter is the most widely used of the “Big Five” across the world. The Black Hawk or one of its variants is used in Australia, Austria, Brazil, Brunei, Chile, China (People’s Republic of China), Columbia, Egypt, Israel, Japan, Jordan, Mexico, Morocco, Norway, Philippines, Saudi Arabia, South Korea, Taiwan, Thailand, Turkey and the United Arab Emirates, in addition to being flown by the U.S. Army, Navy, Marines, Coast Guard, Air Force and NASA.[85]

The Army’s current description of the Black Hawk utility helicopter is in Figure 37.

[84] Author’s calculations using tables from DoD’s FY12 Green Book.

[85] *Jane’s All the World’s Aircraft 2011*, (New York: Jane’s Pub Inc., 2012).

[86] Image from http://www.army.mil/factfiles/equipment/aircraft/Black Hawk.html.



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WEAPON SYSTEMS ALPHABETICAL LIST

AIRCRAFT APACHE LONGBOW BLACK HAWK CHINOOK KIOWA WARRIOR

BLACK HAWK

MISSION

Provide air assault, general support, aeromedical evacuation, command and control and special operations support to combat and stability and support operations.

ENTERED ARMY SERVICE

1979

ADDITIONAL MEDIA

DESCRIPTION AND SPECIFICATIONS

The UH 60 Black Hawk is a utility tactical transport helicopter that replaces the UH-1 "Huey". The versatile Black Hawk has enhanced the overall mobility of The Army, due to dramatic improvements in troop capacity and cargo lift capability, and will serve as The Army's utility helicopter in the Objective Force. On the asymmetric battlefield, it provides the commander the agility to get to the fight quicker and to mass effects throughout the battlespace across the full spectrum of conflict. An entire 11-person, fully-equipped infantry squad can be lifted in a single Black Hawk, transported faster than in predecessor systems, in most weather conditions. The Black Hawk can reposition a 105 mm Howitzer, its crew of six, and lift up to 30 rounds of ammunition in a single lift. The aircraft's critical components and systems are armored or redundant, and its airframe is designed to progressively crush on impact to protect the crew and passengers.

	UH-60A	UH-60L
Max. Gross Weight	20,250 lbs	22,000 lbs, 23,500 (external cargo)
Cruising Speed	139 kt	150kt
Endurance	2.3 hrs	2.1 hrs
Range	320 nm	306 nm
Max. Gross Weight	8000 lbs	9000 lbs
Internal Load	2640 lbs (or 11 combat-equipped troops)	
Crew	4 (2 pilots; 2 crew chiefs)	
Armament	Two 7.62mm machine guns	

MANUFACTURER

United Technologies (Stratford, CT); General Electric (Lynn, MA)

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Figure 37. Description of the Black Hawk Utility Helicopter[87]

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Figure 38. MIM-23 Hawk Anti-Aircraft System[90]

Patriot Air Defense System

Understanding the Patriot air defense system development, production and fielding is a critical part of this research. We will briefly look at the overall characteristics of the acquisition and deep dive on relevant points. There is some literature on the Patriot program for those who desire additional details: *The Patriot Air Defense System and the Search for an Antitactical Ballistic Missile System*, by Steven A. Hildreth and Paul C. Zinsmeister; *The Patriot Project: How the Army Managed the Acquisition and Development of the Patriot Missile System*, a thesis by Jeffrey M. Stevens; *PATRIOT Fielding: Successful as a Function of Integrated Logistic Support (ILS)*, by Gregory A. Rountree; and *The Patriot Missile System: a Review and Analysis of its Acquisition Process*, a thesis by Richard S. Barbera.

[87] Photo from US Army.

Figure 39. MIM-14 Nike Hercules[89]

Secretary of Defense Robert S. McNamara initiated the Surface-to-Air Missile Development (SAM-D) program in 1964 to replace the Hawk and Nike Hercules systems. The Nike Hercules was fielded in 1958 to provide medium- and high-altitude air defense. It was deployed extensively in the United States, Europe and South Korea. It was capable of carrying a conventional or nuclear warhead and could be used in a surface-to-surface role as well as its designed purposed of surface-to-air. The Hawk missile system was deployed in 1960 to the U.S. Army and U.S. Marine Corps for medium-range/medium-altitude air defense.

The SAM-D program received Secretary McNamara's formal approval of concept definition in 1965 and established its program office. The SAM-D program office took over the office space from the recently canceled MIM-46 Mauler, which had been intended to provide short-range/low-altitude air defense but ran into significant developmental challenges that could not be overcome. "The Army based its requirement for SAM-D on three newly available technologies that could be built into an air defense system. Based on the studies which the Army had completed, they found that they could build a system which had extensive computer control, could engage multiple targets simultaneously, and operate in an electronic counter-measures (ECM) environment."[91]

In 1966 the Army issued a request for proposals (RFP) for SAM-D system concept definition. Raytheon was selected and awarded a "five month, $2.5 million contract to define the concept of the system."[92] Concurrent with Raytheon's work on concept definition, the Army requested proposals for advanced development. RCA, GE, Hughes, and Raytheon submitted

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88 Photo from US Army.

89 Photo from US Army.

90 Photo from US Army.

91 Stevens, Jeffrey M., *The Patriot Project: How the Army Managed the Acquisition and Development of the Patriot Missile System*, (Saint Louis, MO: Sever Institute of Washington University, 1996), 22.

92 Barbera, Richard S., *The Patriot Missile System: a Review and Analysis of its Acquisition Process*, (Monterey, CA: Naval Postgraduate School, 1994), 9.

proposals. A team of hundreds of experts evaluated the proposals, providing their assessments to an advisory council of general officers. In May 1967, they recommended the Raytheon proposal and Secretary McNamara agreed.[93]

Figure 40. MIM-23 Hawk Anti-Aircraft System[90]

The advanced development stage of the SAM-D was hampered by repeated Congressional budget cuts. The cuts prolonged the time necessary to develop prototypes and thereby opened the program to criticism as a resource consumer that failed to produce anything and suffered from constant schedule slippages. The deputy project manager, Charlie Cockrell, recognized the need for senior leadership of the program:

> I very carefully put down a Major General assignment for the Project Manager because we were just not opening doors in the Pentagon with the Colonels. So, if you ask for a Lieutenant [General], they won't listen to you. So you ask for Major General. If someone wants to change your TDA [Table of Distribution and Allowances], you'd still have a General officer. They could reduce it one grade and you'd still be all right.[94]

In June 1971 Charlie Cockrell got his wish, with the appointment of BG Joseph Filmiani as the SAM-D project manager. In early 1972 the SAM-D was approved to move forward to full-scale development, and by 1973 program expenditures nearly quadrupled, finally allowing significant work to be accomplished. At the same time, "the Army established a SAM-D Requirements Control Board. This board included two assistant secretaries of the Army along with several general officers. Its mission was to review requirements that increase costs and

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93 Stevens, Jeffrey M., *The Patriot Project: How the Army Managed the Acquisition and Development of the Patriot Missile System*, (Saint Louis, MO: Sever Institute of Washington University, 1996), 29-30.

94 Stevens, Jeffrey M., *The Patriot Project: How the Army Managed the Acquisition and Development of the Patriot Missile System*, (Saint Louis, MO: Sever Institute of Washington University, 1996), 35.

determine, at the senior levels of the Army, what alterations should be made to the program to avoid cost increases."[95]

Figure 41. MIM-46 Mauler[91]

In September 1973, the project manager, MG Charles Means, was called to Secretary of Defense James Schlesinger's office to explain why the SAM-D program should not be terminated.

Schlesinger's arguments against the system were threefold. First, he felt that the Army should not be involved with a system with the range of SAM-D; it was an Air Force mission. Second, he did not believe that the threat existed to the extent that the Army claimed. He was also skeptical of the technical feasibility, given the Army's unsuccessful history in trying to solve the forward area air defense problem. He saw the Army's efforts as a perpetual waste of money that had yet to provide an adequate solution.[96]

[95] Stevens, Jeffrey M., *The Patriot Project: How the Army Managed the Acquisition and Development of the Patriot Missile System*, (Saint Louis, MO: Sever Institute of Washington University, 1996), 36–37.

[96] Ibid, 40.

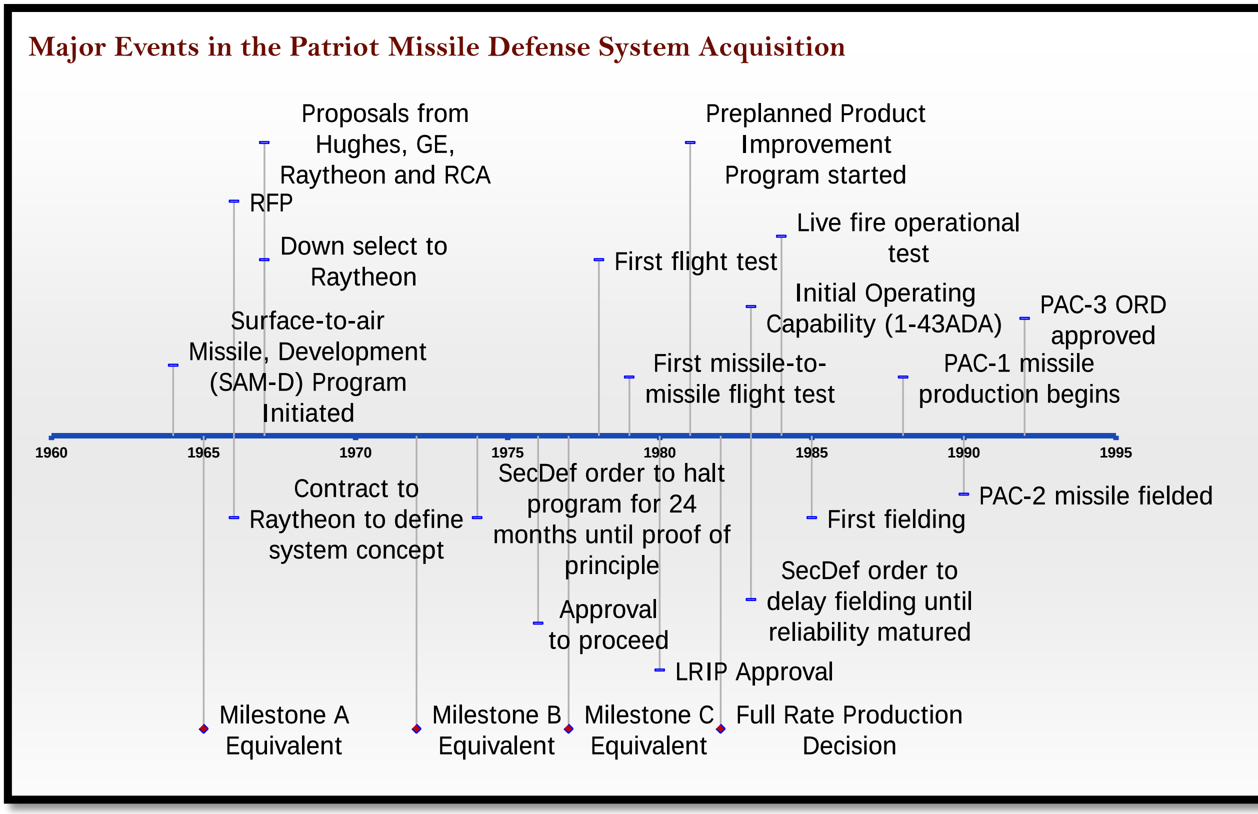

Figure 42. Patriot Missile Defense System Development and Production Timeline.

Secretary Schlesinger decided not to immediately terminate the program, but instead in February 1974 instituted a temporary halt to provide a proof of principle for the Track-via-Missile (TVM) guidance concept. During this period, funding for the program was cut to the bare essentials. Ten missiles were fired at White Sands Missile Range from June through December 1975, providing the proof of principle demanded. Concurrently, the Deputy Secretary of Defense, William Clements, mandated that the SAM-D program, along with four other Department of Defense programs, provide monthly reports directly to him. This ensured that the program was able to be put back on track in a February 1976 review. This Office of the Secretary of Defense review was also deeply concerned with cost reduction, which led to the decision to abandon the nuclear warhead option, to remove one of the two transmitters in the system's radar set, and to forego an analog guidance system in favor of a digital one now available. Around this time, the SAM-D was renamed the Patriot.[97]

In 1980 the go-ahead was given for low-rate initial production. This was followed in 1981 by the initiation of the preplanned product improvement plan, so even before the first Patriots were produced the next version was already on the drawing board. In 1982 the deci-

[97] Ibid, 40–51.

sion was made to accelerate full production. The following year the 1st Battalion of the 43rd Air Defense Artillery Regiment attempted to demonstrate the initial operating capability (IOC) for the Patriot. Operational tests were cut short due to reliability and maintainability issues and Under Secretary of the Army James Ambrose delayed fielding until these could be adequately addressed. Additional live-fire operational testing was successfully conducted in 1984 with the first fielding following in 1985. An improved missile, the Patriot Advanced Capability—1 (PAC-1), began production in 1988, with the next generation, the PAC-2, being deployed in 1990 in time for DESERT SHIELD and DESERT STORM.[98]

Cost is an important indicator of program management and performance. Figure 43 is an historical look at total program costs for the SAM-D program that produced and fielded the Patriot missile defense system. The data are taken from the Department of Defense's mandated reports to Congress on major defense acquisition programs called the Selected Acquisition Reports (SARs). While the format has changed over time, the data have been consistent across reports since the SARs were standardized in 1975. Although reports are submitted quarterly, the figure uses only the December reports to show how the program changed as it progressed. The blue bars in the chart are read from the left axis and represent the estimated total program cost at the time of the SAR. The number over the blue bar represents the planned procurement quantity. The red line is read from the right axis and represents the program acquisition unit cost (PAUC), which is calculated by dividing the total program cost by the quantity. Both total program cost and PAUC are reported in constant dollars, so the effects of inflation have been removed.

Figure 43 shows slight variations in quantity desired. The program started with the expectation of acquiring 49 batteries. In 1972 the unit of measurement was changed from batteries to firing units, with a new projected quantity of 156 firing units. It is not clear from current documentation how many firing units were in a 1971 battery, but the current configuration is four, which would mean that the 49 batteries translated into 196 firing units and that the transition from batteries to firing units was therefore a reduction of 40 firing units or 10 batteries. The quantity was further reduced to 138 firing units in 1974 and again in 1975 to 100. In 1978 the quantity reached its nadir at 88 firing units. In 1981 this was increased to 96. It dipped slightly to 95 in 1983 before increasing to 105 in 1985 and again to 108 in 1989. The total was reduced to 100 firing units in 1990. The SAR reports on the Patriot program ended in 1991, when the program reached more than 90 percent of its procurement objective.

[98] Barbera, Richard S., *The Patriot Missile System: a Review and Analysis of its Acquisition Process*, (Monterey, CA: Naval Postgraduate School, 1994), 14-25.

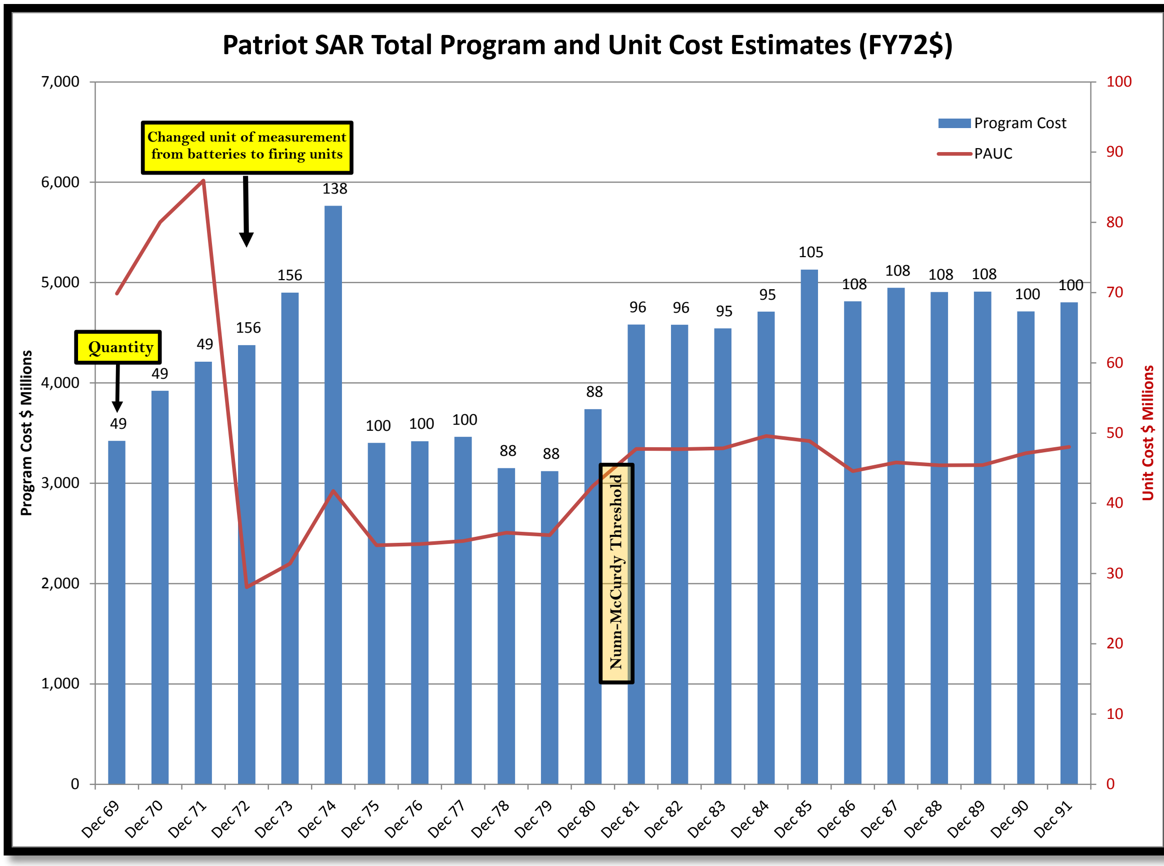

Figure 43. Patriot Selected Acquisition Report Total Program and Unit Cost Estimates

Program costs (blue bars in Figure 43) were estimated at $3.5 billion in 1969, the first year that SAR reports are available. These rose steadily through 1974 when they reached almost $6 billion, but the consistency of these costs with the remainder of the data is questionable so it is better to start with the 1975 estimate of $3.5 billion for the total acquisition program. This remained relatively steady until the estimate dropped to $3.1 billion in 1978 but bounced up to $3.8 billion in 1980 before jumping to $4.7 billion in 1981. The total cost estimate for the program then rose in 1984 and 1985, reaching a zenith of $5.1 billion before coming back under $5 billion and oscillating slightly between $4.8 and $5.0 billion.

Program acquisition unit cost (PAUC), depicted by the red line, is simply the combination of program cost and quantity and represents the average cost including the research and development costs. Starting in 1975 for the reasons mentioned above, the PAUC was $34.0 million and rose to only $35.5 million through 1979. In 1980 the PAUC jumped to $42.5 million and reached $47.7 million in 1981. In 1984 this rose to $49.6 million before falling to

$44.6 million by 1986 and then rising slowly to end at $48.0 million per firing unit in 1991 in 1972 dollars which equates to $160 million in 1991 dollars or $270 million in 2012 dollars.[99]

While the cost growth of the Patriot program was a concern at various times, there were no standardized thresholds for determining programs that were in trouble. This changed in 1982 with the passage of the Nunn-McCurdy Act. Using the Nunn-McCurdy criteria, the Patriot program would have experienced a critical breach in 1981. While the cost increases were reported to Congress as part of the SAR, they did not mandate a full program review to support recertification, as would be required to continue the program today. By the time the December 1981 SAR was provided to Congress, the Patriot had just begun low-rate initial production (LRIP) and had neither demonstrated its initial operating capability (IOC) nor been approved for full-rate production. It is unclear what impact a critical breach would have had at this critical juncture, although the bureaucratic requirements associated with a critical breach would have necessarily slipped the schedule to the right and thereby increased the cost even more. Given the compelling need for the Patriot missile system that was widely recognized within the Army, the Office of the Secretary of Defense, and in Congress, it is likely that the program would have been recertified and been able to proceed.

The Army's current description of the Patriot missile defense system is found in Figure 44.

[99] Author's calculations using tables from DoD's FY12 Green Book.
[100] Image from http://www.army.mil/factfiles/equipment/airdefense/patriot.html.


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WEAPON SYSTEMS ALPHABETICAL LIST

AIR DEFENSE AVENGER PATRIOT

PATRIOT

MISSION

Provide defense of critical assets and maneuver forces belonging to the corps and to echelons above corps against aircraft, cruise missiles, and tactical ballistic missiles.

ENTERED ARMY SERVICE

1985

DESCRIPTION AND SPECIFICATIONS

The combat element of the PATRIOT (Phased Array Tracking Intercept of Target) missile system is the fire unit, which consists of a phased array radar set (RS), and engagement control station (ECS), an electric power plant, an antenna mast group (AMG), a communications relay group (CRG), and up to eight launching stations (LS).

ADDITIONAL MEDIA

The RS provides all tactical functions of airspace surveillance, target detection, identification, classification, and tracking, and missile guidance and engagement support. The ECS provides the human interface for command and control of operations. Each LS contains four ready-to-fire PAC-2, guidance enhanced missiles (GEM, GEM+) sealed in canisters that serve dual purposes as shipping containers and launch tubes.

The Patriot Advanced Capability-3 (PAC-3) upgrade program incorporates significant upgrades to the RS and ECS, and adds the new PAC-3 missile, which utilizes hit-to-kill technology for greater lethality against TBMs armed with weapons of mass destruction. Additionally, up to 16 PAC-3 missiles can be loaded per launcher, increasing firepower and missile defense capabilities.

MANUFACTURER

Raytheon (Bedford, MA); Lockheed Martin (Grand Prairie, TX)

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Figure 44. Description of the Patriot Air Defense Missile System[101]

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> *The success of the total modernization effort was demonstrated in Operations* D*ESERT* S*HIELD*/S*TORM in 1990 and 1991. All of the "Big Five" systems were deployed and performed beyond expectations. The Apache attack helicopter, the Black Hawk transport and utility helicopter, the Abrams main battle tank, the Bradley Fighting Vehicle, and the Patriot missile system validated the combat developments process and products.*[101]

Assessment

Now that we have an understanding of the "Big Five" systems individually, we can examine them collectively and provide an assessment of their challenges and why they were able to overcome these challenges as well as possibly why they avoided other challenges altogether.

The legend of the "Big Five" is based on truth but only the successes appear to remain in the legend. The legend has history backwards; the "Big Five" were all programs of record and also already described as the "Big Five" in 1972, a full year before the Yom Kippur War. Similarly, while the "Big Five" were seen as necessary components of a total force, the doctrinal, organizational, training, leadership, and personnel changes attributed to the legend followed the development of the "Big Five" and incorporated these new systems and their capabilities.

The belief in the purity in the origins of the "Big Five" belies the fact that three of these programs were built on top of failed programs. The advanced attack helicopter program which became the Apache was a follow on to the failed AH-56 Cheyenne helicopter. The Bradley was built on the failed mechanized infantry combat vehicle 65 program. The M1 tank followed two efforts, the MBT-70 and the XM-803, which were both terminated. Even so, the requirements for these systems were not unchanging as best represented by the Bradley which had a complete restart more than two years after the collective group was known as the "Big Five."

Budgets were not unconstrained during the "Big Five" acquisition. There was competition from various programs for limited resources. As Richard Stewart tells us in the Army's official history of the time, "Abrams focused Army modernization on the "Big Five" weapon systems. … In an era of very constrained resources, this is perhaps best understood as an effort to focus limited research and development dollars on key systems. When resources became available in the 1980s, these programs then provided the focus for expanded procurement."[102]

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[101] King, Benjamin, *Victory Starts Here: A 35-year History of the US Army Training and Doctrine Command*, (Fort Leavenworth: Combat Studies Institute Press, KS, 2008), 36.

[102] Nielsen, Suzanne C., *An Army Transformed: The US Army's Post-Vietnam Recovery and the Dynamics of Change in Military Organizations*, (Carlisle Barracks, PA: The Strategic Studies Institute, 2010), 34-37.

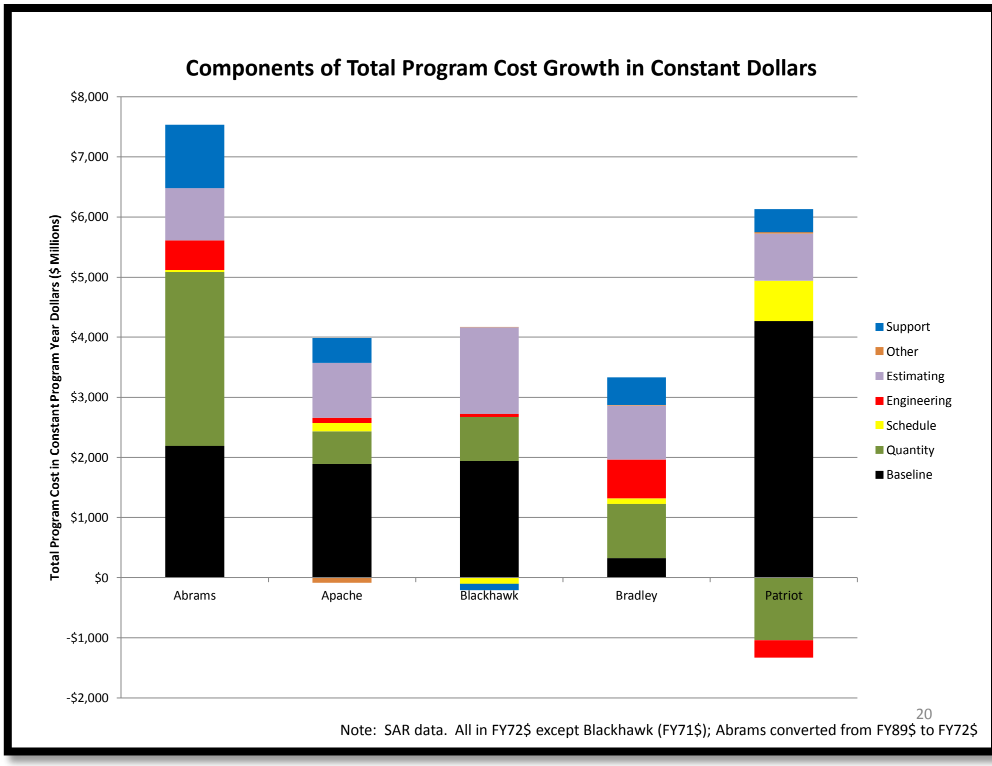

Figure 45. "Big Five" Components of Total Program Cost Growth ($)

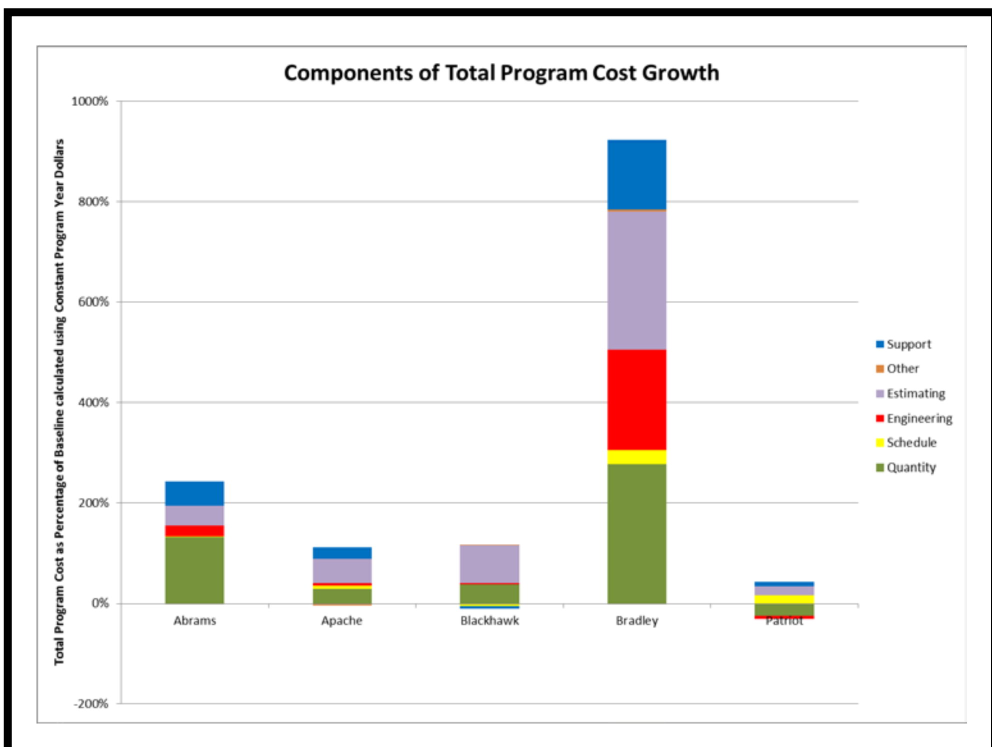

Figure 46. "Big Five" Components of Total Program Cost Growth (%)

While easily forgotten decades after the acquisition, cost growth was a significant factor. Nunn-McCurdy did not exist at the time of the "Big Five." If it had, according to the historic data reported to Congress in the quarterly Selected Acquisition Reports (SARs), all of the programs would have had Nunn-McCurdy breaches and would have required termination or Secretary of Defense certification and re-baselining. Figures 45 and 46 depict the cost growth for each of the "Big Five" programs. In figure 45, the programs and associated cost growth are shown in constant dollars while figure 46 shows the components of cost growth as a percentage of the program's original estimate. The data are taken from the SARs to Congress. Each SAR includes a breakdown of the components of program cost growth. This breakdown is standardized into six categories: quantity, schedule, engineering, estimating, support, and other. Initial (baseline) cost is shown in black. While there is standardization of the categories, there are no universal definitions of the categories or clear delineations between them.

The cost growth of the Abrams program was very large but the preponderance of this was due to a drastic increase in the planned procurement quantity for the program. Each of the programs was underestimated by roughly a billion dollars. The Apache, Black Hawk, and Patriot programs show us that cost reductions are also possible. In the case of the Patriot, reductions came from reducing the quantity and from engineering changes that also reduced the requirement.

At first glance, cost growth of the Bradley in constant dollar terms does not look so bad because as a program, it was the smallest of the "Big Five" in constant dollar terms. This optical illusion is further enhanced by the fact that the Bradley program's initial cost estimate hardly even registers on the graph. The percentage cost growth graph provides the opposite initial impression of the Bradley program, showing cost growth of 900 percent.

It is also important to remember that none of these systems underwent the forced delays that result from Nunn-McCurdy breaches, which can result in having to maintain a substantial workforce and associated cost increases while the schedule continues to slip, as the program fights for its life through the recertification process.

Even after development, there were significant concerns about these systems. After source selection, the Abrams went through a mandatory competition with Germany's Leopard 2 tank. The live-fire testing of the Bradley compelled its own Congressional hearing and required extensive efforts, including the personal involvement of the Chairman of the Joint Chiefs of Staff, Admiral Crowe, to avoid a Congressional cancellation of the program in 1986.

Each of the "Big Five" was a significant step forward, but this was through the integration of available technology, not through revolutionary technological advances. The integration of dozens of recent technologies made the results extraordinary and perhaps revolutionary when comparing these systems to those they were replacing, but they were evolutionary, not revolutionary, technological advances.

The "Big Five" were not produced as optimal systems. They had planned upgrades that were already in design when full production started. It is critical to understand that there was a compelling need to get the systems to the field and a recognition that they needed to incorporate the ability for upgrades in the future. The Apache Longbow, variants of the Black Hawk, and the M1A1 are excellent examples. Indeed, the need for "product improvements" may be deemed a euphemism by some like GEN Starry who had the following comments about the Bradley:

> Recognizing the Bradley's shortcomings for fighting the central battle alongside tanks, despite the serious upgrades just mentioned, the vehicle was inadequate for the task. Therefore a Heavy Infantry Fighting Vehicle Task Force was convened to draw up requirements for such a vehicle based on study of the Arab-Israeli wars, and IFV systems in other armies. We then considered revising the XM1 tank design to provide space inside for an infantry fire team, a concept similar to that of the Merkava tank then being developed for the IDF. Design change of that magnitude would have severely delayed the XM1 program, a risk we decided not to accept.[103]

In concert with the acquisition of the Big Five equipment, the Army rewrote its doctrine and established the Active Defense and then the Air Land Battle concept. Concurrently, the Army reorganized under Division 86. It reexamined the Army's training methods and established centralized training centers for Brigade size operations like the National Training Center at Fort Irwin, California.

In terms of personnel, there was recognition that smart soldiers are better soldiers who make the equipment they use more capable, and consequently the Army made a commitment to recruit and retain quality. GEN Starry recognized this clearly:

> Yesterday I flew in the F-16 for the first time. Last night, as I reflected on that machine, on the M1 tank, the AH64, the Bradley fighting vehicle and the levels of technology they represent compared to the equipment the Army I joined as a private soldier thirty-eight years ago, my judgment switch locked firmly into the 'better quality' divot—better quality, almost regardless of how we recruit and what it costs. There's just no way to realize the combat potential of those machines without very smart guys who are very, very well-trained. And to become as well-trained as they need to be, they must be smart to begin with! I'm afraid the viability of the mass draft Army, or even of volunteer number recruited without strict regard to their smarts, may be a thing of the past for us—in any context, emergency or other.[104]

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[103] Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 29.

[104] Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 719.

As the "Big Five" were being fielded, the Army tested the theory that smarter is better. The result was work like *Are Smart Tankers Better?*[105] published in Armed Forces and Society in 1986 and the 1991 RAND report *Effect of Personnel Quality on the Performance of Patriot Air Defense Operators.*[106] These works provided evidence of the increased effectiveness of smarter soldiers, both in terms of combat capability and improved maintenance and reliability.

> All of the weapon programs suffered through years of mounting costs and production delays. A debate that was at once philosophical and fiscal raged around the new equipment, with some critics preferring simpler and cheaper machines fielded in greater quantities. The Department of Defense persevered, however, in its preference for technologically superior systems and managed to retain funding for most of the proposed new weapons. Weapon systems were expensive, but defense analysts recognized that personnel costs were even higher and pointed out that the services could not afford the manpower to operate increased numbers of simpler weapons.[107]

So the holistic Big Five solution—what the Army calls DOTMLPF for Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities—was deployed in support of DESERT SHIELD and proven in DESERT STORM and again in Operation IRAQI FREEDOM.

This dash through the history of the "Big Five" is in no way intended to diminish the success that these programs became and continue to be. It is intended, however, to shed light on the faded memories of the programs' reality and to reinforce that each had its own struggles, which under a different environment might not have led to success.

[105] Scribner, Barry L., et al., *Are Smart Tankers Better? AFQT and Military Productivity*, (Armed Forces and Society, Volume 12, No. 2, Winter 1986), 193–206.

[106] Orvis, Bruce R., *Effect of Personnel Quality on the Performance of Patriot Air Defense System Operators*, (Santa Monica, CA: RAND Corporation, 1991).

[107] Stewart, Richard W., editor, *American Military History Volume II: The United States Army in a Global Era, 1917-2003*, (Washington, DC: Center of Military History, 2005), 384.

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Environmental Changes

Understanding how the environment has changed from the 1970s to today is important in determining both what lessons are applicable today and the corresponding recommendations. We will highlight five critical environmental variables and describe how they have changed, or not, over the last thirty to forty years.

1. The first environmental change is the threat. During the development and production of the "Big Five," the threat was universally understood as a massive Soviet conventional attack in Europe. This threat was clearly defined and compelling.

The United States as the sole superpower does not make the world unipolar; instead there are multiple nation states with designs on regional hegemony. Nuclear weapons are held by more nations than ever before, while others continue to attempt to build them. Some nuclear nations are of questionable stability, thereby raising the possibility of loose nuclear weapons. There has been a rise in non-state actors and the resort to terrorism. The U.S. military preeminence in conventional force-on-force conflict has led, and will continue to lead, adversaries to find asymmetrical ways and means to attack and challenge the U.S. military.

The world has also become more complex and interconnected. Globalization has fueled advances in the world economy and tied disparate parts of the world together. This has taken economic interdependence to levels heretofore unseen. This interdependence means that indirect attacks can now have significant consequences. The technology that enabled globalization also created a new realm, cyberspace. Cyberspace presents a new set of challenges because it does not fit neatly into the well-understood and widely agreed upon rules for warfare. Cyber also provides new non-kinetic means—not necessarily weapons *per se*—that are at least disruptive and potentially devastating to a nation's economy. Globalization has also meant a blurring of the lines between criminal, terrorist, and state. Recently there has been a rise in the use of proceeds from narcotics trafficking to fund and promote armed conflict. State-sponsored terrorism, in addition to non-state terrorism, is an everyday threat. The increased complexity and interconnectedness means the United States can now be threatened and impacted across the globe, to include in the homeland.

The fall of the Soviet Union led to a new range of missions for the U.S. military. The pace of engagement also increased. New missions—new in that they were previously considered "lesser included cases" or had not been conducted in the previous several decades on a large scale—included what has been variously called "operations other than war:" nation building, security and stability operations, phase IV operations, and reconstruction, as well as counter insurgency operations. These missions provide a diversity of challenges and potential threats.

The mixture or combination of different tactics in different environments has been dubbed "hybrid warfare." Many will take that one step further and include in hybrid warfare the adversary's ability and willingness to learn and to adapt his operations and tactics. This makes the range of potential threats span the full range of warfare, and in locations across the globe. It also calls into question which are the most dangerous and the most likely threats. This means that while the existence of a range of threats is undeniable, in terms of conventional ground forces it is not currently clearly defined in a compelling manner that supports the determination or justification of requirements.

2. The second environmental variable is fiscal. The "Big Five" were developed at the end of the Vietnam War and the years immediately following. As seen in figure 47, using fiscal year 2012 constant dollars to remove the effects of inflation, the Army's research and development budget, reflected by the red line, fluctuated between $8.5 billion dollars and $6.5 billion dollars per year in the 1970s. From a nadir of $6.5 billion dollars in 1976, Army Research, Development, Test and Evaluation funding (RDT&E) general rose until it reached $9.6 billion dollars in 1992 before steadily diminishing to $6.7 billion in 1999. From 1999 until 2004 there were steady increases until leveling off in the $12 billion dollar per year range. 2012 is down to $9.7 billion, which still exceeds any year during the "Big Five" development.

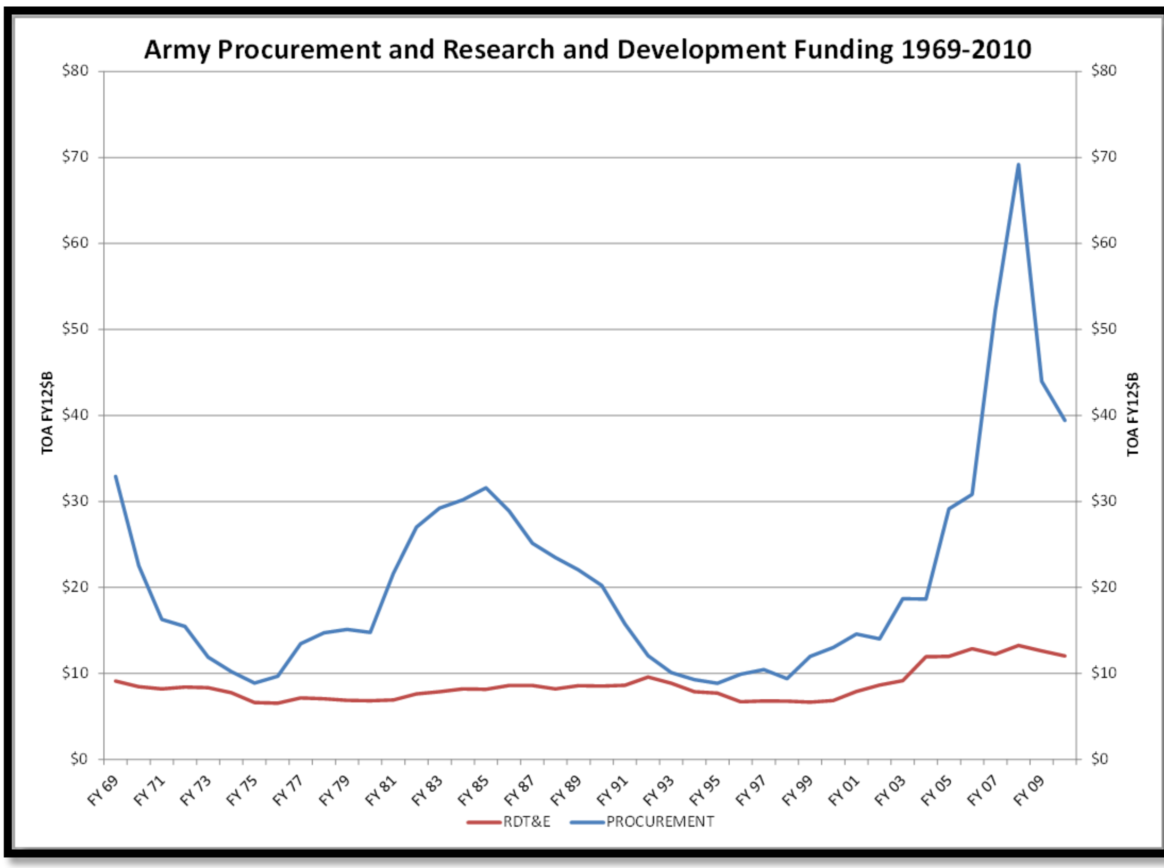

Figure 47. Army Procurement and Research and Development Funding 1969-2010

The Army's procurement budget is also displayed on Figure 47 as the blue line. The plot clearly illustrates the so called "procurement holiday" as the Vietnam War drew to a close reaching a nadir of $9 billion in 1975. This quickly rose to $15 billion under President Carter's administration (1977-1980). The Reagan build up (1981-1988) is quite pronounced before the so-called "peace dividend" years of President Clinton's administration (1993-2000). President Bush's administration was a time of great infusion of funds into Army procurement, reaching a height of almost $70 billion in 2009, including procurement for the wars in Afghanistan and Iraq.

As we have seen by looking at the last forty years, in constant dollar terms, Army funding for both research and development and procurement is higher today than it was at any point during the development of the "Big Five." This suggests that the current level of funding by itself is more conducive to success in major acquisition programs than in times past.[108] This, however, ignores the impact of additional oversight and regulation; policy is not costless. In the case of an added operational or live fire test, or a Nunn-McCurdy Breach the imposed delay necessitates maintaining and paying for the program while it may be idling from a functional stand point. Yet, even incorporating the cost of funding the so-called "standing army" while a program meets these new requirements, funding levels are still above those during the "Big Five" era.

3. The next environmental variable is the industrial base and competition. In the late 1960's and early 1970's, as the "Big Five" were being conceived and developed, there were a plethora of firms bidding on major defense contracts. This included numerous commercial firms like General Motors and Chrysler that had defense divisions. In the 1980s many commercial firms divested of their defense divisions through spinning them off or selling them to defense focused companies.

With the fall of the Soviet Union and the ensuing "peace dividend," the U.S. military was significantly reduced in both personnel and funding. The Department of Defense made a conscious decision in 1993 at Secretary Perry's famous "last supper"[109] to promote consolidation. Consolidation was deemed necessary because projected funding levels were insufficient to maintain the number of defense contractors. Secretary Perry wanted to ensure the viability of a healthy industrial base to support current and future defense requirements.

Barry Watts and Todd Harrison did an in-depth look at the U.S. Defense Industrial Base for the Center for Strategic and Budgetary Assessments. In summarizing the latest round of

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[108] Additionally, today's force is smaller so acquisitions should be proportionally smaller.

[109] Recognizing that the diminishing budgets from the so called "peace dividend" after the fall of the Soviet Union would not support the current level of competition in the defense industry, in 1993 Secretary of Defense Les Aspin hosted a dinner for 15 defense industry CEOs. After dinner Deputy Secretary of Defense Perry explained that DoD could not afford to sustain the current level of competition or capacity and that industry needed to solve this. Perry concluded by assuring the CEOs that DoD strongly supported consolidation.

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consolidation spurred by the "last supper," they produced a telling graphic that is reproduced in figure 48. While focused on the aerospace industry, figure 48 is representative of overall defense industry consolidation. Consolidation has proceeded such that there are now only a few companies able to compete for any of the Army's major acquisition programs.

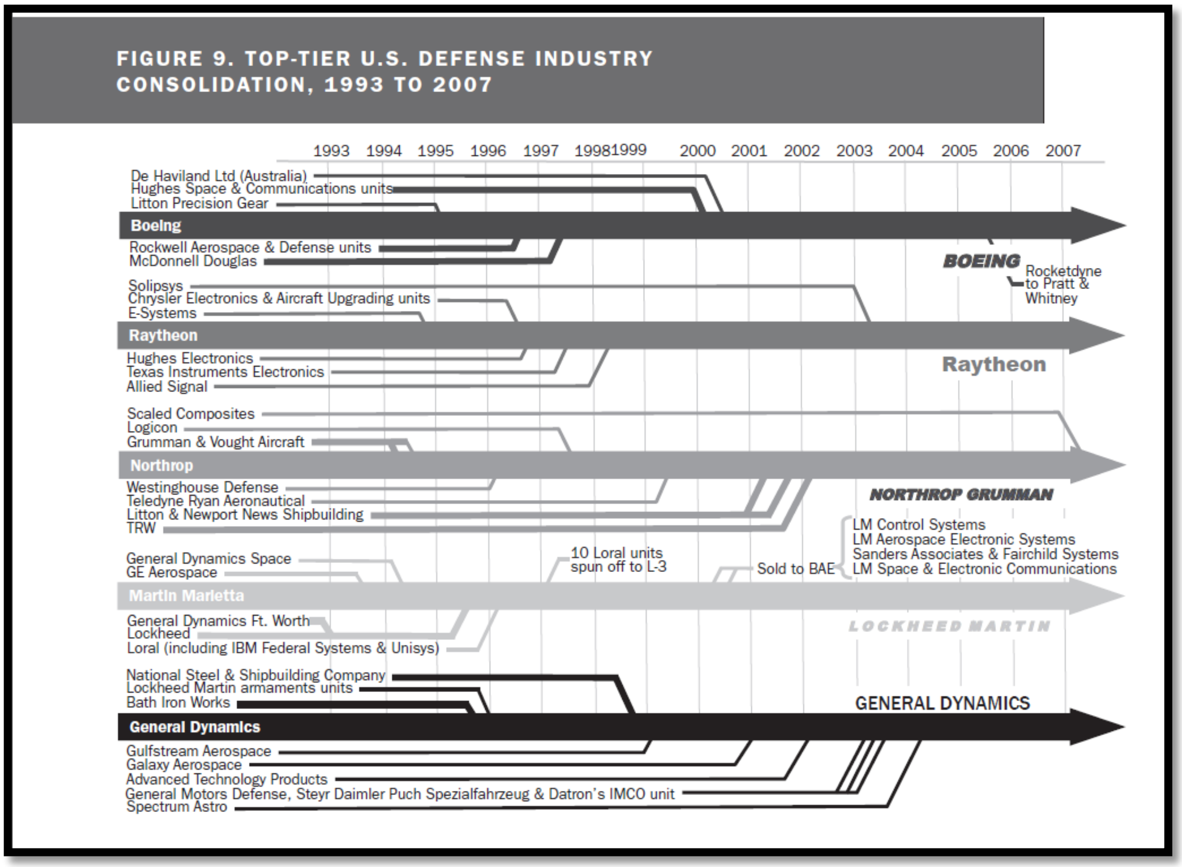
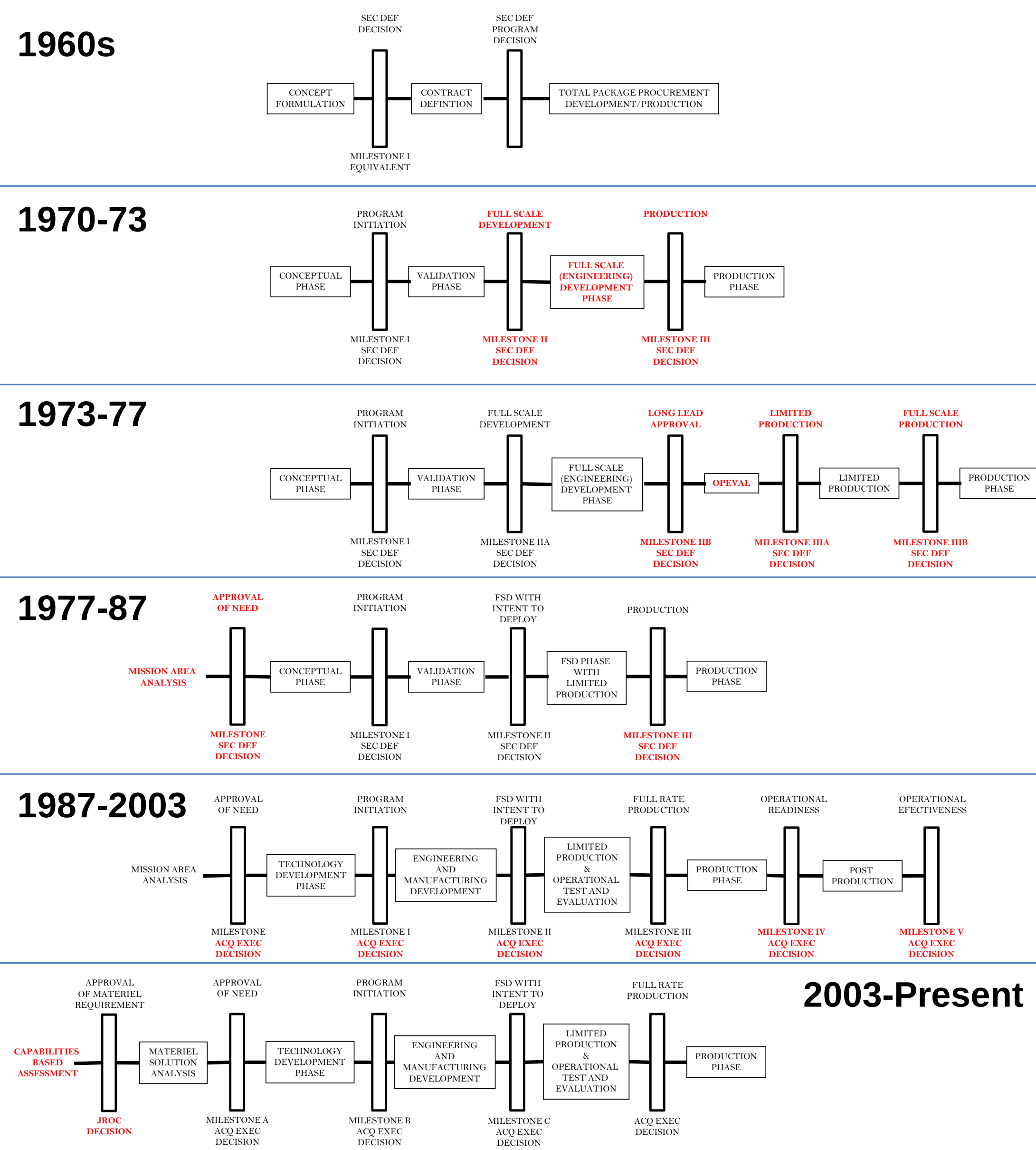


Figure 48. Defense Industry Consolidation 1993–2007[110]

In examining the defense industrial base, the argument can be made that competition was traded for health and viability. However, the by-products of this trade-off are greater risk aversion today, and co-dependence. With few competitors, firms need to maintain their viability within the industry and cannot afford riskier investments that in general have little likelihood of improving their odds of winning contracts. Similarly, the Department of Defense is dependent upon an ever dwindling number of companies as prime contractors on major acquisition programs, and the Department loses future capabilities every time one of them departs the industry.

[110] Watts, Barry D., and Todd Harrison, *Sustaining Critical Sectors of the US Defense Industrial Base*, (Washington, DC: Center for Strategic and Budgetary Assessments, 2011), 75.

Defense Acquisition Decision Process Evolution 1960's –



Framework from *Department of Defense Steering Group Report on Improving the Defense Acquisition System and Reducing System Costs,* 1981 with data from the same as well as *DOD's 5000 Documents: Evolution and Change in Defense Acquisition Policy* by Joe Ferrara in Acquisition Review Quarterly, Fall 1986 and *Defense Acquisition: How DOD Acquires Weapon Systems and Recent Efforts to Reform the Process* by Moshe Schwartz, CRS Report 7-5700, 2010.

Figure 49. Defense Acquisition Decision Process Evolution 1960's - Present[111]

[111] To accomplish this, the figure uses the framework and analysis done in 1981 by the Department of Defense Steering Group on Improving the Defense Acquisition System and Reducing Systems Costs. To this it adds

4. The fourth environmental variable is the acquisition process, which figure 49 attempts to summarize. The vertical boxes represent required approvals, or, as we know them today, "milestone decisions." The horizontal boxes represent the phases in an acquisition program as formally defined. Changes from one "system" to the next are highlighted by using red lettering. Finally, the stages in the evolution of the acquisition process are aligned to make program initiation always appear in the same spot, making it easy to recognize where in a program's lifecycle the process has been changed.

At the start of the "Big Five" the acquisition process was loosely structured and essentially Service-run, with Secretary of Defense approval required to initiate major programs and then again for production. Over the years the process was formalized with the introduction of milestone reviews, standardization, and integration with the Planning, Programming, Budgeting, and Execution (PPBE) process. Goldwater-Nichols created separate defense and Service acquisition executives and pulled the Service Chiefs out of the acquisition process. The result remains a linear process with more oversight and bureaucratic requirements.

5. The fifth environmental variable is government expertise. During the development of the Big Five, the Army possessed incredible in-house expertise. Before the Request for Proposals went out for the M1 prototypes, army engineers understood the tradeoffs. Within the sphere of the feasible, they had actually done the calculations and simulations, so they could understand things like the tradeoff between the width of a track on speed, and maneuverability as components of mobility. During successive attempts to reduce manpower and find savings, the Army reduced or eliminated the expertise that was resident in TRADOC. Today, the in-house expertise is diminished to the point where we have several examples over the last two decades of key performance parameters for systems having thresholds which, when taken together for the system, are simply infeasible. The Army does have expertise in the Research and Development Command inside of AMC but it is limited and not fully integrated into today's programs.[112]

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from the work of Moshe Schwartz at the Congressional Research Service to result in a summary of the Department of Defense's formal acquisition process from the 1960's to the present.

[112] Decker, Gilbert F., and Louis C. Wagner, Jr., *Army Strong: Equipped, Trained and Ready Final Report of the 2010 Army Acquisition Review*, (Washington, DC, 2011), 56-8.

Summary

Environmental changes have been significant over the last several decades but not always in ways that are obvious without some examination. It may be surprising that acquisition budgets have been *more* generous lately than they were in the time of the “Big Five.” Probably not surprising, but nonetheless critically important, are the changes in the threat. These environmental variables provide us an important lens through which to view the “Big Five” programs today.

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Lessons Learned

With an understanding of the reality of the "Big Five" and the environmental changes that have occurred since, we can summarize a few lessons. First, leadership matters, and leaders must be able to prioritize and focus. The "Big Five" name itself is proof of the Army leadership from the Secretary and Chief of Staff. This leadership was widespread from the TRADOC and AMC commanding generals, through the schoolhouse commandants, to the program managers, all the way to the doctrine and requirements writers and the scientists and engineers working on individual programs. The leadership was proactive in focusing limited resources on these weapon systems as priorities and maintaining that focus despite unexpected changes in key leadership positions like the untimely death of GEN Creighton Abrams, the only Chief of Staff of the Army to die in office.

The recognition of stakeholders and the ability to gain support from them was critical to each of the "Big Five" programs. A concerted effort was made to "sell" the Office of the Secretary of Defense, the Joint Staff, and the Congress on each of these programs. The length of the programs also shows how *maintaining* that support from stakeholders is critical; repeated engagement and frequent communications are required to inform stakeholders and ensure they are not surprised. Since the tenure of those within the bureaucracy of the Office of the Secretary of Defense and the staff in Congress is longer than those in critical leadership positions within the Army, a necessary corollary is the need to maintain consistency even as messaging is updated and leaders in the Army, the Office of the Secretary of Defense, and elected officials rotate.

While the acquisition process remains linear, the "Big Five" demonstrates that feedback mechanisms can create flexibility to overcome the challenges and environmental changes that will happen. Since the acquisition process has become more standardized, more formalized, and therefore more rigid since the "Big Five," it is more important now than before to be proactive about creating opportunities within and throughout the program lifecycle for user, engineer, and scientist feedback. Furthermore, the ability to integrate environmental changes within a feedback framework may be the difference between success and failure. As the "Big Five" used ad hoc task forces and committees to create their feedback processes, a continuous revalidation of assumptions and requirements was ingrained into that process.

Expertise, within both the government and industry is critical, to include understanding the art and science of the feasible. Time, money, opportunity, and political capital are wasted when appropriate expertise is not brought to bear in the earliest stages of a program's inception and development. During the "Big Five" era, this was done primarily through in-house expertise, but also by leveraging other governmental agencies like NASA, as well as industry. The post-Vietnam and post-DESERT STORM reductions in the Army's workforce mean that much of this expertise is not resident within concept development or the acquisition program. This is not to suggest that the Army is devoid of relevant expertise. When the "Big Five" were being developed, a great deal of expertise in the Army was at each TRADOC schoolhouse in their combat developments directorates. Because the Army no longer maintains a constant string of major acquisition programs to support each of the branches, the need for this expertise at the schoolhouses was lost in downsizing and efficiency efforts, to include transitioning government civilian positions to contractor support. The expertise that remains has been consolidated away from the schoolhouses to` AMC's Research, Development and Engineering Command (RDECOM) and TRADOC's Army Capabilities Integration Center (ARCIC). This expertise is available to be leveraged in conjunction with expertise from industry, academia, and other governmental agencies in an unbiased, conflict of interest free, focused environment.

Finally, evolutionary change is far easier than revolutionary change. The ability to upgrade the "Big Five" was a persistent theme even before the systems were actually fielded. The "Big Five" models in use in Iraq and Afghanistan in 2011 were quantum leaps forward from the basic models first fielded circa 1980. The product improvements were generally major acquisition programs in themselves, but appear to have been much easier to support and defend in the Planning, Programming, Budgeting, and Execution system, as well as in testimony before the Appropriations Committees. The Air Force appears to have had similar success with its planned block upgrades as a continuous improvement acquisition strategy.

As the "Big Five" resulted from both failures of previous programs and their own success, so too do the ongoing successes and failures of major acquisition programs provide the ability to modify and reinforce the lessons learned. Since there is a perception that the Army has had only repeated failures lately, we need to look at the successes and failures since the "Big Five."

Figure 50 depicts the major defense acquisition programs for systems for the Army that were large enough to mandate reporting to Congress as part of the Selected Acquisition Reports (SARs). The figure does not include signal systems, ammunition, or trucks. The categories represent the combat arms branch that the systems most closely support. The systems are listed as they became reportable programs within their category. The system name is as reported on the SARs and in many cases reflects the evolution of the program over time. The highlighted area where the years are shown reflects the period that the program reported on the SAR.

Green highlighting represents successful programs, defined loosely as systems that reached full production and were produced in quantities close to or in excess of their original objectives. The "Big Five" programs also have a cross hatch within the green highlighting to differentiate them for comparison's sake. In the case of SAFEGUARD, the green is a different shade because while the system was deployed and used, it was used at only one of the three planned sites.

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Blue highlighting represents successful programs that were product improvements to existing systems. To be reported on the SAR, each of these programs had to be expensive and therefore quite extensive. The blue highlighting is intended to differentiate these very successful programs, which were upgrades, from systems that the Army did not have previously.

Red highlighting represents unsuccessful programs. Unsuccessful is loosely defined as programs that were cancelled prior to full production, or that were terminated for major deficiencies while in production.

Category	SYSTEM	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
ADA	SAM-D (Battery) (PATRIOT)	#	########																			
	SAFEGUARD																					
	IMPROVE HAWK (Battery sets)																					
	ROLAND (Fire units)																					
	DIVAD GUN																					
	FAADS LOS-F-H (ADATS)																					
	FAADS-LOS-R (AVENGER)																					
	BAT (BAT P3I)																					
	PATRIOT P3I (PATRIOT PAC-3)																					
	PAT/MEADS CAP																					
	JLENS																					
	PAT/MEADS CAP - FIRE UNIT																					
AR	SHERIDAN																					
	MBT-70																					
	ARSV (SCOUT)																					
	XM-1 (M-1 Tank) (M1/M1A1)					########																
	ASM																					
	M1A2 UPGRADE (ABRAMS UPGRADE)																					
	FCS																					
	LAV(A)																					
AV	CHEYENNE																					
	HLH																					
	UTTAS (UH-60A) (BLACKHAWK) (UH-60A/L)			########																		
	AAH (YAH-64) (AH-64) (APACHE)					########																
	CH-47 MODERNIZATION (CH-47D) (CHINOOK)																					
	AHIP (OH-58D) (KIOWA WARRIOR)																					
	LHX (LH) (COMMANCHE) (RAH-66)																					
	LONGBOW (APACHE)																					
	ICH (CH-47F)																					
	BLACKHAWK UPGRADE (UH-60M)																					
	ARH																					
	LB APACHE BLOCK III																					
	LUH (UH-72A LAKOTA)																					
FA	LANCE																					
	XM-198																					
	PERSHING II																					
	GSRS (MLRS)																					
	MLRS/TGW																					
	CRUSADER (AFAS/FARV)																					
	MLRS UPGRADE (GMLRS)																					
	HIMARS																					
IN	MICV (IFV) (FVS) (BRADLEY)				########																	
	BRADLEY FVS UPGRADE																					
	IAV (STRYKER)																					
	LAND WARRIOR																					
Category	SYSTEM	#	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989

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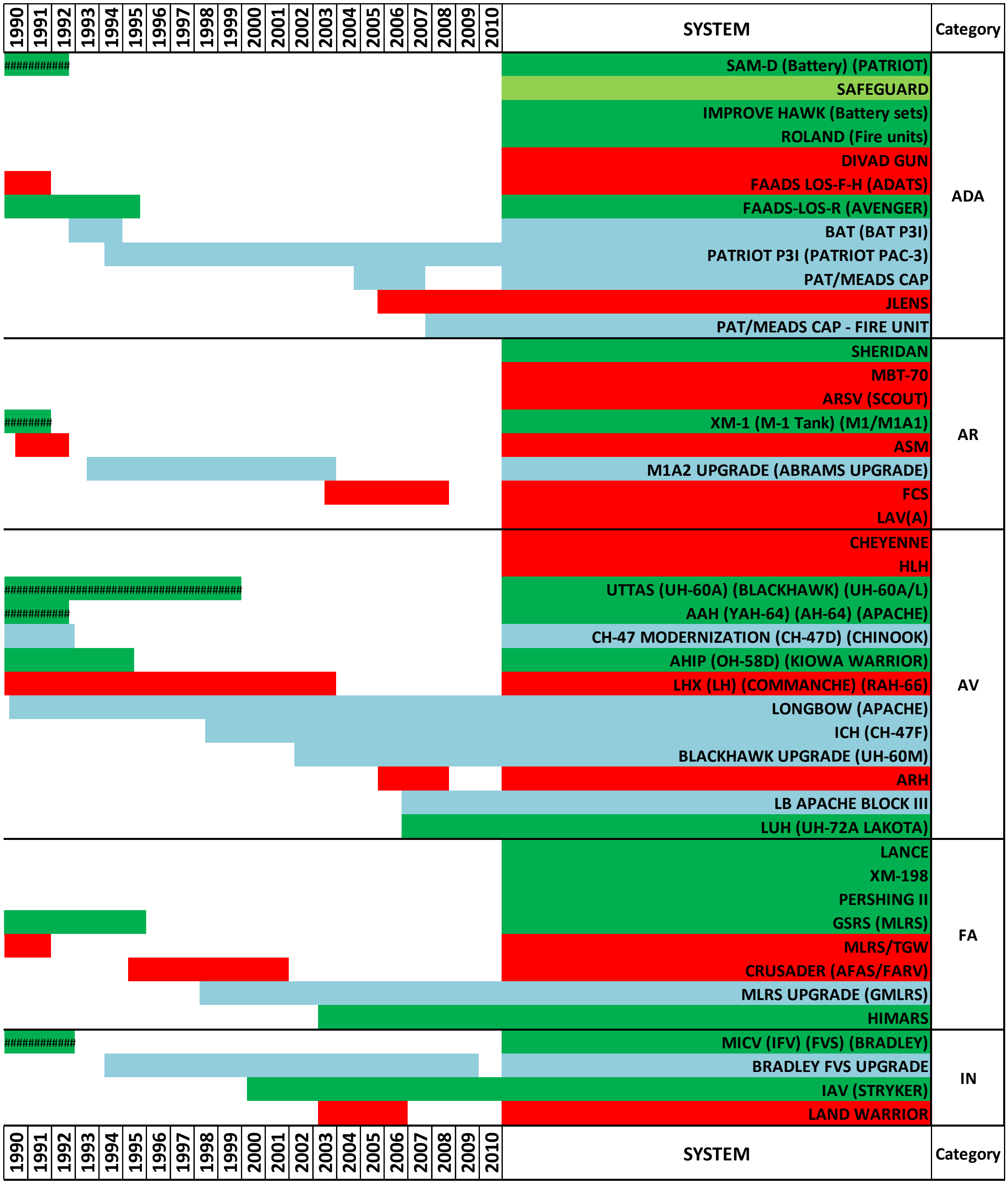

Figure 50. Army SAR reported Combat Programs 1969-2010

As we can see from Figure 50, the Army has had a number of successful programs since the "Big Five."[113] These include the Multiple Launch Rocket System (MLRS), the OH-58D Kiowa Warrior scout helicopter, the Avenger air defense system, the Stryker combat vehicle, the Lakota light utility helicopter, and the High Mobility Artillery Rocket System (HIMARS). It is important to note that the successes since the first Gulf War can be characterized as non-developmental or off-the-shelf programs.

Figure 51. Avenger[114]

Figure 52. Kiowa Warrior (OH-58D)[114]

Figure 53. Multiple Launch Rocket System[114]

Figure 54. HIMARS[114]

[113] Photos from US Army.

Figure 55. Lakota[114]

Figure 56. Stryker[114]

Figure 57. Crusader[115]

Figure 58. RAH-66 Comanche Helicopter[115]

Figure 59. Armed Reconnaissance Helicopter[115]

Figure 60. Sergeant York[114]

To these successes must be added the successful upgrade programs. Each of the "Big Five" has had its own successful follow-on upgrade, and in the case of the Apache and the Patriot, there have been more than one successful SAR-reportable product improvement program. Additionally, the MLRS and the CH-47 Chinook helicopter have also had successful upgrade programs.

[114] Image from http://upload.wikimedia.org/wikipedia/commons/d/d1/M247_2.jpg .

Just as there have been successes since the "Big Five," there have also been failures.[115] These failures among Army programs large enough to mandate SAR reporting are: the Sergeant York, the Crusader self-propelled field artillery system, the Comanche helicopter, the Armed Reconnaissance Helicopter, the Future Combat System, and the JLENS.[116]

At this point it is appropriate to compare the "Big Five" programs to recently challenged programs. In 2009 the Institute for Defense Analyses (IDA) was contracted to examine major acquisition program cost growth across the Department of Defense. Figure 61 depicts the results of IDA's analysis in terms of cost growth of eleven troubled major acquisition programs and compares these to the cost growth of the "Big Five."

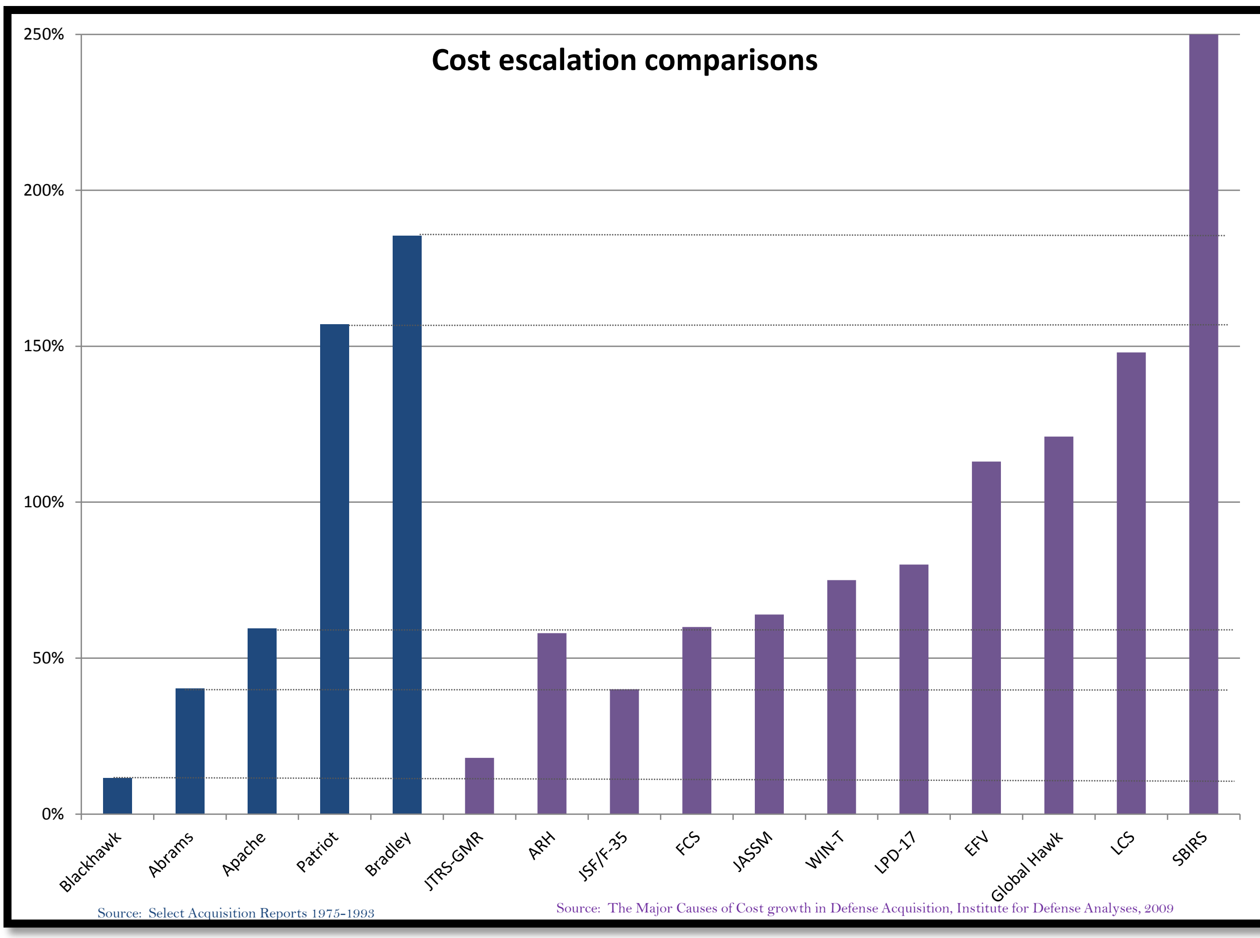

Figure 61. Cost Escalation Comparisons between the "Big Five" and Recent High Visibility Programs

The cost escalation calculations were done using data reported in constant dollars (inflation removed) to Congress on Selected Acquisition Reports. The same methodology that IDA

[115] Photos from US Army.

[116] JLENS is categorized as a failure because its funding was curtailed in the FY 2013 Budget submission.

used was applied to the "Big Five" data to ensure consistency and therefore comparability. While the Black Hawk program compares favorably with any of the recently troubled programs, the same cannot be said for the other "Big Five" programs.

The Abrams program cost growth was comparable to the Joint Strike Fighter (JSF/F-35) cost growth in 2009. But is this a fair comparison, since the Abrams is a completed program and the JSF has yet to be fielded? There are arguments both for and against comparing the two. Clearly, there is a need to note the stage of each program when making this comparison, but as shown in the examination of the Black Hawk, some programs see diminished cost growth as they become more mature.

The Apache program cost growth is on par with the terminated Armed Reconnaissance Helicopter (ARH) and the terminated Future Combat System (FCS). And this is good compared to the Patriot and the Bradley. The successful fielding of the Patriot and Bradley demonstrates that cost growth can be overcome if there is a compelling requirement, pervasively communicated to stakeholders through a continuous effort by an engaged leadership team.

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Recommendations

The lessons learned from the "Big Five," seen through the filter of the environmental changes that have happened since, suggest a number of recommendations. The five most significant recommendations are:

1. Lead
2. Prioritize and focus
3. Create flexibility
4. Maintain expertise
5. Communicate strategically

1. The first recommendation is to lead actively, continuously and throughout. Continuity of leadership at all levels is important. This includes making sure the right individuals are placed in critical roles. An example of this is when the Abrams program was getting ready to enter production and needed a new program manager. The acting commanding general of U.S. Army Materiel Command (AMC), LTG Sammet took personal action:

> … one of the problems was, 'Who can you put in as a PM who knows production of tanks?' Well, I went for Babers. Babers had just moved and taken over a Command. He didn't have three months and they said to me, 'You'll never get Babers. Personnel rules are he's in Command-untouchable. He's been there three months; you don't move him for two years.'
>
> So I went to the Secretary of the Army. I said there's one guy that knows production of tanks in this Army. You want the M1 to be successful? Then we better put Babers in there. They called up and said: 'Send Babers.' Just like that.[117,]

What the business world calls "talent management" was a critical leadership action that led to success. Leadership is multi-dimensional. Another dimension is the ability to maintain continuity at the most senior levels, given that the changes from Goldwater-Nichols mandate conscious forethought and redundancy. When GEN Abrams was unexpectedly diagnosed with cancer and died while still the Chief of Staff of the Army, the "Big Five" continued because the effort was integrated among the Secretary of the Army, the Vice Chief of Staff of the Army (who became the next Chief), and the TRADOC and AMC commanders, as well as a host of others. This pervasiveness was the result of active planning and forethought. The more re-

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117 Besson, Frank S., Jr., *et al.*, *Reflections of former AMC commanders*, (Alexandria, VA: Historical Office, US Army Materiel Command, 1989), LTG Sammet's interview.
Babers refers to then BG Donald M. Babers, who went on to retire as a LTG.

cent increase in the turnover of political appointees in the Army makes this more challenging and therefore requires substantial proactive efforts.

2. The second recommendation is to prioritize and focus. While these could be included under leadership, they are important enough to warrant their own recommendation. Prioritization and focus must be more than PowerPoint deep or simply decreed in a memo; they must be backed by the application of resources and senior leaders' time. A good example from the "Big Five" is the budget request for fiscal year 1976:

> The Army's research and development effort covers projects that range from tanks and helicopters to radios and military medicine. Of highest priority, however, is a group known as the "Big 5." These five programs offer the promise of satisfying the Army's most pressing current materiel needs. Therefore, these programs are given priority on resources. They include two new ground combat weapon systems —the Main Battle Tank, XM-1, and the Advanced Attack Helicopter; two new mobility systems—the Mechanized Infantry Combat Vehicle (MICV), and the Utility Tactical Transport Aircraft System (UTTAS); and a new medium/high altitude sir defense weapon system—SAMD-D [sic] (surface to air missile development). Brief highlights of these programs and technology overview follow.[118]

The budget request goes on to spend more than three pages discussing the details of the "Big Five." The ability and need to prioritize and focus was evident at the major command level as well. In December 1975, at the beginning of fiscal year 1976, the commanding general of TRADOC, GEN William DePuy, wrote an unsolicited letter to the Chief of Staff of the Army classified SECRET, stating, "… because of the severe budget situation, I am prepared to give you a list of ten developmental items which are crucial to our success on the modern battlefield."[119] The first three listed were the XM-1, the MICV, and Attack Helicopters. It is important to note that the Black Hawk was already in the final stages of its fly-off competition and therefore essentially out of development, and that the Patriot was in the midst of its temporary halt for proof of principle. This prioritization and focus was critical to overcome the challenges and obstacles that beset even the "Big Five".

3. The third recommendation is flexibility. Flexibility is needed to overcome the inherent linearity of the acquisition process with feedback mechanisms. This is necessary because of what we will call the "future's dilemma." The future's dilemma is the inherent contradiction between the need to forecast the future to identify capability needs and justify requirements to meet those needs, and the near certainty that these predictions will be wrong. The closer we are to the future (i.e., the further you are into a program), the better able we are to

[118] Weyand, Fred C., *Frederick C. Weyand papers, 1972-1999*, (maintained at United States Military History Institute, Carlisle Barracks, PA, 1972-1999), Army budget request for fiscal year 1976.

[119] Ibid, December 1, 1975 letter from TRADOC CG to CSA [DECLASSIFIED 31 DECEMBER 1981].

see the future. Unfortunately, the rigidity of the acquisition process requires locking in requirements when they are most unknowable and leaves little, if any, room to adjust these requirements as the future becomes better defined. Similarly, technological innovations rarely occur in the exact form and fashion as expected. This puts a premium on the integration of users and engineers—of operators and technologists—throughout the life of a program, as well as continuously re-evaluating assumptions and their implications. This flexibility needs to be carefully differentiated from "requirements creep" that just wants to add to programs, making them unwieldy and unmanageable. Integrating flexibility and feedback successfully will mean continuously refining and tightening requirements and thereby making the weapon system both more capable and more useful (and potentially more affordable, as occurred when Patriot requirements were scaled back).

4. The next recommendation is to maintain expertise. One of the reasons for the challenge of maintaining expertise is that until the 1960s, acquisition programs followed right on top of each other, so called "heel-to-toe" programs, but more recently there have been significant gaps in Army programs. Eliminating these gaps through heel-to-toe programs will increase expertise. Heel-to-toe programs may be upgrade programs that follow on initial developmental programs but only if they fulfill the need of maintaining the cutting edge of relevant expertise. In the case of the "Big Five" and the follow-on upgrade efforts, these efforts have focused on parts of each system and may, in those cases, have afforded the Army the ability to maintain expertise. But in the areas that have *not* been the focus of upgrade efforts, it's been three or four decades since that expertise was called upon and utilized. A good example of maintaining "heel-to-toe" programs is the Navy's shipbuilding program where a concerted effort is made to balance workload across years and individual acquisition programs to ensure ship yards continue to have work and the relevant expertise is maintained.

5. The final recommendation is to communicate strategically. Strategic communications must be compelling, pervasive, and updated regularly. GEN Starry's review of the briefing to support the Bradley is worth reproducing again to emphasize this need:

> 1. I have reviewed the briefing … It falls well short of the mark. In fact it's horrible. If we are to satisfy our critics in OSD, the Congress, and elsewhere of the need for the IFV/CFV, then we must put together a very convincing case, which this briefing does not do. We must describe operational concepts which generate the requirement for an IFV with the capabilities we have said we require, e.g., kill BMPs, XM1-like mobility, etc.
>
> 2. … One of the reasons we have not been successful in articulating our case for the IFV is because our critics view it as just a product-improved 113, which it is not. The 113 is a carrier; the IFV is a fighting vehicle. It is the difference between the two, and why a fighting vehicle is needed, that we have not clearly articulated to our critics. To make the case, we must first describe how tanks, long-range infantry

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> and short-range infantry must fight together on the battlefield, clearly describing the complementary roles of each. Structuring the battlefield by infantry as described in the briefing certainly is not one of them. Then we must show why the M113 is inadequate for operations with the M60 series tanks, given its limited armor protection and limited firepower. When we go to the XM1 the situation just gets worse. Here we must clearly describe the stress on the tank due to the 113's inability to operate with our current and future tanks. Having done all this, the operational concept for employment of the IFV with the XM1 must be shown. But, again, not described as simply a product-improved 113 nor, on the other hand, should it be made to appear as a light tank. It must be shown as a fighting vehicle that can unstress the tank and also carry infantry."[120]

The communications planning effort for major acquisition programs needs to be integrated within the total Army framework. While a program manager may be able to focus on his or her individual program, the career bureaucrats in the Office of the Secretary of Defense and professional staff on the Hill do not have a similar luxury. Instead these very capable, long-serving individuals have oversight over a variety of programs and need to be able to succinctly grasp the rationale for commitments of very large amounts of resources over a significant length of time. In general, the manning of the Army staff in the strategic communications realm is short term and high turnover. This means that the Army has a *de facto* personnel process that puts it at a disadvantage in dealing with its stakeholders. While this is something that can be overcome, it requires the active leadership already discussed as well as an open, proactive, and two-way approach to communicating with stakeholders.

These recommendations are purposely broad. Success requires a holistic approach; a detailed list as others have prescribed in the past is easy to cherry-pick; and may solve some specific problems but is likely to result in other challenges, or risk falling to the tests of time.

[120] Starry, Donn A., *Press on!: Selected Works of General Donn A. Starry*, (Fort Leavenworth, KS: Combat Studies Institute Press, 2009), 240.

Appendix A: Illustrations

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Appendix C: Abbreviations

A-X	Developmental Close Air Support Aircraft Program that produced the A-10
A-10	Warthog Close Air Support Aircraft
AAFSS	Advanced Aerial Fire Support System
AAH	Advanced Attack Helicopter
AH-1	Cobra Attack Helicopter
AH-56	Cheyenne Attack Helicopter
AH-64	Apache Attack Helicopter
AIFV	Armored Infantry Fighting Vehicle
AMC	Army Materiel Command also USAMC
APC	Armored Personnel Carrier
ARCIC	TRADOC’s Army Capabilities Integration Center
ARH	Armed Reconnaissance Helicopter
ARSV	Armored Reconnaissance Scout Vehicle
ARVN	Army of the Republic of Vietnam
BMP	Boyevaya Mashina Pekhoty Soviet Infantry Fighting Vehicle
BRL	Ballistic Research Laboratory
CAIG	Cost Analysis Improvement Group
CFV	Cavalry Fighting Vehicle
CH-47	Chinook Helicopter
CSA	Chief of Staff, Army
CTE	Critical Technology Event
DoD	Department of Defense
ECM	Electronic Counter-measures
FCL	Fully Combat Loaded
FCS	Future Combat System
FMC	Food Machinery Corporation
FVS	Fighting Vehicle System
GAO	General Accounting Office later Government Accountability Office
HIMARS	High Mobility Artillery Rocket System
HLH	Heavy Lift Helicopter
IDA	Institute for Defense Analyses
IFV	Infantry Fighting Vehicle
ILS	Integrated Logistic Support
IOC	Initial Operating Capability
JSF	Joint Strike Fighter
LRIP	Low Rate Initial Production
M1	Abrams Main Battle Tank
M2	Bradley Infantry Fighting Vehicle
M3	Bradley Cavalry Fighting Vehicle
M-48	U.S. Patton tank
M-60	U.S. tank

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M113	U.S. Armored Personnel Carrier
M247	Sergeant York Division Air Defense Gun
MBT-70	Main Battle Tank—70
MICV	Mechanized Infantry Combat Vehicle
MIM-14	Nike Hercules
MIM-23	Hawk Anti-Aircraft System
MIM-46	Mauler Anti-Aircraft System
MIM-104	Patriot Air Defense System
MLRS	Multiple Launch Rocket System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
OH-58D	Kiowa Warrior
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
PAC-1	Patriot Advanced Capability - 1
PAC-2	Patriot Advanced Capability - 2
PAUC	Program Acquisition Unit Cost
PPBE	Planning, Programming, Budget, and Execution system
QMDO	Qualitative Materiel Development Objective
QMR	Qualitative Materiel Requirement
R&D	Research and Development
RAH-66	Comanche Helicopter
RDECOM	AMC's Research, Development and Engineering Command
RDT&E	Army Research, Development, Test and Evaluation funding
RFP	Request for proposals
SAM-D	Surface-to-Air Missile Defense
SAR	Selected Acquisition Report
TILS	The Improved Lift Ship
TOW	Tube-launched, Optically-tracked, Wire command data link, guided Missile
TRADOC	Training and Doctrine Command
TVM	Track-via Missile
UH-1	Huey Helicopter
UH-60	Black Hawk Helicopter
USACDC	U.S. Army Command Developments Command
USAMC	U.S. Army Materiel Command
UTTAS	Utility Tactical Transport Aircraft System
XM-1	U.S. Army developmental tank program that produced the M1
XM-701	Pacific Car and Foundry MICV-65 prototype
XM-723	FMC MICV-70 prototype
XM-734	FMC MICV-65 prototype
XM-765	FMC MICV-65 prototype later sold as AIFV
XM-803	U.S. Army tank program
YUH-60A	Sikorsky UTTAS prototype

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