Mission Emphasis and the Determination of Needs for New Weapon Systems

by

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ABSTRACT

Efforts to understand the determination of needs of new weapon systems must take into account inputs and actions beyond the formally documented requirements generation process. This study analyzes three recent historical cases of fighter aircraft development to identify decisions made independently from the documented requirements process, about the need for new systems. The primary inputs to those decisions are identified, and a qualitative model for understanding the undocumented inputs, and their role in determining weapon system needs, is presented. By analyzing data across the cases, which span a period of significant change in fighter design, the concept of a Dominant Mission Emphasis (DME) is introduced. The DME is defined as that mission which receives the most emphasis from the majority of participants in the needs determination process, and which the majority of other missions support, either directly or indirectly. It emerges when enough participants become convinced that it is appropriate to address the military, economic, political, social, and other needs that exist, and it serves as a means for bounding the intractable array of possibilities for weapon system needs. The convincing of participants occurs primarily through a social process, not a technical or an authoritative one. Over time, as conditions change, the appropriateness of the DME will decrease. The appropriateness over time can be modeled with a bell-shaped curve. Cues are identified which suggest the need to re-examine the DME. The strength of a DME can be measured by qualitative and quantitative indicators, including such things as verbal statements, military doctrine, intellectual and academic writings, organization within the military, resources committed, and promotion decisions. These indicators can also be used as controls to strengthen or weaken a DME in response to the perception of its appropriateness for existing conditions. The DME is constantly being questioned and challenged by individuals who seek to convince others that its appropriateness is not sufficient for existing conditions. Alternative missions are proposed and advocated as new DMEs. The roles of the primary means for convincing participants of the appropriateness of a DME are presented.

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Biographical Summary of Author

Daniel Gillespie is a Lieutenant Colonel in the U.S. Air Force. He graduated from the U.S. Air Force Academy in 1990 with a degree in Aeronautical Engineering. After attending pilot training he worked for three years as a weapons development engineer in the Aeronautical Systems Center at Eglin Air Force Base, Florida. Over the next nine years he flew in operational assignments in the KC-135 air refueling aircraft and the C-21 operational support airlift aircraft. During this period he was involved in training, scheduling, and flight safety, as well as serving as flight commander and assistant director of operations. In 1997 he was awarded an MS degree in Aerospace Engineering from the University of Colorado. Prior to attending MIT, Daniel was an assistant professor at the U.S. Air Force Academy, in the Military Strategic Studies Department. He and his wife, Laura, have six children.

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Even though I am the one who gets to cross the stage and receive the degree that comes as a result of this dissertation, there would be no fancy robes, colorful hoods, or framed diplomas without the efforts of many others. I would like to acknowledge a few of them here, although I cannot fully express the impact they had. Nor can I include everyone who had a part in helping me achieve this goal.

The faculty of the Military Strategic Studies Department at the U.S. Air Force Academy, especially Colonel Tom Drohan, Dr. Dorri Karolick, and Dr. Jim Titus, showed great confidence in me by selecting me for this opportunity, and providing the sponsorship. I am also grateful for their encouragement and advice.

Many faculty members and friends at MIT had a great influence on me, and helped me along the way. Debbie Nightingale and others in the Lean Advancement Initiative provided a forum for the exchange of ideas, as well as financial and administrative support during my course of study and research. My friends at the Silo, Joao Castro, Dan Livengood, Dave Long, Pedzi Makumbe, Sid Rupani, and Robb Wirthlin, were especially helpful in teaching me the ropes of student life at MIT, and making the experience fun. I am especially grateful to Robb Wirthlin for his example of standing up for what is right, and doing so at great personal sacrifice, while at the same time completing a PhD at MIT. Mike Kometer, and especially Jason Bartolomei were my pacesetters in the program and showed me the level of effort, and intensity it would take to finish the program within the time constraints imposed by the Air Force.

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One of my methods of data collection was live interviews of people who participated in the development of the Air Force fighters I studied. I would like to thank Colonel Everest Riccioni, Harry Hillaker, Chuck Myers, General Larry Welch, Brigadier General Bob Titus, Dr. Robert Seamans, and Lieutenant General Glenn Kent, who very graciously hosted me, in some cases in their homes, spent time with me, and unselfishly shared their knowledge, experiences, and ideas. I consider each of these people to be great men, and great Americans who gave (and in some cases continue to give) of themselves to improve our nation and the world. The opportunities to meet and converse with them were among the most memorable experiences I had during my MIT education.

I am also indebted to the historians and archivists who helped me locate and acquire data. Joseph Caver, Sylvester Jackson, and Jerome Ennels, at the Air Force Historical Research Agency; Jerry Martin, at the U.S. Strategic Command History Office; and Dan Harrington, at the Air Combat Command History Office gave both help and encouragement.

The traits I possess that have allowed me to complete this work; the desire to learn, the interest in the world around me, the confidence, the ability and desire to work hard and persevere, and the humility to be taught are thanks to the great parents I have. Their influence extends far beyond my schooling or my career, and will be felt eternally.

I also acknowledge my brother, Paul, who pioneered the world of higher education for me, as well as many other areas in life. Life is easier following in his footsteps, and his advice and encouragement continue to be invaluable.

Returning to school after many years, especially to a school as demanding as MIT, was a commitment and a challenge for the whole family. I am grateful for the patience and understanding of my children: Mark, Helen, Mary, Anna, Christina, and Selina. Not only did they put up with not having as much of their father's attention, but sometimes when they got it, it was diluted by stress, sleep deprivation, or other effects of having a PhD student for a father. I am grateful for their desire to be good. It makes parenting easy and fun.

If it were possible, I think MIT should confer two degrees, with the second one going to my wife, Laura. She has worked every bit as hard as I have, she has felt the stress, and she has shared the disappointments and the successes along with me. Of all those I have acknowledged who have helped me so much, Laura was the one essential person in this effort. I can honestly say that without her help and support, I would have failed. More significantly, however, she has been a strength to our family. The most important and lasting work we will do is in our home, and Laura made sure that work continued uninterrupted throughout my time in school. She carried her own load as a wife and a mother, and then took on much of mine so that I could complete my degree. She is the best, and I will love her forever!

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List of Acronyms

ACC	Air Combat Command
ACF	Air Combat Fighter
ACTS	Air Corps Tactical School
ADC	Air Defense Command
AFHRA	Air Force Historical Research Agency
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
AMC	Air Materiel Command
AoA	Analysis of Alternatives
ARDC	Air Research and Development Command
ASC	Aeronautical Systems Center
ASD	Aeronautical Systems Division
AWACS	Airborne Warning and Control System
BuWeps	Navy Bureau of Weapons
BVR	Beyond Visual Range
CAS	Close Air Support
CDD	Capabilities Development Document
CFP	Concept Formulation Package
CONOPS	Concept of Operations
DCP	Development Concept Paper
DDR&E	Director of Defense Research and Engineering
DME	Dominant Mission Emphasis
DoD	Department of Defense

ECM	Electronic Countermeasures
EM	Energy Maneuverability
FAA	Functional Area Analysis
FMS	Foreign Military Sales
FNA	Functional Needs Analysis
FSA	Functional Solutions Analysis
FSD	Full Scale Development
FX	Fighter, Experimental
FY	Fiscal Year
GAO	Government Accountability Office
GD	General Dynamics
GOR	General Operational Requirement
ICBM	Intercontinental Ballistic Missile
IFF	Identify Friend or Foe
ISR	Intelligence, Surveillance, and Reconnaissance
JATO	Jet Assisted Takeoff
JCD	Joint Capabilities Document
JCIDS	Joint Capabilities Integration and Development System
MAP	Mission Area Plan
MASA	Modern Air Superiority Fighter
MNS	Mission Needs Statement
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization

ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
PACAF	Pacific Air Forces
PIA	Post Independent Analysis
PMD	Program Management Directive
QOR	Qualitative Operational Requirement
RADM	Rear Admiral
RGS	Requirements Generation System
RHAW	Radar Homing and Warning
ROC	Required Operational Capability
SAB	Scientific Advisory Board
SAC	Strategic Air Command
SAGE	Semi Automatic Ground Environment
SAM	Surface-to-Air Missile
SDR	System Development Requirement
SEAD	Suppression of Enemy Air Defenses
SOR	Specific Operational Requirement
SPO	System Program Office
STOL	Short Takeoff and Landing
TAC	Tactical Air Command
TFX	Tactical Fighter, Experimental
TPP	Total Package Procurement
UAV	Unmanned Aerial Vehicle
USAF	United States Air Force

USAFE	United States Air Forces in Europe
V/STOL	Vertical/Short Takeoff and Landing
WADD	Wright Air Development Division
WS	Weapon System

Chapter 1
Introduction

> *The survival of nations or even of whole cultures may depend upon the ability to procure superior weapons. It behooves us to be certain that our system is adequate to ensure this superiority. The experience of men who have grappled with this problem in the past should prove valuable to those who must deal with the question in the future.*
>
> *I. B. Holley, Jr.*[1]

In 2002 the U.S. Air Force began an attempt to replace its fleet of aging KC-135 air refueling ("tanker") aircraft. Seven years later the average age of the fleet has increased to over 45 years, and there is still no program in place to procure a new tanker. Recently a competition was held between two proposed designs, and although the Air Force selected one of them, the competition was deemed unfair, which eventually led to the program's termination. Even though either of the designs would have met the requirements specified by the Air Force, it is apparent that the selected design did not meet some unspecified requirements held by some stakeholders involved in the process.

This study seeks to use a *systems*-level[*] approach to investigate the undocumented inputs to the determination of needs for new Air Force weapon systems. A modern weapon system such as a fighter aircraft is extremely complex, with tens of thousands of precision parts that must be joined with tight tolerances using complicated processes in

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[*] The word "system" will be used in two distinct and different ways in this thesis. The first is in the context of a weapon system, which can be defined as: "A set of interacting components having well-defined (although possibly poorly understood) behavior or purpose; the concept is subjective in that what is a system to one person may not appear to be a system to another." With the extensive experience the military has with aircraft weapon systems, there is a relatively consistent understanding of what the term means when used in this context. The other usage refers to an engineering system, as used by MIT's Engineering Systems Division, which is defined as: "A system designed by humans having some purpose; large scale and complex engineering systems, which are of most interest to the Engineering Systems Division, will have a management or social dimension as well as a technical one." In this paper, when the word "system" is used in this context it will be italicized in order to avoid confusion as to which meaning is intended. For definitions, see: Allen, T., et al., *ESD Terms and Definitions*, in *ESD Working Paper Series*. 2002, Massachusetts Institute of Technology: Cambridge, MA. p. 8.

such a way that they will withstand the enormous aerodynamic forces, harsh flight environments, and even man-made threats. Deciding what machine to build to function effectively within those constraints is no simple matter. When one also considers the large number and variety of people and organizations that influence the decision, and who have a stake in the outcome, the question becomes even less straight-forward.

According to its stated policy, "The Defense Acquisition *System* exists to manage the nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces."[2] "Strategy originates in policy," according to Air Force doctrine, and is a "matching of means to ends." Doctrine, on the other hand, "presents considerations on how a job should be done to accomplish military goals… in support of national objectives. … [It] shapes the manner in which the Air Force organizes, trains, equips, and sustains its forces."[3] This somewhat simplistic explanation gives a generally accepted process by which national policy translates into military actions; that is, by providing the *means* through the organizing, training, *equipping*, and sustaining of forces, in part through the procurement of weapons.

The extension of this chain, that connects security strategy through technology to weapon systems, is an especially strong link for the U.S. Air Force, because of its dependence on the weapons it employs. As Meilinger points out, armies and navies have long existed using only basic technologies. "Man has been able to fight with his hands or simple implements and sail on water using wind or muscle power for millennia."[4] On the other hand, fighting in the medium of air and space was not even possible until one of the most significant technological breakthroughs was achieved; that of sustained, powered flight. This dependency on technology for the very existence of air and space power capabilities links the weapons used to the strategy employed, the doctrine that guides the strategy, and the national policies they support. To succeed in furthering national policy, an effective link must be made to weapons. As Holley asserts, "Doctrine is inadequate without an organization to administer the tasks involved in selecting, testing, and evaluating 'inventions.'"[5] The technology available determines to a great extent, especially for the Air Force, the effectiveness of the weapons it procures.

Security studies and military strategy are widely studied, and indeed whole academic departments at major universities, as well as professional military schools, are devoted to these areas. Military doctrine has also been, and continues to be, thoroughly studied, not only at the professional military schools, but also through practical experience. Similarly, constant efforts are underway to find new technologies, and to improve the technology that is in use. The challenge arises when integrating these three areas. The integration of technology, which obviously requires a high degree of technical expertise, with strategy and doctrine, which have traditionally been studied and practiced by people with non-technical educations and backgrounds, is especially challenging. As technology becomes more complex the challenge increases along with the necessity to overcome that challenge.

The intricate details of program schedules, contracts, budgets, etc., and the myriad other activities and responsibilities that fall under acquisition preclude the intimate involvement of all parts of this *system* in strategy or doctrine, despite the fact that they are tied together. While the acquisition *system* sits at the intersection of the three, the very beginning of the acquisition process, when a weapon system is conceived, is at the very heart of that intersection. The decisions that determine what technology will be used to implement strategy, in accordance with doctrine, and what form that technology will take, will also determine the outcome of the process; that is, how well the system will fulfill its purpose. The function of specifying what systems will be built is fulfilled by the requirements generation *system*, and is therefore the focus of this study.*

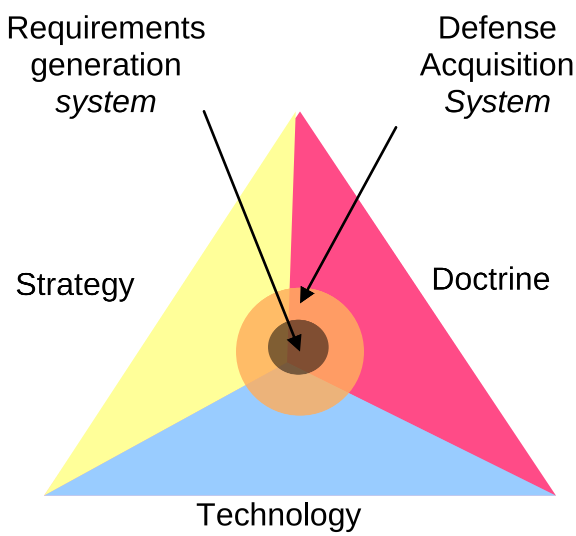

Figure 1.1. At the intersection of strategy, doctrine, and technology lies the Defense Acquisition *System*, and more specifically the requirements generation *system*.

As the technological systems required to implement national strategy have become more complex, so has the *system* for acquiring them. The end of World War II marked the first time in American history that a war ended, but the nation was not able to safely disarm. That, along with the significantly increased costs associated with high-technology modern weaponry, made defense expenditures a much higher percentage of the national budget. The concern was voiced that those who bought and sold weapons would gain undue power and influence. President Eisenhower warned of the dangers of the military-industrial complex. With greater sums being spent on weapons and concerns

* The current process is the Joint Capabilities Integration and Development System (JCIDS), which is introduced briefly later in Chapter One.

that money and influence might be misused, more oversight was applied by Congress and other organizations. There began to be much more scrutiny of what the military services procured. Questions such as whether the services needed the weapons, whether another service already had the capability, whether the capability provided by the weapon was worth the cost of procuring it, whether the country could afford all of the weapons the services asked for, and if not what should be the priorities, are examples of oversight involvement.

The result of this scrutiny was that the process for procuring weapon systems became much more involved. Instead of a process that was relatively well contained within each service for deciding how to spend money allotted, each service became more accountable to the other services, to Congress, and even to the President before a procurement strategy could be pursued. After the Department of Defense was created in 1947, more layers of approval, both formal and informal, began to emerge as the department grew in size, authority, and relevance. With more expensive weapons and higher percentages of the national budget being spent on them, public approval became increasingly important as well.

The scrutiny, oversight, and need for approval of more people and organizations in the weapons procurement process could not help but influence the decisions of what the services procured. Whereas before World War II a few dominant leaders within the relatively small military services could exert a large measure of control over the procurement process, after the war the decisions had to be agreed upon by a consensus of many participants, both military and civilian, and at various levels of different organizations within the government. Furthermore, it increasingly had to satisfy conditions controlled outside the government, including watchdog groups, and public opinion.

No longer could a weapon be procured on the basis of its military utility alone. It also had to provide a capability which complemented but did not duplicate that provided by other services to do so in cost effective manner, to fit into the President's defense strategy and into the budget, and to support the foreign policy. Furthermore, Congress had to be satisfied with not only the weapon but also the specifics of the program, and the public had to approve.

Evidence of the necessity of better understanding the process for determining the needs for weapon systems is provided by the weapons themselves. In a period of just under two decades both the F-111 and the F-16 were conceived, developed, and produced. Both aircraft were procured in the attempt to support national policy in a cost effective manner, but the results of the two aircraft programs were very different, showing the variability and uncertainty of the process.

The F-111 was the result of years of dedicated efforts to determine the needs for future combat, and to define a system that would meet the needs. It incorporated cutting-edge technology, some of it yet to be fully developed. It outperformed all previous fighter aircraft in virtually every category, according to accepted performance measures. Despite all of this, the aircraft was called a failure by many, and was procured in far fewer numbers than envisioned. Instead of becoming the frontline fighter of the Air Force, it was given one mission in support of the overall effort, which was largely fulfilled by other aircraft.

The F-16, in contrast, has been called an afterthought. It was adapted as a production fighter from a technology demonstration prototype which had been developed for the purpose of demonstrating the utility of existing technologies on fighter aircraft. No requirements were written, and a primary defining characteristic was low cost. Despite these impromptu beginnings, the F-16 became the frontline fighter of the Air Force, and has been one of the most successful fighters ever developed.

It is tempting to allow a positive result to justify the *system* that produced it, while blaming negative results on so-called "external" factors. These examples raise questions about a *system* that can produce such disparate results, even if it is subject to external factors. Determining the inputs to the resulting aircraft systems, whether classified as internal or external, is very important. Understanding how the inputs influence systems can allow more deliberate determination of weapon systems needs.

Related to the perceived success and failure of systems is the ability to conduct military operations. When the Air Force enters combat, it does so with the weapon systems it has previously developed based on the needs it determined in anticipation of that combat. There have been times when it has entered combat with inadequate systems for accomplishing its missions. For example, in Vietnam Air Force fighters were lacking in the ability to conduct air-to-air combat. Operation Desert Storm provides the opposite example, where systems proved to be very well suited to the combat missions required. Understanding the process by which needs are determined can have an impact on future combat success.

Secretary of Defense Robert M. Gates is currently advocating a "balanced approach" to the national defense strategy. The proposed strategy would de-emphasize traditional combat operations, with an increased emphasis on strengthening good government in areas of the world that spawn terrorists, building the local economies in those areas, and promoting development.[6] The ability of the military, including the Air Force, to accomplish its missions is reliant upon the weapon systems it employs. The systems the Air Force will have available to support the change in mission emphasis advocated by Gates will be the product of the needs determination process.

The Air Force has announced that among its top five acquisition priorities are a new aerial tanker, a combat search and rescue helicopter to rescue downed pilots, the F-35 tactical fighter, and a new strategic bomber, all of which support an emphasis on traditional combat operations.[7] This apparent disparity between Gates' balanced approach, and the traditional combat approach supported by these weapon system acquisition priorities raises further questions about the determination of needs, and the role of mission emphasis in that process. Understanding the relationship between mission emphasis and weapon systems needs determination, as well as a broader understanding of the process by which agreement is obtained regarding what mission should be emphasized, are significant in order to be prepared for future national security scenarios.

The problem of determining needs has been studied before, but the focus invariably has been on the formal process. Efforts have alternated between identifying general capabilities, which allows for more creative ideas to be introduced, and producing more specific requirements, which allows for more control of the outcome. Despite these oscillations, the basic effectiveness has remained somewhat constant over the past several decades. Lieutenant General Glenn Kent, who spent over forty years in and around the

Pentagon as an analyst and decision maker heavily involved in weapon systems acquisition, stated that despite periodic revisions,

> …the general characteristics [of the defense acquisition system] have remained more or less constant:
> - a set of "milestones" that must be accomplished and certified before services are permitted to proceed with the development of new concepts
> - a tendency to conflate statements of operational need with potential hardware-oriented solutions
> - a stultifying inclination to impose centralized control over efforts to explore new concepts for accomplishing operational tasks.[8]

These attributes are evident in the latest shift in the documented requirements generation process.

Up until 2003 the process was known as the Requirements Generation System (RGS). Under this system a list of tasks necessary to support strategy was determined in the Air Force's Mission Area Plan (MAP), through Mission Area Analysis. This task list was then examined to identify deficiencies in the required task capabilities using Mission Needs Analysis. These needed capabilities were documented in a Mission Needs Statement (MNS), along with potential alternatives for remedying the deficiency. A validation process was then used to narrow the alternatives and produce an Operational Requirements Document (ORD) for a new system.[9]

In 2002 the system was deemed inadequate. A Joint Staff memorandum entitled "Changes to the Requirements Generation System," released on 7 October, 2002, stated, "The current process [the RGS] frequently produces stovepiped solutions that are not necessarily based on the future capabilities required by the joint warfighter."[10] Stovepiped solutions refer to those which satisfy only one part of an organization, while neglecting the needs of the whole enterprise. These solutions referred to by the memorandum, which are "not necessarily based on the [needs] of the warfighter," are commonly presumed solutions, predetermined based on preconceived ideas.

The RGS was replaced by the Joint Capabilities Integration and Development System (JCIDS), which was an effort to move away from detailed requirements of predetermined systems, and focus instead on capabilities that were needed. A material solution is only one option that is to be considered. Furthermore, the process is designed to be joint, focusing on overall military capability, not the specific needs of each service.

The JCIDS parallels the RGS, with the Concept of Operation (CONOPS) being analogous to the MAP. Functional Area Analysis (or FAA, analogous to Mission Area Analysis) is accomplished to determine a list of capabilities needed to support CONOPS. Functional Needs Analysis (FNA, similar to Mission Needs Analysis) identifies deficiencies in the ability to provide needed capabilities. These are documented, along with proposed solutions (found using Functional Solutions Analysis, or FSA) in a Joint Capabilities Document (JCD), which replaced the MNS. The final presentation of validated needs is documented in a Capability Development Document (CDD), which took the place of the ORD. Figure 1.2. gives an overview of the JCIDS process.

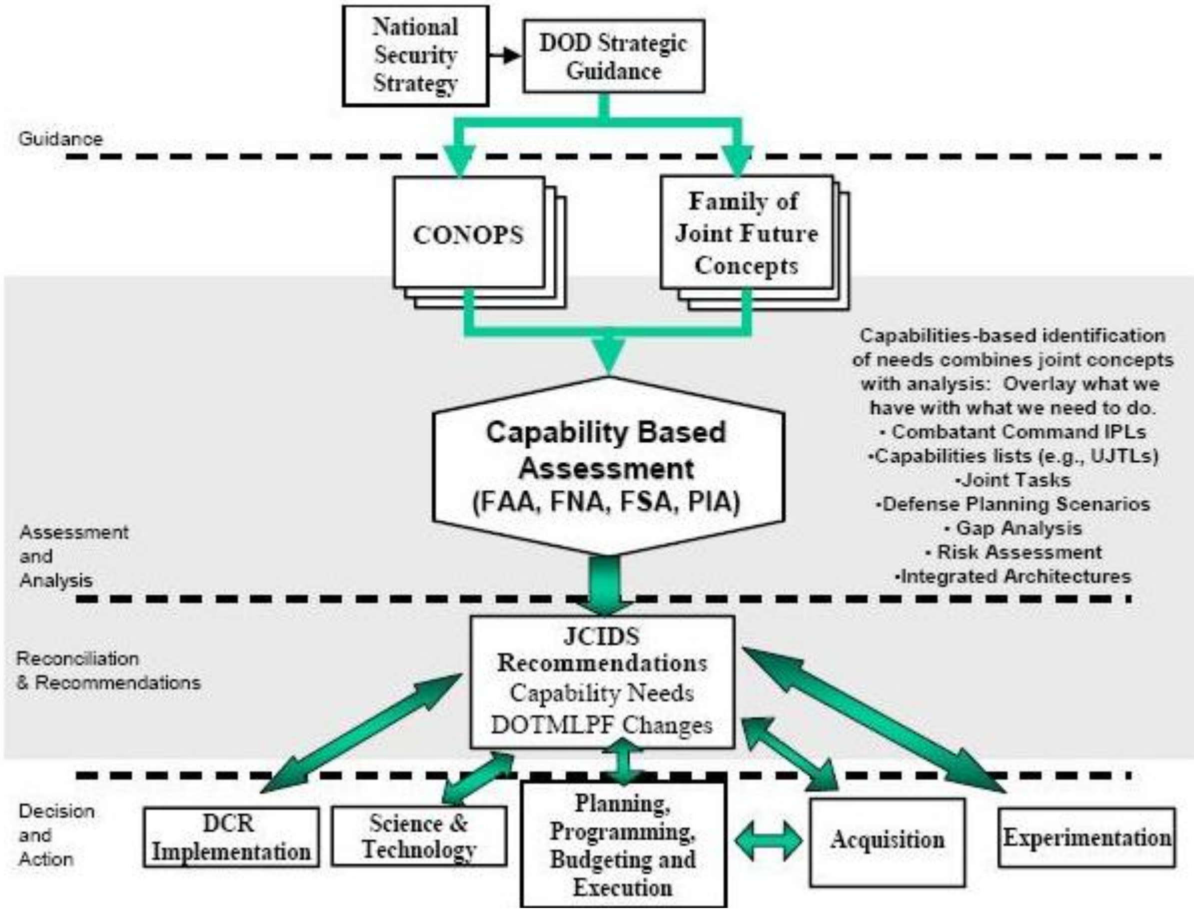

Figure 1.2. Top Down Capability Need Identification Process, as presented in the documented requirements generation process.[11]

This comparison of the JCIDS to the RGS it replaced supports Kent's assertion that the general characteristics of the process have remained more or less constant. In fact, a similar makeover occurred in the late 1960s, when the operational requirements were replaced by Required Operational Capabilities (ROC). The focus, and semantics, have again moved away from requirements to needed capabilities.

Despite the effort to move away from preconceived systems solutions, and solutions that meet the needs of only one part of the enterprise, there is strong evidence that JCIDS produces similar results. Senator Claire McCaskill, who sits on the Senate Armed Services Committee recently decried stovepiped solutions, even under the new

JCIDS. She referred to the system as "all the services getting together and basically giving each other what they want."[12] The phrase, "what they want," implies that the services have already chosen a predetermined solution that is being pushed through the JCIDS process. Kent agreed with the JCIDS approach in concept, but as far as implementation is concerned he called the effort "absolutely obscenely wrong" because he believes it still focuses too much on preconceived ideas for specific systems.[13] Charles E. "Chuck" Myers, Jr., a consultant for acquisition matters who has been involved in the field for nearly fifty years in contractor, government, and consultant positions, contends that the JCIDS is simply used as a tool to introduce presumed solutions that already have support.[14]

The fact that the documented requirements process begins with preconceived ideas indicates that the decisions made prior to the beginning of that documented process are important to the selection of weapon systems, and the relating of new technologies to strategy. In order to improve results, the entire process, documented and otherwise, must be understood. Inputs to decisions made outside the documented requirements process must also be understood and taken into account.

Research Questions

To focus the effort to understand the relationship of strategy, doctrine, and technology, manifested in the determination of needs, the following two questions have been identified:

1. How can undocumented inputs to needs determination be understood in the overall process, and how do they influence the selection of new systems?

2. What influences can be exerted on the mission being emphasized by the Air Force to meet its objectives?

The existence of stovepiped and preconceived solutions, suggesting that inputs to requirements are coming from sources other than those inputs that are an established part of the documented requirements generation process, highlights the need to understand the role undocumented inputs play. The second question, pertaining to the mission being emphasized by the Air Force, addresses a concept that was found to be related during the course of the research. The determination of weapon systems needs and the missions those systems support are obviously related. This study will explore that relationship in order to understand the *system*-level process of determining needs.

Research Approach and Methods

In order to answer the research questions, fighter aircraft from recent history were chosen as weapon systems to investigate. Specifically, three cases of fighter development were studied: the "TFX" program, which resulted in the F-111; the "FX" program, which resulted in the F-15; and the Lightweight Fighter program, which resulted in the F-16. Besides being major development programs that offer a favorable opportunity to investigate decisions that were made outside of the formal requirements process, they also span a change in mission emphasis by the Air Force.

The investigation of historical cases allows a more complete *systems*-level treatment of the weapon systems, while still being recent enough to retain relevance to current and future situations. While it could be argued that more current systems, such as the F-22 or F-35, would be more relevant because those aircraft are at the beginning of their service lives, their success or failure cannot yet be determined. This would preclude the ability to fully analyze early decisions since the full outcomes of the decisions are still unknown.

Access to data for current programs would also present a problem since most of it is still classified. Even much unclassified information, such as that having to do with source selection, would be sensitive and unusable in an open document. Another factor that would limit data collection is the unwillingness of those involved in current programs to discuss many of the undocumented sources of decision inputs. The documented process relies on the ability to convince all stakeholders that decisions are justifiable based on documented inputs. Participants would therefore be less willing to discuss such inputs as intuition, bias, and politics, which could open them or others up to incrimination, or put the future of the program in jeopardy.

Case study methodology combined with historical research methods were used to answer the research questions. Case studies were determined to be appropriate for investigating this topic. The conception, development, and production of a new weapon system encompasses all parts of the needs determination process, yet such a case is discrete enough to be considered as a separate incident. These characteristics provide the opportunity to learn about all aspects of the topic.

According to Yin, when research seeks to answer how and why questions which need to be studied over time, and do not lend themselves to mere frequencies or incidence, the methods of case studies, histories, and experiments are preferred. Experiments are done when behavior can be manipulated directly, precisely, and systematically, which is not the case with the development of large-scale complex systems. Furthermore, case study methodology is appropriate since it copes with situations where there are more variables of interest than there are data points, as with the determination of needs for weapon systems.[15]

Yin refers to the historical methods as those situations where no one relevant is alive to report what occurred, even in retrospect, but he concedes that for more recent events the methods of histories and case studies overlap, as with this research. Because the most recent cases that allow the entire life spans of weapon systems to be studied occurred over thirty years ago, historical research methods were essential to gather sufficient information about those cases to study them.

There are also practical reasons for using case studies. Over the past half century new fighter aircraft have entered service at an average rate of only two per decade. Since a fighter program can span a period of ten to twenty years or more, it represents a discrete case that must be considered in its own setting. Besides making it impractical to try to study more than a small number of cases, this time span also limits the number of cases available, and therefore increases the relevance of any particular case.

Much of the data for the case studies were acquired from archival documents. The Air Force Historical Research Agency (AFHRA), the Library of Congress, the archives of the National Museum of the Air Force, the Alfred M. Gray Research Center, and the National Archives and Records Administration were the main sources of archival documents. These documents were of a variety of types, including official histories of Air Force organizations and units, official letters and memoranda, requirements documentation, reports from studies and analysis, program reports, meeting notes and conference proceedings, official message traffic, slides and notes from briefings, white papers, talking papers, and personal letters. Many of these documents have been declassified, several at the request of the author specifically for this study. These documents were supplemented by records of Congressional testimony, journal and magazine articles, newspaper articles, theses, books, government documents, and other publications.

Documents only reveal part of the story, however. Pierre Sprey, a staff member in the Office of the Secretary of Defense during much of the time period of interest described it this way:

> One thing that you should realize about all these things that you see in print, in messages, is that those reflect decisions taken previously. They are all made with the barest glimmer of some great battle that was taking on. And in the Air Force, like most military services, the battle is mostly verbal; they're never carried out with documented evidence. If this was a typical program, you'd never even be able to see the briefing charts of what was presented and what issues were presented.[16]

Insights into the verbal battles referred to were gained through interviews with participants, together with the documents, in order to discover the rationale behind the decisions that were made.

The interviews proved especially valuable in establishing the reasons behind various decisions, especially those influenced by inputs not documented in the official requirements generation process. Interviews were either conducted live, or they were historical interviews conducted during or shortly after the period covered by the case studies. Due to the effects of age and health of those remaining participants of the three programs, live interview opportunities were limited. Seven such interviews were conducted, and despite the limitations inherent in such interviews, such as the possibility of incomplete memories, the influence of subsequent events, and other factors, the interviews were valuable because of the ability to ask specific questions and follow up on answers given. The limitations were mitigated by corroboration with other sources. The opportunity to meet and talk to people who played such an important part in Air Force, and even national history, was also extremely rewarding from a personal standpoint.

The historic interviews were conducted by Air Force historians as part of an oral history program. Interviewees were selected based on rank, position, and/or affiliation with noteworthy programs or events. Most were conducted as the interviewee was finishing his career. Other interviews were either conducted mid-career, or after retirement. The obvious advantage of these interviews was the proximity to the events of interest. Also, because of the archival nature of the interviews, as opposed to media or press type interviews, and because of the professional detachment due to retirement, the interviewees were relatively candid in their responses. The main disadvantage was the inability to select questions, however due to the open-ended nature of the interviews and the prominence of the programs of interest, the unstructured comments of the interviewees generally covered numerous relevant and useful points. A total of 139 historic interviews of 97 people were used in this study.

Research Limitations

The topic of this study is broad enough that without bounds it would be intractable. For that reason it has been limited in scope. The subject matter, and methods required to study it, also impose limitations on the study.

As stated, this study will focus on fighter aircraft, and specifically the three cases listed above. It will also be limited to the initial concept generation of new fighters, and not follow-on versions or modifications. Despite the unique nature of each of the fighter programs studied, similarities found in the *system*-level process imply generalizability to other large complex projects. Proving generalizability by studying cases of other projects, such as non-fighter aircraft, aircraft of services other than the U.S. Air Force, non-aircraft military projects, or even large civilian projects, is beyond the scope of this study.

The historic nature of the study imposes limitations as well. Carr wrote of the dilemma of determining facts from history,

> Our picture has been preselected and predetermined for us, not so much by accident as by people who were consciously or unconsciously imbued with a particular view and thought the facts which supported that view worth preserving.[17]

Any historical study will be affected by the survival of historic facts, at least to some degree. The challenge, then, is to gather enough credible evidence to convince the researcher and the audience that the facts collected reveal a picture that is complete and accurate enough to be instructive about the process being studied. The cases studied in this research are recent enough that much information exists from a variety of sources. The “people” spoken of by Carr possess varied enough views, which were preserved due to the advanced methods of data collection, dissemination, and preservation which existed even fifty to sixty years ago. Because of this, a reasonable picture, even if not a perfect one, can be reconstructed.

Dissertation Outline

This dissertation is organized into eight chapters, which can be divided into three parts. The first part, comprised of chapters one and two, is introductory in nature. Chapter one explained the research area, asking questions that this study attempts to answer. It gave the motivation for the research, the approach taken to answer the questions and the methods used, along with the limitations of the study. Chapter two is an overview of previous work done in areas related to this research. It identifies areas that have not been studied, and which this work addresses. Finally, it situates this research within the literature that exists.

The second part, comprised of the next four chapters, presents the results of the case studies, as well as analysis to extract insights applicable to the research questions. Chapters three, four, and five present the results of three case studies. The most important part of each is the identification and analysis of decisions about the systems that were made outside of the documented requirements process. These are contained in the section of each chapter called, "Predetermined [Program] Decisions and Origins." Chapter six develops a qualitative model for framing the needs determination process from a *systems*-level perspective. It incorporates not only the documented process, but also the undocumented inputs that influence the resulting weapon systems, and the ways they are used.

The final part offers conclusions and recommendations. Chapter seven offers some conclusions that can be drawn from the case studies using the model, and offers some suggested high-level actions to work within the constraints of the undocumented inputs to needs determination. Finally, chapter eight discusses the applicability of the model to current situations.

Notes for Chapter One

1. I.B. Holley, Jr., *Ideas and Weapons* (New York: Yale University Press, 1953), v.

2. *DoDD 5000.1 – Defense Acquisition Guidebook* (Washington, DC: Department of Defense, 2004), 4.

3. *AFDD-1 Air Force Basic Doctrine* (Washington, DC: U.S. Air Force, HQ AFDC/DR, 2003), ix, 11.

4. Phillip S. Meilinger, *10 Propositions Regarding Air Power*. (Washington, DC: Air Force History and Museums Program, 1995), 57.

5. Holley, *Ideas and Weapons*, 19.

6. Robert M. Gates, "A Balanced Strategy: Reprogramming the Pentagon for a New Age," *Foreign Affairs* 88 (2009): 13.

7. "CSAF White Paper: The Nation's Guardians – America's 21st Century Air Force" by T. Michael Moseley, 29 Dec 2007.

8. Glenn A. Kent, *Thinking about America's Defense: An Analytical Memoir* (Santa Monica, CA: RAND Corporation, 2008), 106.

9. Joseph R. Wirthlin, "Best Practices in User Needs/Requirements Generation" (Masters Thesis, Massachusetts Institute of Technology, 2000).

10. "Memorandum for Record, Subject: Changes to the Requirements Generation System DJSM-0921-02" by Maj Gen James A. Hawkins, Vice Director, Joint Staff, 7 Oct 2002.

11. Chairman of the Joint Chiefs of Staff, ed. *Joint Capabilities Integration and Development System, CJCSI 3170.01E* (Washington, DC: Department of Defense, 11 May 2005), 62.

12. William Matthews, "Amid Buzzwords, Senators Push for Defense Acquisition Reform," *Federal Times*, 3 Mar 2009.

13. Lt Gen Glenn A. Kent, USAF (Ret.), telephone interview by author, 9 June 2008.

14. Charles E. "Chuck" Myers, Jr., interview with author, Gordonsville, VA, 28 April 2008.

15. Robert K. Yin, *Case Study Research Design Methods*, 2nd ed. (Thousand Oaks, CA: Sage Publications, 1994), 1-9.

16. Oral History Interview of Pierre Sprey, by Jack Neufeld, 12 June 1973. Typed transcript p. 29, K239.0512-969 Iris No. 01021511, in USAF Collection, AFHRA.

17. Edward H. Carr, *What is History?* (New York: Random House, 1961), 13.

Chapter 2
Literature Review

This study focuses on decision making, especially as it relates to how the Air Force decides which weapon systems to procure, and more generally which missions it will emphasize. Before commencing the study, it is useful to review work that has already been accomplished in related fields, and to situate this work within the existing literature.

Decisions about which products to develop make up part of the overall product lifecycle, and are situated at the front end where ideas are generated and concepts are initially conceived. This part of the product lifecycle lies at the intersection of several different areas of literature, including requirements, technology integration, innovation, product design, and product feedback. The front end is part of the wider topic of program management, which addresses the cost, schedule, and performance of a program, and for which a body of literature exists. The area of interest, which I have labeled "product decisions," can be thought of visually as follows.

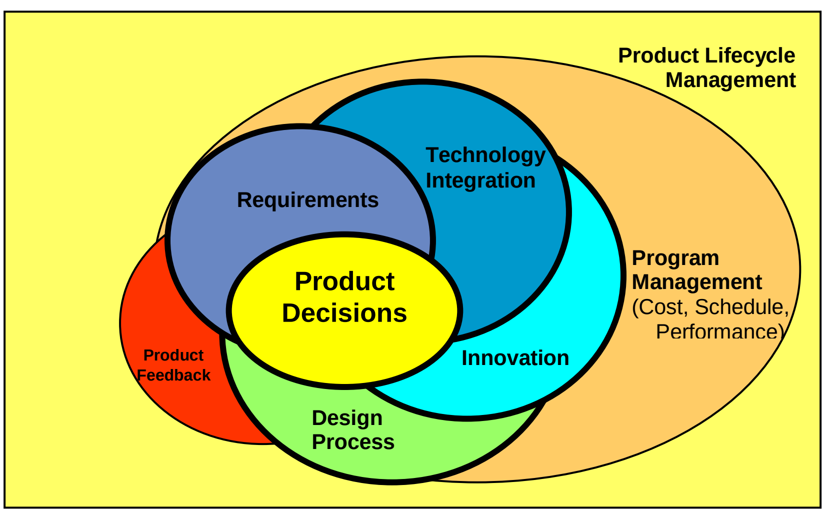

Figure 2.1. "Product Decisions" lie at the intersection of different bodies of literature.

The broad nature of the areas referred to in this figure allows the literature to be generalizable to products of all types, however this research focuses on military weapon systems. While there is necessarily overlap between the definition of products in general and the subset comprised of military weapon systems, there are aspects of the military case that are unique and justify separate treatment. Applying that focus alters the figure slightly. Besides the broad material in each of these areas, there further exists literature that addresses the specifics of military systems.

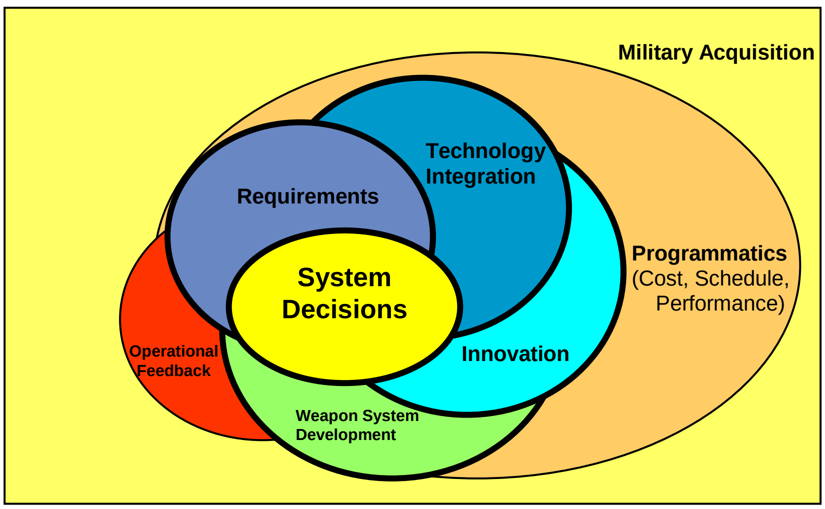

Figure 2.2. "System Decisions" with a focus on military weapons systems.

Military acquisition is a complex topic, and is related to many other areas. Specifically for this research, which focuses on the decisions made before a program is begun, and during the very early stages after its inception, it is necessary to understand the environment that contributes to those decisions. This includes the historical events and systems that have led up to the program. This also encompasses information about prior and existing leadership and organizations, and their philosophies and strategies. Pictorially this environment would provide a backdrop against which the decisions were made.

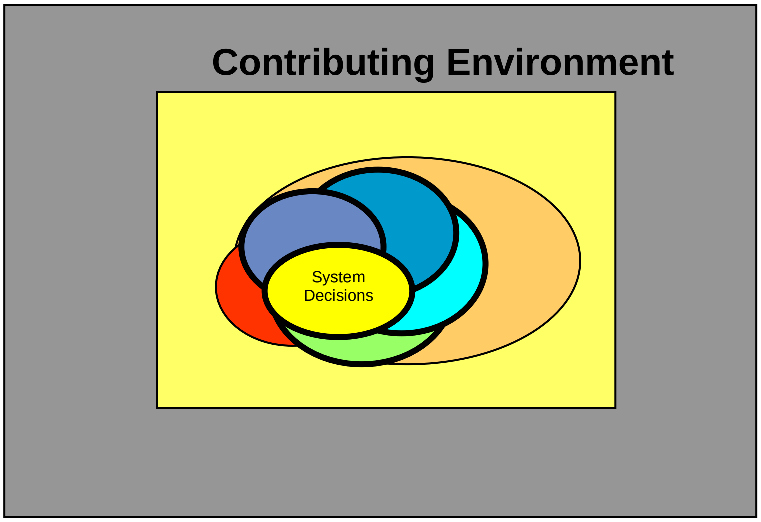

Figure 2.3. "System Decisions" must be appropriately situated in the environment that contributes to them.

Requirements

Recognizing that the specifications to which a product is designed determine much of the cost and level of effort of the program, extensive research has focused on the generation of product requirements. Product development textbooks inevitably include some related discussion. Ulrich and Eppinger's *Product Design and Development* provides a good example of this type of literature.[1] It explains the process in terms of a product plan that identifies the portfolio of products to be developed, based on suggestions from marketing, research, customer input, current product development work, benchmarking, and competitors. The state of technology, including the future state insofar as it can be determined, needs to be taken into account as well. Assessments of success or failure of existing products also need to be factored in when requirements for new products are written. All of this must be accomplished in accordance with the company's goals, capabilities, constraints, and competitive environment.[2] These sources of product requirements are echoed in the journal literature.[3-6]

In this literature a successful requirements generation process is measured by such factors as coverage of markets with competitive products, expeditious introduction of new products on the market, efficient matching of company resources with the number of new products being pursued, the avoidance of ill-conceived projects that must be abandoned, and consistency in the direction of projects. These measures can be applied to any requirements generation effort, although they are more readily adapted to commercial products, the goals of which are to generate profit by meeting the desires of the maximum number of customers. These concepts also apply to products such as military weapon systems, however some adaptation needs to be accomplished. Market share and profits, for example, are replaced by military utility and combat capability. This adaptation is not well-covered in the literature.

The necessity for commercial firms to make profit often drives them to either efficiency or failure. Because of this, successful firms often find innovative ways to improve processes. Study of those successful firms' best practices can provide useful examples of processes, including the requirements generation process that can be adopted.

An example of this approach is a portion of a broad best practices study completed by the Government Accounting Office (GAO), which found that overall product success improves when requirements for maintainability are included.[7] Wirthlin conducted a best practices comparison of requirements generation processes for both military weapons and commercial products, producing an idealized best process, as well as a comparison matrix which allows an existing process to be compared to the ideal process.[8]

Lewis, et al. conducted a study specifically applicable to Air Force requirements generation, but gave only a high level model using the framework of demand, supply, and integration to determine needs. It asserts that the Air Force should match its vision and core competencies with the future threat environment. Left unelaborated was an explanation of how to define those elements of the framework.[9]

The most relevant document for military requirements generation is the latest DoD instruction that contains the documented process by which requirements are to be generated. Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01, titled *Joint Capabilities Integration and Development System (JCIDS)* defines the process, of the same name, by which the requirements for all military programs are to be defined. It came at the end of an exhaustive study of the existing process and best practices, and as presented in chapter one, directs that instead of defining requirements in the form of system specifications, requirements will be defined as (and called) capabilities that the joint military community needs.[10]

Conceiving products to provide a desired capability rather than to meet a set of specifications, or even broader requirements, is not a new concept. It has come up periodically during the history of the Air Force, but has always seemed to migrate back to a more rigid system of requirements generation. Kent provides several examples of what he calls “the tyranny of the requirements process,” as well as discussing some of the efforts made to focus instead on capabilities.[11]

Technology Integration

An important part of introducing new products is the integration of new technology into those products. The last section identified research and new technology as sources for generating requirements. More relevant to military systems is the integration of technology into military missions. When a firm develops a new product, new technology is integrated into it during the design process, which is after the product has been defined. Those cases where the definition of a product is inspired by new technology are addressed in the innovation literature, which will be discussed below. Integrating technology into military missions presents a unique challenge, and there is literature, although limited, that addresses this specific area.

Holley's *Ideas and Weapons*, one of the most important books in this area, asserts that superior arms favor victory, but they must be accompanied by doctrine regarding their use. The military must also devise effective techniques for recognizing and evaluating potential weapons that use technological advances, and have appropriate organizations to do so.[12] In a later work Holley updated his position by reaffirming the importance of establishing accompanying doctrine, but added an emphasis on the need to disseminate and teach that doctrine throughout the service or it will be ineffective.[13]

At the end of World War II, General Henry H. "Hap" Arnold set the tone for the Air Force with a study he commissioned called, "Toward New Horizons." Arnold and Theodore von Karman, who led the effort, were committed to pushing technological solutions, which led to today's heavy emphasis on technology in the Air Force. The influential report, which predates Holley, calls first for technological development, and then strategy development. It has influenced the level of research in the Air Force by calling for the establishment of a permanent Scientific Advisory Board, and investment in basic research to produce new technology.[14] Later work has been done to follow up on these initial ideas, and has, in general sustained these early efforts.[15]

Innovation

Much of the literature on innovation addresses the reaction of organizations to innovation, as opposed to the methods in which innovations originate. Utterback and Christensen warn against the attitude that innovations are invasive, and tell how to structure an organization to capitalize on new technologies, or at least how to mitigate the effects of disruptive technologies.[16, 17]

Some writings do discuss sources of innovation, but in more general terms, such as users, suppliers, manufacturers, etc. Von Hippel develops a model to determine who derives the most benefit from an innovation, and therefore predict which source is most likely to produce an innovation.[18] Utterback, et al. suggest applying new materials and design techniques to traditional products as a source of innovation.[19]

Military Innovation

Innovation in the military has been addressed as a unique situation in many studies. The investment of more than the traditional resources, and the difficulty of determining returns on those investments have at times made acceptance of innovation in the military more difficult. While traditional resources invested in a product or technology include money, facilities, tooling, time, training, and company identity, the military adds to that list, careers, tradition, esprit de corps, purpose and justification for existence, belief systems, and other investments that are less tangible.

Much of the writing on this topic addresses armies and navies, since air forces are relatively recent arrivals. Historians have pointed out that an Elizabethan "Sea Dog" would feel almost as much at home on most mid nineteenth century naval vessels as he did on Sir Francis Drake's sixteenth century Golden Hind.[20] During the nineteenth century, however, after thee hundred years of incremental progress, several revolutionary technologies began to transform naval weapons. The study of one of these, the use of iron for the hull of the ship, provides an example of military innovation, and its literature.

Initially iron was used to clad the wooden hulls of ships to provide protection from cannon fire, but the technology was slow to be accepted. Baxter, who in 1933 wrote the first complete history of the transition, identified as one of the impediments to the acceptance of the technology, the difficulties of designing ships with the heavy cladding that were seaworthy, fast enough, and maneuverable enough to outperform traditional wooden ships. He credits the introduction of shell guns, naval guns with flat trajectories and exploding shells, which were extremely effective against wooden hulls, with facilitating the acceptance of ironclad ships by demonstrating their worth.[21]

Other factors, which were not strictly technical, that played a part in the acceptance of innovation have been acknowledged. Mindell stresses the primacy of combat experience in convincing participants to accept a new technology. In his account of the experience of the USS Monitor, he shows how the ship became a symbol of technological advancement, thus furthering its acceptance, despite its dubious combat results.[22] Roberts adds economic factors to the reasons for the slow acceptance of ironclad technology, showing that they can be more influential over the long term than lessons from combat, as evidenced by the technological regression in America after the Civil War ended.[23]

In a related case study, Morison gives some interesting insights into how innovation occurs in the military using the example of continuous-aim firing of naval guns, instead of fixed guns that were fired only as the ship rolled through level. Morison introduces such factors as tradition and habit as impediments to the acceptance of innovation. He concludes that, “The tendency is apparently involuntary and immediate to protect oneself against the shock of change by continuing in the presence of altered situations the familiar habits, however incongruous, of the past.” He contends that the right conditions, as well as people (personalities) must be present for innovation to occur, and more importantly to be accepted.[24]

Similar examples have continued to arise, and have been studied. The so-called “Dreadnaught revolution” which introduced steam turbine engines and an armament configuration of all big guns (ten inch on the original *Dreadnaught*) onto battleships made all earlier ships obsolete, but had the effect of negating any pre-existing numerical advantages. The replacement of battleships by aircraft carriers as the premier weapons for wielding seapower soon followed. Gray [25], Friedman [26], and Kennedy[27] provide examples of such studies.

Aircraft technology has been the focus of study as well. Edgerton recounts how Britain readily accepted aviation technology into its arsenal, and attributed it to an inherent enthusiasm for new technology in the country. He also presents a political dimension. He profiles the nation as a “warfare state,” as opposed to the common label of “welfare state” it has been given by historians. This focus on the ability to make war naturally encouraged the acceptance of new technologies, such as the airplane.[28] The previously mentioned research by Holley studied the much slower integration of airplanes in the U.S. Army during the same period.[29]

These studies recognize that military innovation is not solely a function of a new technology. Nor is it just a matter of exercising creativity to match a new technology to an appropriate mission. The influence of politics, economics, combat experience, personalities, and other factors play a part. However, a focused study with the primary goal of addressing all of the social factors that influence the selection of new weapons would be a useful addition to existing literature.

Design Process and Weapon System Development

The design process is the broad area within which “product decisions” are made. It encompasses the formulation of a concept and its engineering design. There are numerous sources, such as the previously referred to Ulrich and Eppinger textbook, which explain product design and development. Much current focus concentrates on integrating lean principles, well-known for their application to manufacturing products, to the design and development of products.[30]

Other work seeks to integrate information in the design process to improve program performance. Dong and Whitney use a design structure matrix based on the design matrix to ascertain the patterns of information flow early in the design process when changes can be most effective.[31] Ross uses a multi-attribute tradespace exploration process to track unarticulated requirements over time.[32] These requirements include the so-called –ilities, such as flexibility, adaptability, rigidity, robustness, scalability, and modifiability, which are valued, but difficult to specify and measure.[33]

Program Management and Programmatics

Program Management is a huge area of literature too vast to address in depth in this research summary. Instead this review focuses on some recent literature addressing the improvement of cost and schedule performance of military acquisition programs. Much of the literature in the area of product lifecycle management, and specifically military acquisition, which will be cited below, overlaps with this area.

The comprehensive GAO study of best practices presented several recommendations aimed at improving the management of military programs. Previously cited was the recommendation to add maintainability targets to the initial requirements.[34] Cost, budget, and schedule can be maintained more successfully when technologies are not used until they reach sufficient maturity.[35] Early identification of resources needed for a program before it is started, and efficient matching of those resources to program requirements will improve program performance.[36] Capturing knowledge in the form of milestones such as finalized drawings and well-defined and mature production processes, will improve program outcomes as well.[37]

McNutt found that lack of emphasis on meeting development schedules, the lack of scheduling tools, the lack of schedule-based incentives, and the impact of funding limitations lead to very long development programs for military systems. This, in turn, contributes to cost overruns. It also necessitates predicting threat-based needs years in advance, which often do not materialize. Better information and scheduling tools, along with proper incentives can help decrease development times to alleviate these problems.[38]

Product Feedback and Operational Feedback

Much has been written about using customer feedback as an input in the product development process for commercial products.[39] Market research and customer feedback have their own set of literature. For military systems the process is quite different due to the limited number of users of the systems, as well as the infrequent opportunities to employ systems in actual combat. Operational exercises, and especially actual combat operations are highly regarded for their value to provide information about the successes and failures of military systems. In order to obtain useful feedback, the evaluation must consider the equipment in the context of the combat setting, the physical environment and conditions, the strategy employed, the relative strength of the enemy, underlying geopolitical factors, the individual performance of the operators of the systems, and other factors. For this reason combat assessments are of varying degrees of value, and are open to dispute.

A well-known example of this is the U.S. Strategic Bombing Survey commissioned at the end of World War II. Its generally favorable view of strategic bombardment and the weapons that accomplished it was used to help guide the development of strategic forces during the cold war, but it was not without critics. Some viewed it as being a political tool used to help establish the Air Force as an independent service, as well as deemphasizing tactical airpower, which turned out to be more important in limited warfare. The Gulf War Air Power Survey, commissioned after Operation Desert Storm, is another example of a report from which conflicting conclusions can be drawn.[40]

Product Lifecycle Management and Military Acquisition

Although the general structure of product lifecycle management has the same basic elements as the military acquisition process, the details of how each step is done is quite different. Accordingly, military acquisition has been studied and documented in a unique body of literature, often drawing on principles developed for commercial product lifecycle management. The official process is documented in DoDD 5000.1 - Defense Acquisition Guidebook[41] and DoDI 5000.2 - Operation of the Defense Acquisition System[42]. Despite the numerous studies to improve this process, lasting improvements to the military acquisition system have eluded all who have attempted make such lasting improvements. Weidenbaum describes a cycle of reform in which outcries over inefficiencies lead to studies and attempted reforms, which inevitably fail, leading to the cycle beginning again.[43]

McKinney, et al. summarized the major reform studies commissioned by the DoD, and documented their major contributions.[44] While they have altered the organization, changed the structure, mandated constraints, and changed steps in the process, the major problems of inefficiency and poor program performance still exist in numerous programs. Others have studied the system and made less sweeping recommendations. Doane found that existing culture in acquisition centers affects their ability to change, and concluded that strong sustainable leadership is required to make lasting changes.[45] Coulam concludes that more rigorous analysis of decision options will improve results.[46] Forseth found that young program managers are the least likely to take risks, and that by educating and incentivizing them to change, the system will improve when they assume leadership roles.[47] McNaugher asserts that having significant levels of oversight creates inefficiency, and that due to the numerous concerned parties who will never permanently relinquish oversight, it is futile to expect consistent efficiency in the military acquisition system.[48]

Contributing Environment

This is a very broad heading which contains literature in the areas of past and current weapon systems and technologies; airpower theory and strategy; roles and missions; leadership, including positions, personalities, and backgrounds; the Department of Defense, including its history, its roles and responsibilities over time, its leaders, its impact on military acquisition, and its interactions with the individual services; and world events. System development decisions were made with inputs from these areas, and they are therefore relevant to this study.

Decision Theory

When studying the decision making process there is an insurmountable body of literature to consider.* Tang provides a cogent summary of decision theory literature in chapter two of his thesis that addresses corporate decision analysis. He presents the division of the literature into three branches, as identified by scholars. Normative Theory

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* A Google Scholar search of the topic returned over 2.5 million references.

is that theory concerned with employing logic to decide based on expected utility derived from the outcome of the decision. Descriptive Theory acknowledges the limits of Normative Theory recognizing that rational consideration of all possible outcomes is impossible, and analyzes the irrational, or subjective inputs that influence the decision. Prescriptive Theory goes beyond analyzing decisions, and seeks to apply Normative and Descriptive Theory to real world settings.[49]

This study is based in part on descriptive decision theory. It does not prescribe a specific decision making process, but seeks to provide understanding of the deviations from purely analytical decisions (or rational decisions, as Herbert Simon defines them) regarding military missions and related weapon systems.

Of particular relevance to this study is the work of Herbert Simon. In his thesis of bounded rationality, he proposed that humans are not strictly rational beings, and in fact cannot be because of the complexity of the situations in which they are required to make decisions. Instead, he argues that they are only partly rational, with the other part being made up by emotional and irrational inputs. Humans employ heuristics to place bounds on the problem, narrowing down the possibilities until a rational decision can be made. The result is not a maximization of utility, but instead a satisficing, or meeting at least the minimum requirements to achieve the desired outcome.[50]

The limitations of the human capacity to make rational decisions about weapons and their missions in this very complex environment manifest themselves in the various decision making mechanisms they contrive, both conscious and unconscious. The inputs to those decisions, both undocumented and documented in the formal process, provide the heuristics by which the problem can be bounded such that rationality can be employed in the decision making process. This research studies these bounding mechanisms, such as various forms of analysis, experience, biases, and intuition.

Science, Technology, and Society

When considering how decisions are made regarding high-technology weapon systems and their employment in military missions, the field of science, technology, and society (STS) offers some important insights. Along with the numerous scientific and technological breakthroughs that occurred during the beginnings of the industrial age people became more aware of the unintended consequences that accompanied the new technologies. Understanding the interaction between science and technology, and the society in which they exist is the basis for STS.[51]

The inability to bridle the negative effects of technology, along with continued increases in new technologies led some to believe that technology followed its own trajectory. Winner, for example, argued that once a society makes the initial choice to define human progress in terms of technological advancement, technology continues on a course determined by technology itself, and not by humans.[52] This concept of a natural technological trajectory, applied to military weapons and their corresponding missions, suggests that the humans involved in the weapons procurement process have less of a role than the technology itself. This line of argument has been used to explain the fielding of nuclear weapons with far more accuracy and destructive power than can be rationally justified.[53]

A more moderate view of the role of technology in determining technological choices, but one that still concedes a significant amount of influence to it is the idea of technological momentum presented by Hughes. According to this view, when a technological system – comprised of the physical artifact, as well as the people, organizations, and institutions that derive value from the artifact – becomes established, it can resist manipulation due to the momentum it achieves. This momentum consists of vested interest of stakeholders, fixed assets, and sunk costs. A system that has momentum has mass, velocity, and direction, according to Hughes.[54] This concept suggests that decisions about new weapon systems and military missions are determined, in part at least, by the momentum that exists in the system and group of participants procuring and employing the weapons.

Another approach removes the emphasis from the role technology plays in the decisions of which technological systems will be developed and how they will be used, and instead places that emphasis on the social interactions between stakeholders. In the theory of the Social Construction of Technology (SCOT), as put forth by Bijker and Pinch, a completed artifact is considered one of many options that could have been chosen for development. The model suggests that each stakeholder has some problem that he or she expects the artifact to solve. They then categorize those people with similar problems into "social groups." Each social group advocates a design that best solves its respective problem or problems. The emergent design is the result of more effective advocacy on the part of those social groups whose problems are more fully solved by that design. Thus the possible results of an engineering effort are "multidirectional." That is, any of the proposed solutions could have been selected, and only looking at the effort after the fact does it appear that the solution that was implemented was the result of a calculated linear progression of engineering knowledge.[55] Applied to military systems and missions, this implies that advocacy, in all of its social forms, plays as important a role as deliberate technical efforts.

Organizational Change, Leadership, and Change Management

Decisions that are made within large organizations, such as the Air Force, must take into account the characteristics of the organization to which decision makers belong. The dynamic conditions and environment of combat operations require military organizations to change along with the conditions and environment if they are to be successful. One way this change is manifested is in the systems that the service chooses to develop and use. Because of this, the ability, or inability, to change as an organization is a part of this study of weapon system decisions.

Organizational change and change management address working with organizations, and people within those organizations, to change from the existing state to a different, desired state. Lewin, one of the first people to study this problem and whose work has provided a foundation for this area of research, asserted that behavior is a function of the people in the organization and the environment in which they work.[56]

Military personnel are carefully screened and trained, making the environmental influences more relevant than they otherwise would be since the "people" in the equation are somewhat controlled through selection and training. The criteria for screening, the objectives and methods of the training, as well as the environment within a military organization, are influenced greatly by those who lead the organization. Lewin was also one of the first to experiment with the effects of leadership style on organizational behavior, and concluded that the style employed has a strong influence on organizational outcomes. He determined that a democratic style of leadership produced better results than autocratic or laissez-faire styles, although his studies did not specifically consider military organizations.[57]

Leadership, and in particular military leadership, constitutes its own field of study, and much has been written.[58] Leadership theory is broken up into general categories including trait theory, which focuses on the behavior and personality of the leader; situational theory, which concentrates more on the events and environment surrounding the leader; and behavior theory, which focuses on the style of leadership. The subset of military leadership often includes biographical studies of past leaders who are considered successful.

As with the areas of organizational change and leadership, the intersection of these two, change management, is also a very large field. Lewin's groundbreaking work also included research in this area, which resulted in a three-step process for organizational change. In step one, the "unfreeze" step, the organization must break down the barriers to accepting change. Step two, "change," is that confusing stage where the new ideas are still being challenged and there is uncertainty about how to proceed. The final step, "freeze," entails returning to a comfortable working environment, but with the new ideas in place.[59] This relatively simple model has provided a starting point for further research in this area.

Later models expand on this, adding and describing steps to more fully represent the process. One such model is the recent ADKAR model, which characterizes the organizational change process in five steps, with the first letter of each creating the acronym: Awareness of the reason change is needed, Desire to be part of the change, Knowledge of how to change the organization, Ability to actualize the change, and finally Reinforcement to maintain the new conditions and practices resulting from the change.[60]

Additional models have been developed to describe change in more complex environments. Nelson and Winter used the idea of an evolutionary process to model economic change in an environment where conditions are emergent and not controlled by a single authority. They use intricate Markov modeling to represent firms as biological entities, the genes of which are the routines developed and used by the firm. When a mutation occurs, or in this case a deliberate search for a new way of conducting business, routines are altered. If the mutation (or new routine) is useful, the organism (or firm) perpetuates itself as an evolved entity. Failure to evolve results in an inability to survive in the changing environment.[61] While there are useful ideas in the evolution model, application to the situation of military weapons and missions is limited by the wide range of organizations that cannot all be modeled in the same way. Survival cannot simply be equated to profitability, but is a function of many factors, such as relevance, influence, level of technology, and combat results, to name some that affect the Air Force. For other participants survival could be determined by re-election, public image, or other factors that are difficult to quantify.

Defining Success

The goal of the acquisition process is to produce "successful" weapon systems. In order to draw conclusions about the effectiveness of the process one must be able to evaluate the results of the process. Unlike commercial products, whose success can easily be determined by the response of consumers, measured in quantity sold or more importantly profit generated, weapon systems must be evaluated by those who derive value from them.

Little research has been done that attempts to quantitatively measure the overall success of a system over its entire lifespan, especially with attempts to make useful comparisons across systems, and over long time spans. A survey of technical literature revealed that measures of weapon system success are of greatest interest during development efforts, and comparisons of specific performance parameters are used to compare the new system with design specifications, desired capability requirements, estimated performance of threat systems, the system that will be replaced by the new system, or similar comparisons.*

Qualitative research exists that addresses overall system success, but in general these are not useful for comparison across systems or different periods of time. There are numerous histories and detailed descriptions of various weapon systems that evaluate the performance of aircraft, but a consistent set of metrics has not been established. Often metrics are used which highlight the strengths of the system being described, such as using velocity as a measure of success for the SR-71. Efforts at consistent comparison are usually limited to basic performance parameters, standards for which change over time.[62]

To achieve a broad strategic level comparison of weapon system success the metrics would have to take into account data from the point of view of all stakeholders, which presents unique challenges. To illustrate, an example of how this could be done is

* A search of the Defense Technical Information Center documents returned over 400 entries, none of which addressed broad measures of weapon system success over the entire lifespan of the system.

to use the previously referenced SCOT framework. First each of the relevant social groups would need to be identified. Next it would be necessary to determine to what extent their problems have been solved by the system. Difficulty arises, however, when one attempts to determine who expects a weapon system to solve their problem. There may even be disagreement on who should expect it to do so. Whether or not that can be agreed upon, the question is further complicated by the fact that each social group does not provide an explicit list of their problems. Expectations of a system can be listed in a requirements document or list of desired capabilities, but there are also unstated, and often very subjective requirements. Furthermore, the actual operating conditions of a weapon changes over its lifespan, thus changing the expectations of its performance.

The development of agreed-upon, consistent measures of weapon system success is a problem that is not easily solved, and is beyond the scope of this work. Despite these challenges, however, some criteria for success have been widely used in the literature, and are generally accepted, even if their usage and application have not been consistent. These will be discussed briefly, and will provide a basis for establishing the level of success achieved by the systems discussed. They also apply to the level of the perception of success of a system, which is relevant to parts of this study.

Combat Success

Successful performance of the specified mission, especially in combat, is often touted as the ultimate test of system success. A cursory look through the *Air Force Magazine* will turn up several advertisements with the ultimate testimonial: “combat proven.” This is not unfounded. After all, if the system functions as expected when real threats are encountered, live weapons are released, protective equipment is actually relied upon, and extreme conditions which would never be tolerated in training are encountered, that is convincing. This is the definitive example of what Vincenti calls “direct trial” as a source of engineering knowledge.[63]

Occasions for testing systems in combat, however, are sporadic and relatively rare. Furthermore, as a test of system performance, combat is not fully conclusive. The chaotic and unpredictable nature of combat that makes it challenging also makes it unreliable as a test. As Mindell stated about naval battles, but which can be applied to all combat operations, “Numerous other factors besides technical capability affect the outcome; the skill of the commanders, the training and motivation of the crews, the weather, and sheer circumstance, to name but a few.”[64] Interpreting or even determining the results of a combat mission can be very problematic. Despite the unreliability of combat as a test, virtually all participants regard positive combat performance as the standard for determining success.

Design Characteristics

In the absence of actual combat or simulated combat, a weapon system is often judged by its ability to perform against standards that are assumed to be valuable in combat. These are often based on assumptions derived from the technological model contributing to its development. For decades, aircraft increased in size, which was indicative of payload; service ceiling and top speed, which were contributors to survivability; and range, which improved mission radius. Because these characteristics had some measure of correlation with aspects of mission performance “bigger, higher, faster, and farther" began to take on the role of determinants of a successful aircraft. Maneuverability (turn radius and load factor capability) has similarly been used as a criterion for success.

Programmatic Measures

Programmatic success is generally based on the cost, schedule, and performance of a development program. Because many of the investment decisions are made during development, this area receives close scrutiny. Often the success or failure of a program is judged by how successful the development program is. The advantage of using programmatic criteria is that cost, schedule, and performance are readily quantifiable. The drawback is that judgments made during these initial phases do not take into account the decades of service life that follow. Furthermore, often there is not a known standard with which to compare programmatic data for unprecedented innovative systems.

Longevity

Longevity can be applied in two different ways. The first refers to the production run of an aircraft, either in time or numbers. The logic inferred is that a large number of systems produced, or a long production run, correlates to a willingness on the part of decision makers to invest in the system, which implies that they are gaining value from it. The other application of longevity as a measure of success is the overall lifespan of the weapon system. If an aircraft remains in the inventory for a long period of time it is assumed to have "stood the test of time" since it has continued to provide usefulness even though it has been subjected to prolonged usage in changing conditions.

Safety

Because safety is valued so highly, and is expected to be designed into systems, safety records in the form of such metrics as accident or mishap rates or accident-free hours are often used to determine the overall success. While the objective of achieving a safe design, and the value placed upon it, are relatively consistent, the extent to which safety is relevant in determining success is dependent on the ability to accurately compare safety across systems. Safety records are a function of reliability, flying qualities, weather, combat mission, combat conditions, combat mission rates, threat conditions, average length of sortie (takeoffs per flying hour), control complexity, crew ratio, training levels, and many other factors. Since these factors will differ across systems being compared, care must be exercised when comparing safety records.

Technological Achievements

There is a distinction between technological success and weapon system success, yet the former is often referenced when assessing the success of a system. The reliance on technology in the conduct of combat often results in some correlation between the successful implementation of new technology and mission success. The strength of the correlation depends upon the utility of the mission for which chances of success are improved, the cost to develop the new technology, the suitability of available alternate solutions, and other factors. While successful technological advances are not enough to establish the success of a system, they may be an indicator.

Placement of This Study

As indicated above, each body of literature discussed has some application to this study, which seeks to understand, and thereby enable improvement of, the process for deciding which weapons will be developed and procured, and how they will be used in military missions. A review of the literature, however, reveals that a broad *systems* approach has never been used to study this question. Studies and improvement efforts have targeted specific parts of the process, and almost exclusively the documented part. These efforts have resulted in limited success because they fail to adequately address factors outside the bounds of the documented process. This is shown by the discussion of the JCIDS presented in the introduction (chapter one).

If the process has produced preconceived and stovepiped solutions, as it has been accused of doing, a broader study which considers the sources of, and reasons for, those solutions is needed. Understanding and influencing the inputs to the documented process will have more effect than trying to change that process through which those inputs are validated. This dissertation provides a unique *systems*-level study of the sources, both documented and undocumented, of decisions regarding military weapons and the missions they are developed to perform.

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Chapter 3
Case Study: The TFX

The Tactical Fighter, Experimental, or TFX was Tactical Air Command's (TAC) program to develop a follow-on fighter with a mission to interdict targets at intermediate range at night or in bad weather, with secondary missions of air superiority and close air support. It began during a period when the nation, and especially the Air Force, placed great emphasis on the nuclear bombardment mission, and was eventually influenced by an effort to conserve resources through commonality. This commonality was to be achieved by combining Air Force fighter requirements with those of other services, as well as other mission requirements within the Air Force. The end result was the F-111 aircraft, a very large and fast aircraft with revolutionary technological features, that was designed to accomplish a wide variety of missions. Eventually it was produced in far fewer numbers than envisioned, and was flown by only one service. It spent most of its life relegated to the single specific mission of interdiction bombardment. The prevailing opinion is that it was marginally successful as a weapon system, if not a total failure, although in later years that opinion softened somewhat.

Background Leading Up to the TFX Program

After World War II ended with the deployment of two atomic bombs against Japanese cities, Army Air Force (soon to be United States Air Force) leaders placed great confidence in that weapon as the means for achieving success. This was true for success in defending the nation, as well as in establishing the Air Force as a relevant service. Many in the nation, including key leaders, seized upon by a desire to bring troops home and invest in something other than the military, were inclined to agree with this reliance on nuclear weapons, as opposed to deployed forces, for defense. As a result America's post World War II war plans were dominated by the delivery of nuclear weapons.[1]

The Strategic Nuclear Bombardment Mission

The Air Force emerged from World War II as the recognized leader of nuclear combat since it was the only branch with any practical experience. Differences of opinion persisted, however, about future control of nuclear weapons, including their relative importance and which service should play the dominant role in administering and employing them. The determination of those roles would in turn determine funding levels of the services. While the Army and Navy recognized nuclear weapons as a vital element to the nation's war capability, the Air Force asserted that they offered a war-winning capability. Air Force leaders were convinced that the unprecedented power of nuclear bombs could quickly destroy an enemy's will and capacity to resist.[2] But even as these ideas were being debated, and services were competing for a share of the decreased post World War II military budgets, momentum was building behind the Air Force philosophy.

Air Force responsibility over the strategic nuclear bombardment mission began during the Truman administration as a way to protect the nation during the post war drawdown. The key role in any war plan that was based on the use of nuclear weapons was the ability to effectively deliver them. With its unique rapid strategic delivery capability, the Air Force was able to withstand powerful bids by the other services, especially the Navy, to take over control of nuclear weapons employment. The Air

Force's role was reinforced in December 1946 when President Truman created the Strategic Air Command (SAC) within the Air Force, which would be responsible for the delivery of nuclear weapons using long range bombers.[3]

Receiving the mission was more of an administrative gesture until the accompanying funds were committed. It wasn't until the Soviet Union exploded their first atomic bomb in 1949 that significant amounts of funding were allocated to build up the force. After that event lawmakers authorized funding for 70 groups (later called wings) of aircraft with the personnel and facilities to support them. The Air Force began to receive over half of the overall defense budget.[4]

When Eisenhower took office he immediately called for an assessment of the national security policy. The resulting policy, called the "New Look," formalized the strategy of massive retaliation as a deterrent to any enemy aggression. In his 1954 State of the Union address, in which he introduced the new policy, Eisenhower stated that in order to implement it the Air Force would receive increased funding, and this would be offset by reductions in the Army and Navy budgets.[5] It was clear that money invested into the fledgling new Air Force would be based on its leadership role in the nation's plans to conduct nuclear war.

Besides fostering the continued development of long range bombers, the emphasis on the strategic nuclear bombardment mission also had a profound influence on fighter aircraft design as well. Future wars would be decided based on the ability of American bombers to reach their targets unmolested. One lesson derived from experience in World War II was that the probability of a bomber reaching its target increased when it was accompanied by escort fighters.[6] As a result, fighters began to be developed that could accompany bombers in the escort role. Perhaps considered more important, however, was the ability to stop incoming enemy bombers attempting to employ the same strategy. Therefore, another role for which fighters were developed was that of interceptor. A brief overview of the fighters that were developed in conjunction with the nuclear bombardment strategy manifests the prevailing attitudes leading up to the development of the TFX.

Overview of Fighter Aircraft Supporting the Strategic Nuclear Bombardment Mission[7]

Missions for the delivery of nuclear weapons in a post World War II scenario would inevitably require the capability of flying long distances. The Air Force immediately began to acquire versions of its newest long range bomber that were capable of carrying nuclear weapons. The B-29, which had been used successfully in the Pacific theater in the later stages of the war, were modified for this mission, as well as being upgraded in several areas, and were given the designation of B-50. They were soon replaced by aircraft that could fly farther, faster, and at greater altitudes, including the B-36, the B-47 and the B-52.[8]

In order to provide protection for the offensive bombers, fighter capability would have to be improved as well. One of the first attempts was based on the successful P-51 *Mustang*. The new design, the F-82 *Twin* Mustang, resembled two P-51s joined side by side at the wings and the horizontal stabilizers, and had greater range as well as two pilots to share the flying load on long flights. As technology improved, speed and altitude were increased through the use of turbojet engines. The F-80, followed by the F-84, and F-86 were the earliest turbojet fighters to be produced.

During this period research efforts were directed at attempts to improve the altitude, speed, and range capability of fighters. While turbojets allowed the fighters to reach higher speeds and greater altitudes, they did so by trading off range, since early turbojet engines burned fuel at a very high rate, making range the limiting design factor. The XF-81 and XF-83, which never went into production, were experimental aircraft used in this research. Mixing turbojets with turboprops to improve the fuel consumption rate, and installing large capacity internal and external fuel tanks to increase fuel quantity were investigated with these two experimental aircraft.

As radar technology improved, fighters were equipped with radar equipment for locating enemy aircraft and providing targeting information. The increased weight of the radar and accompanying avionics was offset by increasingly more powerful engines, and increasingly bigger aircraft.

The same characteristics that made a fighter effective as an escort also enabled it to perform as an interceptor. Immediately after World War II, leftover fighters from the war were employed in the interceptor role, but as the defense posture changed from one supporting theater war to one focused on intercontinental nuclear war, fighters were designed more deliberately for the interceptor role. In fact because the perceived danger of incoming enemy bombers was considered greater than the threat of enemy fighters shooting down U.S. bombers, the interceptor role soon came to receive greater emphasis than the other fighter missions. The confidence in U.S. bombers' ability to reach their targets was based partly on the newer bombers' high performance flight capabilities, and partly on a belief that enemy air bases would be targeted thus destroying enemy defenses on the ground.[9]

As the emphasis shifted to interceptors, high speed, high altitude, radar-equipped aircraft were preferred. The effective range and speed were soon augmented with the use of air-to-air missiles. The modified F-86D, the F-89 (which had a secondary mission in the ground attack role), and F-94 are examples. As the escort mission was deemphasized in favor of the interceptor mission, range was often sacrificed for speed, since the limiting factor in an interception was the time to intercept after detection, and in the 1950s detection ranges were limited. While range was still valued, carrying the extra fuel to allow more range was generally traded off for a higher top speed. Other fighter missions were accomplished using aircraft designed primarily as interceptors and secondarily as escorts. Ground attack and interdiction missions were generally performed by aircraft that were previously used as interceptors, but had since been replaced by more modern aircraft. The aerial combat mission requiring maneuvering flight was abandoned, since it was considered unlikely to occur in modern warfare.

After Chuck Yeager's pioneering flight in 1947 demonstrated the ability to exceed Mach 1, efforts quickly followed to improve on designs of supersonic aircraft, and develop supersonic production fighters. The F-100 was the first production supersonic aircraft, and was designed as a day visual air superiority fighter, with an emphasis on speed. It was soon followed by the F-102 interceptor, the first all weather supersonic fighter. Not only could it achieve intercept speed greater than the speed of sound, but unlike the F-100, it had an on-board radar and avionics which could help locate enemy aircraft, and then calculate an intercept solution. An upgraded version of the F-102 was designated the F-106. It was equipped with the MA-1 electronic guidance and fire control system, which allowed it to interface with the SAGE (Semi Automatic

Ground Environment) control system, which tracked incoming targets, calculated an intercept, and could actually send commands to the MA-1 which would automatically fly the F-106 aircraft to the intercept point using the autopilot, and then launch the missile. The extreme complexity of the SAGE system attests to the emphasis placed on the air defense mission during the Cold War.[10]

Other proposed aircraft which proved too costly for full scale development, especially since the utility of interceptors was questioned with the advent of intercontinental ballistic missiles (ICBMs) as delivery platforms for nuclear weapons, included the XF-108 and the YF-12. The F-108, which never progressed beyond the mock-up stage of development, was initially planned as a long range, high altitude aircraft with a cruising speed over Mach 3. The YF-12, which flew as a prototype, and from which a reconnaissance version (the SR-71) was derived achieved performance levels that exceed an altitude of 80,000 feet and a top speed of Mach 3.5.

The post World War II fighter aircraft, up through the 1950s were clearly not designed for maneuverability or close-in tactical air-to-air combat. The remaining fighter aircraft that were fielded, but which have not yet been mentioned, further attest to that fact. The F-101 was a very heavy, very fast long range interceptor, and the F-104 (which was conceived as an export fighter) was designed as a Mach 2 interceptor. The F-104's four-foot wings precluded any meaningful maneuvering capability.

The weaponry of this period also emphasized the intercept mission. Guns were replaced by missiles which would either be guided to the target, or which had a large enough warhead to be effective with minimal accuracy. Guided missiles homed in on infrared signatures produced by the engines of enemy aircraft, or were directed by radar.

The unguided AIR-2 Genie air-to-air missile relied on a 1.5 kiloton nuclear explosion to defeat the anticipated large formations of incoming Soviet bombers. These new weapons further obviated the requirement for maneuverability in fighter aircraft.

The emphasis placed on the escort and intercept missions coincided with a de-emphasis on the tactical air-to-ground mission. As previously mentioned, this mission was usually performed by aircraft designed primarily as interceptors or escorts which had become outdated. Such was the case with the P-51, the F-84, F-86, and the F-100. Officers assigned to the tactical forces of the era lamented the lack of investment in tactical fighters for the air-to-ground mission.[11] The main reason for this was the emphasis on the strategic bombardment mission. Another reason was that up until 1979 interceptors belonged to Air Defense Command (ADC), and up until 1957 SAC maintained its own escort fighters. Responsibility for tactical fighters was spread over three smaller commands, TAC, United States Air Forces in Europe (USAFE), and Pacific Air Forces (PACAF). Although TAC bore the responsibility for procuring weapon systems, the divided organization often led to conflicting opinions on fighter requirements, which made it that much more difficult to compete with larger and more homogeneous commands such as SAC.[12]

Tactical Nuclear Weapons

Soon after the initial development of the atomic bomb, scientists began working on decreasing the size of the weapons. Part of this was an effort to increase the efficiency of delivery. The first two bombs weighed 9000 and 10,000 pounds respectively. Only the B-29, the country's newest bomber, was capable of carrying that much weight, and even then the bomb bay had to be enlarged due to the large dimensions of the bombs.[13] Major General John Stevenson, who led the effort to procure tactical nuclear weapons for the Air Force, maintains that there was another, more personal reason that scientists, especially Dr. Robert Oppenheimer, were enthusiastic about the development of smaller weapons. He states that one motive, "…stemmed from, not a feeling of guilt, perhaps, but, certainly, a feeling of responsibility. They had created a weapon which could destroy tremendous populations and that was the way it had been used until that time. They were looking for ways in which their developments could be used in battlefield use, rather than in pure strategic roles – city or industry destroying roles." The result was the development of smaller weapons in the 1 kiloton range that could be carried on tactical aircraft.[14]

Once this new weapons capability became apparent, the Air Force planning staff immediately began to determine ways to take advantage of it. To Stevenson, a fighter pilot, the obvious use was to load them on tactical aircraft. During this period of time, the early 1950s, the Air Force's strategic bomber was the B-50, a propeller driven aircraft, while the tactical aircraft were jets. This, along with the fact that tactical aircraft were forward-based in the theater in which they would fight, gave them the distinct advantage of being able to employ the weapons much more rapidly, and in more locations than using strategic bombers alone. While there were those in the Air Force that felt like this strategy would dilute the strategic capability, and siphon resources from the primary combat capability, tactical nuclear weapons were accepted, and entered the inventory in 1952.[15]

The institutionalization of the de-emphasis of the air-to-air mission, and the emphasis of strategic warfare over tactical warfare left the leaders of TAC concerned about the future of the command. While funds were scarce for procuring tactical weaponry, it was clear that the Air Force and the Congress were willing to invest in the delivery of nuclear weapons. Therefore there was practical motivation to find ways to participate in the nuclear bombardment mission. Doing so would increase relevance for a command whose traditional mission was considered unimportant at the time. It would also qualify the command to receive the necessary funding to modernize its weapons.[16]

The first aircraft outfitted with tactical nuclear weapons was the F-84G. Although the nuclear bombs had been drastically reduced in size, they were still a significant load for the F-84, with its primitive turbojet engine. A jet assisted takeoff (JATO) system was installed, which increased the logistics support of the tactical nuclear mission. This allowed the plane to takeoff using a reasonable length of runway, but was a stopgap measure to get the new weapons fielded as soon as possible. TAC began to look to the future for aircraft that could perform the mission more efficiently, and without the use of JATO.[17]

F-105: The predecessor to the TFX

For this study, the most notable tactical fighter before the start of the TFX program was the F-105. Up until that point all of TAC's aircraft had been either leftovers from World War II development efforts, adaptations of interceptor or escort aircraft, or transfers from the Navy. The F-105 was conceived by Republic (designer of the F-84) as a much improved successor to the F-84F swept-wing fighter bomber. The F-84F, which arrived in the inventory after the G-model, was developed as a modification of the basic F-84, which began development during World War II in 1944 to replace the P-47.[18] The F-105 would be specifically designed for the purpose of delivering TAC's new tactical nuclear weapons.

In 1952 TAC planned to use the F-100, which was in development at that time, as its frontline fighter until around 1958, when it would be replaced by a more modern airplane with better performance.[19] Two years later a General Operational Requirement (GOR) was released calling for a "Tactical Fighter Bomber Weapon System." The primary mission of the new aircraft would be delivery of nuclear weapons. A secondary mission was as an air-to-air fighter, mainly as a means of fighting its way to and from the target area.[20]

As national security became more dependent on nuclear bombardment, there was a decrease in emphasis on the aerial combat mission. Air Force doctrine in use at that time stated that "One of the fundamental means for providing security of the homeland from air attack is the destruction of the enemy air forces at their bases."[21] While mentioning that a need for fighting aircraft in the air was a possibility, it added, "Lack of control of the air must not, in itself, deter commitment of the entire striking force in order to achieve results calculated to be decisive."[22] The F-105 reflected this heavy emphasis on the bombardment mission at the cost of air-to-air capability.

The F-105 was the aircraft that was eventually developed to fulfill the role detailed in the GOR, and began its operational service with the 335th Tactical Fighter Squadron, after that unit became fully equipped in August 1959. Its powerful engine and relatively small swept wings made it extremely fast at low altitudes, and therefore ideal for penetrating defenses for bomb delivery. Furthermore, it was designed with an internal bomb bay to carry nuclear weapons, which at the time were too sensitive to be carried externally during high speed flight. In keeping with the existing mission emphasis of the era, it did not perform well in the air-to-air role, as demonstrated by its record during the Vietnam War. While the F-105 was generally praised for its ability to fly at high speed thus increasing its survivability, and its ability to accurately drop nuclear weapons even in bad weather, it did have some drawbacks. These became more apparent as available technology surpassed that used on the F-105. Poor conventional bombing accuracy, especially in bad weather, and a dependence on large vulnerable runways were among the weaknesses of the aircraft.[23] Whatever its shortcomings, the F-105 was definitely TAC's airplane, and therefore provides a good representation of TAC's philosophy, just prior to the genesis of the TFX program, of what a fighter should be.

Setting the Stage for the TFX Program

The TFX program came from the convergence of many inputs. Absent any other motivation, the programmed modernization of Air Force aircraft was already cited, and was planned even before the predecessor of the TFX had been developed. Of course changing strategy and threat considerations influenced the conceptualization of the new aircraft. New available technologies always play a role in new weapons, and that is especially true of the TFX. As the ideas for a new fighter began to materialize, various groups and individuals that would be affected by the program began to influence the definition process, influencing the decisions that would lead to the formal requirement generation process.

Genesis of the Concept

On August 1, 1959, the same month the 335th Tactical Fighter Squadron became the first complete operational F-105 squadron, General Frank Everest became the commander of TAC.[24] Having spent much of his career in tactical operations, including his previous assignment as commander of United States Air Forces in Europe, which was a tactical force with a wartime commitment to the North Atlantic Treaty Organization (NATO), General Everest came to TAC with a desire to modernize. Although the F-105 was just beginning its service, Everest felt like it would become obsolete before a replacement could be fielded if development of a follow-on aircraft was not begun immediately. While he was still stationed in Europe he had already began writing out in longhand his ideas for what the new fighter would be able to do.[25]

The F-105, like all early jet fighters, required a long takeoff run in order to build up the speed necessary for flight, especially when carrying enough ordnance to be useful. Given the fixed and conspicuous nature of a two mile long piece of concrete, as well as the ramp space and buildings that accompanied it, airbases in Europe would be obvious targets should a war break out. This vulnerability became even more acute after the Soviet Union developed and deployed nuclear-capable surface-to-surface missiles in Eastern Europe. During the 1950s the U.S. was concerned about the vulnerability of their bases, as evidenced by the reaction of the Supreme Allied Commander of NATO, U.S. Air Force General Lauris Norstad. He sternly warned the Soviets that NATO forces would strike back with the retaliatory capability that he claims would exist despite an attack.[26] To bolster that position, Norstad requested that Matador surface-to-surface nuclear-armed missiles be deployed in Western Europe. This was done in January of 1954.[27]

The problem of airfield vulnerability weighed heavily on the mind of General Everest for two reasons. The first was the obvious potential loss of his fighting force to missile attacks. He calculated that at best he might be able to launch 30 to 40 percent of his fighter inventory prior to the arrival of the missiles in the case of an attack. This would allow them one sortie, since recovery would be impossible after the missiles hit.[28] The other threat was to the relevance of TAC as a viable fighting force, and therefore to its existence as a command. Worried about the vulnerability of NATO airfields in Europe, Norstad proposed replacing aircraft with surface-to-surface missiles. There was support for at least augmenting aircraft with missiles even within TAC.[29] During a period when TAC was already being dominated by SAC, in terms of missions, budgets, and influence, the loss of their role in Europe, arguably the most important theater, could spell the demise of TAC as a major command. In order to overcome these challenges Everest sought a more capable weapon system to replace the F-105, which was becoming outdated by the new advanced missile systems, even as it was being introduced into the inventory.

It was with the intent of overcoming these challenges that Everest started to pen the requirements for a replacement fighter bomber. His plan was to base the aircraft out of range of the Soviet missiles, which meant keeping them on American soil. To avoid dependence on SAC, who owned the air refueling tanker force, the new fighter would need the ability to fly across the Atlantic Ocean unrefueled once a war started. Assuming that most, if not all of the existing bases would have been bombed, the new fighter would need to have the ability to operate from unimproved (sod) strips. This would make a long takeoff run impossible, so the takeoff distance would need to be short; around 1000 feet, or less than a tenth of that required by the F-105. Once in the theater, the fighter would still need to be able to defeat enemy defenses, which to most people at the time meant high speed flight. Everest wanted at least a Mach 2 capability at altitude, and near or greater than Mach 1 for low altitude ingress and egress to and from the target. From his familiarity with the European theater and targets, Everest chose 400 nautical miles for the low altitude ingress/egress leg. And of course it would have to perform this combat mission carrying at least one nuclear bomb.[30]

This set of capabilities was a tall order. The biggest conflict, from a strictly engineering standpoint was the ability to fly long range across the ocean, and then fly high speed at low level. The characteristics that would allow the first capability; large straight wings and efficient turbofan engines, are the opposite of those needed to fly high speed at low altitudes; which are swept wings and high-thrust afterburning engines. Despite the ambitious performance targets, Everest immediately began sharing his ideas with other people to determine how feasible development of such an aircraft would be.

Technology

Langley Air Force Base, besides being the location of TAC Headquarters, was also home of the National Advisory Council for Aeronautics (NACA) Langley Research

Center.* In 1959, when General Everest arrived, the assistant director of the center was a celebrated researcher named John Stack. Stack had won several awards, including sharing the Collier Trophy with Chuck Yeager in 1947 for his work with the X-1, the first aircraft to fly faster than the speed of sound.[31] As assistant director, Stack oversaw research of the concept of a variable geometry wing design. This research was conducted using the Bell X-5 experimental aircraft.[32]

The concept of a variable geometry wing, or "swing wing" as it is often called, originated in this country with the capture of the German Messerschmitt P.1101 in April 1945. This small experimental jet plane could adjust its wings while on the ground to one of three fixed sweep angles between 35 and 45 degrees. Although the plane had never flown before its capture, it inspired Bell Aircraft chief design engineer, Robert Wood, to propose the development of a larger version for further research. The Air Force approved the project in February 1949 and two aircraft were built. A major difference from the Messerschmitt design was that the X-5, as it was called, would be able to change its wing sweep from 20 to 60 degrees while in flight. The Air Force conducted several test flights up until January 1952, before giving one of the aircraft to the NACA for further research.[33]**

Everest and Stack met and Everest was immediately impressed with Stack and his abilities. He would later call him "the number one aerodynamicist in the United States."[34] Everest approached Stack and explained his idea for a new fighter to Stack and asked his opinion on the feasibility of such an aircraft.[35] The request came at an

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* On 1 October 1959 the NACA became the newly created National Aeronautics and Space Administration (NASA).

** The second aircraft was flown by Air Force test pilots for another year before it was destroyed in a crash, killing the pilot, Major Raymond Popson, on 13 October 1953.

opportune time, since the recent launch of Sputnik and resulting emphasis within NASA on space projects had left Stack's team with a decrease in meaningful research work. They welcomed the challenge, and began to work enthusiastically on the project.[36]

There is consensus that the otherwise impossible mission requirements of the TFX became somewhat achievable only by using the variable geometry wing technology that had been studied by Stack's group. In order for this to occur, however, a major problem with the technology had to be worked out. In the design of the X-5 the aerodynamic center of the aircraft changed as the sweep varied. This resulted in the necessity of moving the pivot point of the wings as it swept forward or backward. While this was acceptable for an experimental research aircraft, the demanding flight conditions in which a fighter aircraft would fly, and the loads that would be placed on the wings, made a moveable pivot point unrealistic. The breakthrough that solved the problem is credited to Stack himself. Instead of having the wings pivot on the same axis, he separated the pivot point of each wing, and moved it to the edge of the fuselage, in the wing roots. This allowed the wings to pivot without changing the aerodynamic center, and it could therefore use a much simpler mechanism. Stack reported back to Everest in March of the following year telling him that such a plane was feasible with the only question being the ability to sustain Mach 1 on the ingress/egress legs. He had, in fact, already designed a conceptual airplane and successfully conducted some wind tunnel testing on a model of the design.[37] Whether the specific mission Everest contrived was only possible with variable geometry technology as many suggest, whether Stack's initial application of that technology to the problem dissuaded further creativity, or whether the new technology was so appealing that it was unquestioningly desired by decision makers, from that point onward a variable geometry wing was in integral part of the TFX program.

A large factor in the development of any new system is the contribution made by the aircraft design companies. Because the main customer, and in some cases the only customer, for a defense contractor is the U.S. government, close liaison is maintained between the contractors and government agencies. The close working relationship and personal interaction between contractor employees and government personnel allow contractors to channel their investment in directions that can put them in a position to be competitive for future development contracts, while the government can increase the chances that when a technological capability is needed there is a company that can provide it. Sometimes the contractors are the ones who initiate a requirement through application of a new technology before government agencies recognize the value.

Significantly for the TFX program, Boeing had taken an early interest in variable geometry wing technology, and through communications with the Air Force they were aware that eventually a new fighter would be needed and could benefit from the new technology. Consequently, as early as mid 1959 Boeing had a conceptual design for a fighter aircraft with a variable geometry wing. Communication with Everest and Stack allowed them to focus their efforts toward a solution to Everest's concept for a new fighter. General Dynamics began work on a similar conceptual design about a year after Boeing began.[38]

Selling the Program

All of the previous activities were done before the TFX program existed. While some people were thinking ahead with plans to start a program to build a fighter based on a mission, a technology, or other inputs, no such development program existed in the Air Force. In order for that to happen enough people in enough positions of authority would have to be convinced to commit resources to build a program. With the ideas that Everest had, and the preliminary results of the engineering work, which at that time was still in progress, at the beginning of 1960 he went to the Air Force Headquarters at the Pentagon to gain enough support, and funding, to begin a program.

The point when a program can be said to exist is open to subjective interpretation. Some may choose the point at which the needed capability is articulated, while others may wait until a fully staffed program office is in place. While selecting a precise definition can be problematic, identifying an exact point in time for program initiation is not important for this study. In fact, regardless of when a program is said to begin, events such as changing the name, the requirements, the funding source, the scope or the program office location can take place which confuse the status of a program. And of course program initiation does not preclude the possibility of program cancellation. Despite the imprecise nature of the existence of a program, it will be sufficient for this study to consider a program to begin when money has been committed to some initial articulation of requirements.

Brigadier General Bob Titus, who served on the Air Force Staff in Requirements and Development Plans near the end of TFX development, recalls seeing a large wall chart in his area in the Pentagon which detailed the procurement process for a new weapon system. At the time efforts were underway to gain approval for the follow-on fighter program to the TFX, and he asked his more experienced colleagues where they were on the chart. He soon learned that the chart bore little resemblance to reality because no two weapon systems gained approval in the same manner. The actual process was a loosely specified effort to gain approval from those who controlled the funding.[39] Equally unspecified is the list of people who must approve a program. Ultimately Congress has to appropriate the funds, and the President must sign the appropriations bill. Under normal circumstances there is support within the service, the Air Force in this case, and the Department of Defense (DoD) before this happens. There have been cases, however, when Congress appropriated funds and the service was less than willing to spend them due to lack of support for the program for which they were appropriated.* Very rarely, if ever, is there complete agreement through the entire service chain of command and throughout the DoD for a program. Most commonly there is agreement by enough decision makers in key positions to override the objections of those who are opposed.

Everest's purpose for going to Washington was, in his words, to "sell" the TFX, as he and Stack had conceptualized it.[41] His cause was helped by the fact that he was a four-star general, and as commander of TAC, could represent the using command. His

* One example is the Ling-Temco-Vought A-7, which was a subsonic Navy ground attack aircraft. Although officially the Air Force accepted the aircraft, evidence suggests that very few, if anyone in the Air Force wanted it. Numerous officers interviewed stated this clearly, including Maj Gen John C. Giraudo, who served as Air Force Legislative Liaison during that period, and who states that he was told directly by Senator John Tower, of Texas where the A-7 was produced, and who was the powerful chairman of the Senate Armed Services Committee, that if the Air Force did not accept the A-7, they would not have his support. Maj Gen James R. Hildreth, who was in charge of the A-7 procurement program for the Air Force, stated that no one in the Air Force wanted the planes, and that he was "working against the interests of his bosses." He said that he got threats from people in TAC that it would ruin his career if he continued to work for the procurement of the A-7. No interviews found by the author revealed anyone in the Air Force who was enthusiastic about procuring the A-7.[40]

representation was accurate because during the past decade of building up SAC, TAC pilots had experienced decreased levels of funding, and a dearth of modernization programs. Therefore, the general attitude within TAC was one of acceptance of any new aircraft which could be successfully procured.* For this reason no serious debate or negotiations within TAC were necessary before or during the advocacy process at the Air Force level.

Besides the general acceptance of the TFX in TAC, also to Everest's advantage was the fact that the TFX, as then defined, would contribute to, and improve in a significant manner the nation's nuclear combat capability, which was the top priority at that time. Even though both the Air Force Chief of Staff, General Thomas D. White, and the Vice Chief of Staff, General Curtis E. LeMay, were strong proponents of strategic forces, and saw little need for fighters at this time, they were willing to support the program based on the capability it would add to the nuclear weapons delivery capability.[43] Thus, both fighter pilots and bomber pilots were amenable to the idea of the TFX.

Everest also sought to convince the civilian leadership in the Air Force of the value of the TFX. Dr. Courtland D. Perkins, who was serving as the Assistant Secretary of the Air Force at that time, said that Everest and Stack came to his office together to present their briefing of the concept. As a civilian, Courtland was more concerned with the technical feasibility of the proposed airplane, and needed to be convinced of that before he could support it. Despite Stack's reputation as an engineer, Courtland consulted the Air Force Scientific Advisory Board (SAB). His biggest questions focused

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* Virtually every interview with a fighter pilot of that era conveys this attitude. Even many of the bomber pilots concede that TAC was neglected and underfunded. Maj Gen James R. Hildreth, USAF (Ret.) colorfully described TAC's status: "[TAC] suffered like poor country cousins."[42]

on the proposed weight of the aircraft, which Stack had calculated at 50,000 pounds. Courtland questioned the ability to keep the weight that low for such a complex aircraft.[44]

The question of feasibility was referred to the Wright Air Development Division (WADD), responsible for aeronautical research at Wright-Patterson Air Force Base, Ohio; the center for aircraft development in the Air Force. In preparation for the study, on 5 February 1960 the Development Planning office at Air Force Headquarters issued System Development Requirement (SDR) No. 17, titled: "Short Take-Off and Landing (STOL) Fighter System." The SDR is taken almost directly from requirements Everest originally conceived, and specified a fighter with the following capabilities:

- The ability to take off and land in less than 3000 feet using "austere" airstrips
- The capability to deploy nonstop from the United States, with a 3300 nautical mile ferry range
- An 800 nautical mile mission radius, including a 400 nautical mile low altitude ingress/egress
- Maximum speed of Mach 1.2 at sea level for the ingress/egress, and Mach 2.3 – 2.5 at altitude
- Maximum altitude of 70,000 feet (desired)
- The ability to carry nuclear and conventional weapons, and be able to employ them accurately in all-weather (at least for fixed targets)
- The ability to launch air-to-air missiles

The SDR does not specify a swing wing, but interestingly it does direct that the aircraft will have a crew of "two pilots," and that it will "be equipped with at least two engines."[45]

WADD set up a task group with personnel from their own organization and from another group within Air Research and Development Command (ARDC), the Aeronautical Systems Center (ASC) which was responsible for developing new aircraft once a program was approved. The group was rounded out with personnel from Air Materiel Command (AMC), the organization that would have responsibility for maintaining the aircraft once developed, if the program made it that far. The study was completed in April 1960 and it confirmed the feasibility of the concept by providing notional performance for two conceptual designs, designated WADD63 and WADD46. WADD63 had a gross weight of 76,000 pounds and WADD46 weighed 60,000. The only SDR requirement that was not met was the ingress/egress distance at Mach 1.2, which came out to be 230 and 160 nautical miles respectively. All other requirements could be met, according to the study.[46]

The results of this analysis crystallized sufficient consensus within the Air Force to begin planning the development program for the new system. Along with the results of its study, WADD submitted an abbreviated development plan (estimated cost and schedule) to ARDC. Based on this, ARDC and the Air Force Staff worked with NASA to structure a formal program with money designated in the defense budget for development. The result was "Development Plan for the Short Take-off and Landing Fighter/Bomber Weapon Systems, No. 649C," dated 11 May 1960.[47]

Armed with a development plan, Perkins took on the responsibility of gaining approval at the DoD. The first level was the Director of Defense Research and Engineering (DDR&E, now called the Under Secretary of Defense for Acquisition, Technology, and Logistics), who at the time was Herbert York.[48] Perkins saw the preoccupation with the upcoming presidential election as an opportunity to garner approval from the necessary people, while going unnoticed by those who could potentially impede approval. In a 19 May 1960 Memo to General White, besides indorsing TAC requirements (which he acknowledged as being conceived by Everest), he stressed these "favorable" conditions (i.e., distraction by the upcoming election) for finalizing the requirements and initiating competition for the development contract.[49]

With a development plan in place, the Air Force set about to formalize the requirements that had been captured in SDR No. 17, with inputs from the WADD study. The result was the "Specific Operational Requirement for a Tactical Manned Weapon System," or SOR No. 183, dated 14 July 1960. SOR-183 expanded on SDR-17, with minimal changes. Specifically, SOR-183:

- Introduced the requirement for a reconnaissance capability by requiring the existing avionics to add the capability to locate targets
- Specified a capability to "support surface forces in the immediate battle area" (close air support, or CAS)
- Retained the requirement to take off and land in less than 3000 feet using austere airstrips, but specified "dry sod" and some other surfaces as a description of "austere"
- Retained the requirement to deploy nonstop from the United States, with a 3300 nautical mile ferry range
- Retained an 800 nautical mile mission radius, but lowered the ingress/egress leg to 200 nautical miles, with 400 as a "desired" target
- Retained maximum speed of Mach 1.2 at sea level for the ingress/egress, but lowered top speed at altitude to Mach 2.2, with Mach 2.5 being "desired"
- Maximum altitude of 60,000 feet became a requirement, with a 70,000 feet ceiling being retained as "desired"
- Retained the requirement to carry nuclear and conventional weapons, and to be able to employ them accurately in all-weather for fixed targets
- Retained the requirement to launch air-to-air missiles
- Retained the requirement to be manned by a crew of two pilots and equipped with at least two engines
- Added a section listing vulnerabilities in existing systems, which are the same as those listed by Everest as his initial motivation, specifically vulnerability of air bases and inadequate weapons delivery accuracies.[50]

White agreed with Perkins' plan to expedite program approval. Accordingly, Perkins presented the new requirement to John Ruble, York's assistant, and convinced him of its worth. Ruble was then able to get York to sign off on the requirement, which was then forwarded up to the Office of the Secretary of Defense (OSD) for approval.[51]

In August 1960 there was enough support and documentation to justify funding in order to begin work. The "Development Directive of Tactical Manned Weapon System" (DD no. 406) was signed on 10 August 1960, and authorized the expenditure of $5.3 million of carry-over fiscal year 1960 (FY-60) money, with an additional $29.3 million of FY-61 money becoming available upon approval by OSD. While the directive cautioned that release of the funds "should not be interpreted as program approval," it did authorize "the initiation of all development actions leading to but excluding source selection."[52]

The Air Force moved ahead quickly, and began making preparations so that source selection could happen as soon as authorization was received. On 12 October 1960 that authorization was received and final preparations were made to send out a Request for Proposals (RFP) to defense contractors.[53] It was also at this time that the designation of the proposed weapon system was changed from 649C, to the permanent designation of Weapon System No. 324A (or WS-324A), and given the name of "Tactical Fighter Experimental," or TFX.[54]

With a signed operational requirement, consensus within the Air Force, support by many key players in the DoD, a formal program name, funding authorized, and approval for source selection, it seemed that the program could be considered securely established. Program status, however, is never secure. The TFX program demonstrated this as it came to a complete halt in November of 1960.

Just before the election occurred OSD denied program approval. At first the denial was based on a delay while a review of the FY-62 budget was conducted, but just over a week later, just after the election and days before the RFP was scheduled for release, all program activity was halted by Secretary of Defense Thomas N. Gates. President Kennedy had just won the election, and Gates thought it would be improper to commit the new administration to such a costly new weapon system, and especially one that would require a large measure of new and high-risk technology. Despite Gates' explanation for the decision, Everest believes it was based on a flawed belief that with the strategic-dominated defense plan a new fighter was simply unnecessary.[55]

The TFX program remained halted until the Kennedy administration was in place, including the new Secretary of Defense, Robert S. McNamara. As one of his first official acts, McNamara commissioned a study called Project 34, which analyzed the overall problem of tactical aircraft in the 1962-1971 time period. Based on the cost savings of developing one aircraft for more than one purpose, McNamara made a decision on the TFX program.[56] The aircraft would be developed, and it would fulfill not only the Air Force's requirements, but also those of the Navy's new fleet air defense fighter. Furthermore, it would meet the CAS requirements of the Army and Marine Corps. Accordingly, less than a month after taking over as Secretary, McNamara gave instructions for the program to resume, but with the stipulation that it would be "reoriented." In a 14 February 1961 memo the DDR&E directed all four services to participate in the development of the aircraft, which would be "conducted as a joint Air Force-Navy program with the Air Force being responsible for accomplishing the development," with the objective "to provide an aircraft that will meet the requirements of both the Air Force and Navy… [and be] satisfactory for accomplishment of the close air support missions in support of the Army and Marine Corps forces."[57]

The TFX Development Program

With the decision of Secretary McNamara, and the clear direction he provided, the TFX program was decidedly begun, and would prove to last through the production of an aircraft. The program that began, however, was clearly not the same program that was halted three months prior. The reorientation of the program, with the ensuing introduction of requirements from the other services, would have a profound effect on the resulting product. Negotiations, compromises, and power struggles, external to any formal requirements generation process used by the individual services, had a significant influence on the overall process of determining the final design.

Coordination of Requirements

In his memo directing program reorientation, York requested that the Secretary of the Air Force "accept the responsibility for initiating action to develop a coordinated specific operational requirement." The due date for a SOR that was agreed upon by the Army, Navy, and Air Force was one month later on 15 March 1961. If an agreement could not be reached, the report submitted was to be a list of points upon which agreement was reached, and a list of points on which no agreement could be reached, along with comments from the services. These conflicting requirements would then be resolved by the office of the DDR&E.[58] In order to take advantage of work that had already been done by the Air Force, because the Air Force was to be the largest user of the system, and because it was the lead agency, SOR-183 became the starting point for the exercise.

The Navy had an existing fighter requirement for a fleet air defense fighter. Its mission was to loiter over the Navy fleet for long periods of time, and then if an intruder approached, to intercept it. Its main weapon would be a long-range autonomous radar-guided air-to-air missile. While a swing wing, which the Navy had studied, would support this mission by allowing a straight wing for endurance flight during loiter and a swept wing for high speed interception (although the requirement was for a subsonic interceptor), many of the SOR-183 requirements, such as supersonic speed, low altitude high speed flight, and austere field capability, were extraneous and would degrade other flight capabilities desired by the Navy. Similarly, Navy-specific requirements, such as shorter length to enable it to fit on an aircraft carrier elevator, or a heavy tailhook for carrier landing capability, would degrade capabilities necessary to fulfill the Air Force mission.[59]

The Army, who was the lead service for CAS and thus represented the Marine Corps requirements, had a completely different set of requirements for that mission. Army planners envisioned a very short takeoff, subsonic aircraft that could loiter over the battlefield. Because it would be operating in close proximity to friendly forces it would carry only conventional weapons. The short takeoff capability would allow it to operate from forward airstrips, allowing a much less demanding range requirement, in favor of loiter time. A much smaller, straight wing, subsonic aircraft would be optimum for the Army. A SOR-183 type aircraft would provide significant excess capability in some areas, such as high speed capability, at significant excess cost. Some characteristics of the more expensive airplane, such as larger size – making it a bigger target to ground fire

– would detract from the capabilities of the smaller, less expensive airplane envisioned by the Army.[60]

Because each of the services had already developed their respective requirements, the work of developing a joint SOR was not the typical requirements generation process. Instead the task became one of merging the existing sets of requirements into one combined set. As previously stated, many of the requirements were conflicting, such that an increase in one capability would cause a decrease in a different capability. The determination of which tradeoffs to make had to be reached through negotiations between the three services. While analysis and calculations could provide data on the level of capabilities being traded, the decision of a service to actually trade desired capability away in order to allow another service to gain capability was based on the willingness of each service to compromise mission effectiveness in the new fighter.

Given the importance placed on mission accomplishment by each service, and the relative disinterest in sharing a common fighter, which was a DoD imposition, it is not surprising that there was little willingness to compromise. Faced with unacceptable mission degradation, the Army and Navy attempted to withdraw from the joint program. Just days before the joint SOR was due, Navy Director of Research and Development, Dr. James H. Wakelin, sent a letter to Secretary McNamara which concluded that commonality was not consistent with national defense interests, and rejected the TFX for Navy use. The Army also sent a memorandum which stated that the TFX was primarily a nuclear delivery vehicle, and was not suited, as well as being too expensive, for CAS.[61]

In response to the inability to reach an agreement on requirements, the Assistant Secretary of the Air Force for Research and Development, Dr. Joseph V. Charyk, dissolved the committee to develop the joint SOR. He then formed a new committee comprised of himself, and his counterparts in the Army and Navy who would resolve the differences and submit a report to York, the DDR&E. When again no resolution was forthcoming, Dr. John Parker, Assistant DDR&E for Naval Weapons, was given the job of leading a DoD committee to coordinate requirements and report them to York and McNamara.[62]

To demonstrate the confusion during this period of time one can look at the public statements being made compared to the positions maintained by the different services. On 1 April 1961 President Kennedy referenced the TFX in his military budget saying it would emphasize the non-nuclear role.[63] This is in direct contradiction to SOR-183 and the Army's contention that as it was currently designed, the TFX was primarily a nuclear delivery platform. On 8 April 1961 McNamara testified to Congress that the TFX would have the capabilities specified in SOR-183, and then added that it would "be suitable for operation from aircraft carriers."[64] Even though he directed the services that this would be the case, no compromise had yet been reached between the Navy and the Air Force that would allow for all of these capabilities to be possible. Finally, Air Force Chief of Staff General White testified to Congress a few days later that the TFX's "slow speed maneuverability will make it an ideal airplane for providing close support to ground and amphibious forces."[65] Again, this was not supported by the Army's contention that the aircraft was ill-suited and too costly for the CAS mission.

This stalemate continued into the summer of 1961 with very little if any progress toward a joint set of requirements being made. In late July the DoD committee, with the participation of representatives from each of the services, and based in part on data from the ongoing Project 34 study, reached a consensus that the CAS requirements were too divergent from those of the other missions. They recommended pulling those requirements out of the TFX program to be met by a separate aircraft. McNamara acquiesced, and gave the Navy lead service responsibilities to develop a separate ground attack aircraft.[66]

The Air Force and Navy, left as the remaining participants in the TFX program, still diverged sharply in their views of what the new airplane should be. The Air Force maintained as its first priority the weapons delivery mission which required the low altitude supersonic dash. To enable this, the aircraft would need to have a long fuselage with a small frontal area, relying on a titanium structure to withstand the large forces generated. The Navy’s first priority was the fleet interceptor role, which required a large frontal area to accommodate the radar dish that would allow it to locate potential intruders. The Navy also required a lower overall weight so it could perform carrier landings, however the greater impact forces involved in carrier operations dictated that a larger portion of the weight be dedicated to structure supporting the landing and arresting gear. Carrier deck and elevator limitations also impose limits on size, including length. The major conflicting required/desired characteristics of each service can be summarized as follows.

	Air Force	**Navy**
Primary Mission	Weapons Delivery (especially nuclear)	Fleet Air Defense
Length	82.5 ft: Long to allow lower drag during supersonic flight	56 ft: Limited for carrier operations
Radar Dish Diameter	Small, for low frontal area	48" Diameter

Seating Arrangement	Tandem, for decreased frontal area	Side by side, for more effective crew coordination and shorter length
Frontal Area	Small (no more than 24 sq ft according to Stack's design work)	Large enough for search and intercept radar, and sided by side seating
Structure	Titanium, concentrating on aerodynamic forces	Lower cost than titanium, concentrating on landing gear and arresting system
Weight	75,000 lbs design estimate	No more than 50,000 lbs for carrier limitations
Altitude / Speed	Emphasis on low altitude dash at supersonic speeds	Emphasis on long loiter at medium to high altitudes at subsonic speeds

Table 3.1. The major conflicting required/desired TFX characteristics of each service.[67]

At the end of April 1961 Herbert York resigned as DDR&E as part of the change in presidential administration and the arrival of McNamara as the Secretary of Defense. He was replaced by Dr. Harold Brown, a young and energetic scientist who took a personal interest in the TFX program. During his first few months in the position of DDR&E he worked with his technical staff to conduct a study using data available from Project 34 and other analysis, to resolve the impasse at which the services found themselves. In the absence of any agreement, the requirements remained those documented in SOR-183, which were unacceptable to the Navy. Accordingly, in August 1961 the Secretary of the Navy reported to McNamara that the Navy requirements could not be met by the TFX. When this occurred, Brown was ready with a set of requirements he and his staff had devised, and proposed them to McNamara in a memo on 31 August.[68]

Perhaps showing McNamara's impatience with the delays and his eagerness to move ahead with the program, the very next day, 1 September 1961, McNamara sent a memo to the Secretaries of the Air Force and Navy dictating what the TFX requirements would be, which was the exact compromise that Brown had proposed in his memo. After reiterating his belief that it was technically feasible to provide "genuine tactical utility to both services" with a single aircraft, he directed the two services to proceed with the joint program. The memo directed that the Air Force version "shall be developed to meet as nearly as possible the minimum required performance as specified in SOR-183," within certain constraints that would allow a Navy version to be developed with maximum commonality. Six constraints were imposed:

1. Radar antenna dish minimum diameter of 36 inches
2. Maximum aircraft length of 73 feet
3. Maximum weight of approximately 60,000 pounds (full internal fuel and 2000 lbs of internal stores)
4. Minimum weapons delivery capability of 10,000 pounds of conventional ordnance
5. Ability to carry a minimum of two 1000-pound air-to-air missiles internally, and four more externally or semi-submerged
6. Capable of aircraft carrier operations

Finally, the services were directed to collaborate on a program management plan, and submit it to the McNamara's office by 15 September 1961.[69]

During the ensuing two weeks, the Air Force updated SOR-183 to reflect the requirements imposed by McNamara. The revised SOR was released on 8 September 1961. Besides the basic requirements, it included three annexes with information about specific versions of the aircraft. Annex A was for the Air Force tactical fighter, and was closest to that envisioned by General Everest. Annex B was for a follow-on interceptor version that was to be developed later.* Annex C was for the Navy fighter.[70] From

* As noted in chapter one, this study has been bounded to exclude follow-on versions and major modifications of existing aircraft. Since the interceptor version of the TFX falls into this category, it is

this documented and validated set of requirements was produced the statement of work from which the TFX aircraft would be designed and built.

The sequence of events that led to the requirements used by contractors to develop the TFX lasted over two years, and had no semblance of any process that had been documented. Left out of this narrative was the account of the actual established procedures followed by staff officers in the various Requirements Branches of TAC or the Air Force Staff. Of course these entities played a role, especially in the articulation of the broad requirements considered in this paper into detailed specifications. This is evidenced by the formal documents detailing these specifications. With that acknowledgement, however, the account of the actual process by which the requirements were established reveals that several important defining decisions were made about the requirements of the TFX through an informal process of creativity, persuasion, negotiation, imposition, and compromise. It was only after these decisions were made, and coordinated via memo or other less formal means, that the formal requirement documents were written to reflect those decisions. Also noteworthy is the fact that the final decision on what the requirements would be were made by civilians who joined the process part way through, and were far removed from the operation of weapon systems. They had never served in the Air Force, yet they were in positions of influence during this process.

Also absent is a detailed account of the hours of analysis that took place to provide information to decision makers. The documentation makes it clear that much analysis took place, but for the purposes of understanding this process as it occurred for

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beyond the scope of this study. Furthermore, due to the lengthy and controversial development of the F-111, the interceptor version was never developed.

the TFX, the results, not the details of the analysis are of interest. For example the initial wind tunnel work of John Stack and his team that convinced Everest, and many to whom they presented their ideas, of the feasibility of the initial TFX concept, was very relevant. It is important to note, however, that Stack's rigorous analysis did not convince everyone. Therefore the WADD study, which confirmed Stack's contention that the design was feasible is also of interest. Similarly, the Project 34 study and related analysis that convinced McNamara to direct a joint aircraft, and which allowed Harold Brown to determine the feasibility of tradeoffs that would later be imposed, were very important. Finally, the ongoing studies of the Navy and Air Force during the months of deliberation provided answers to questions for decision makers, and had the effect of confirming the services' positions. They also provided information about the implications of various tradeoffs which allowed the leaders in the Air Force and Navy to make informed decisions.

Programmatics

The TFX was one of the most controversial military acquisition programs ever undertaken. It received an inordinate amount of attention while it was occurring, as well as afterward. Most of the attention focused on the management of the program, especially the questionable and disputed source selection process, which set off Congressional hearings to determine if it was done fairly and legally. F-111 crashes during and soon after development have also drawn attention to the program.

Because of this attention the TFX has been well studied and analyzed. Most of that research has focused on program management, or the technological artifact, which is not the purpose of this research. Data from those studies can be used, however, to learn more about how the aircraft became what it eventually did, as well as how it came to be perceived.

The day after the revised SOR-183 was released, the source selection for the TFX was directed. It called for a submission of an RFP to industry by 1 October 1961, followed by an evaluation of submissions, and the award of a development contract by 1 February 1962.[71] On 1 October the RFPs were sent out to ten contractors with the statement of work attached.* By 1 December 1961 six proposals had been received, including one from Boeing, and one from General Dynamics/Grumman. The WS-324A Evaluation Group, set up to support the source selection board, conducted an intense evaluation based on technical feasibility and design performance; operational feasibility and performance, including test plan and considerations; logistical considerations, including maintainability; and program management, including cost. In each of these categories the historic performance of the contractor was taken into account. Evaluation teams for each of these categories dissected each proposal and gave each part a numerical grade from a scale defined in detailed instructions. The grading system was thoroughly explained in order to achieve consistency across proposals.[73]

At the completion of the evaluation the scores for the proposals submitted by Boeing and General Dynamics/Grumman were roughly equal, with Boeing scoring higher in the operational area, and GD/Grumman scoring higher in the technical area. These two proposals were far superior to the other four, but both fell short of meeting the requirements. The evaluation group recommended instead of choosing one contractor

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* Contractors receiving the RFP were Boeing, Chance Vought, Douglas, Grumman, North American, Lockheed, Republic, McDonnell, General Dynamics Fort Worth Division, and Northrop.[72]

and awarding the development contract, that the two contractors with more promising proposals be allowed to continue to develop their concepts before a final choice was made. Despite this, the voting members of the source selection board voted unanimously in favor of Boeing. This action was sustained by TAC, Air Force Logistics Command (AFLC), and the Navy Bureau of Weapons (BuWeps), but not Air Force Systems Command (AFSC), who had replaced ARDC and was responsible for developing the aircraft.[74]*

Air Force and Navy military and civilian leaders chose to follow the recommendation of the evaluation group to proceed with two contractors. They were put on contract to complete an intensive $2 million, 90-day study, and were each given detailed feedback on what needed to be improved. At the end of this period, and based on a more thorough proposal as a result of the study, one contractor was to be selected to develop the aircraft.[75]

Boeing and GD/Grumman submitted their second proposals in 2 April 1962, and by 14 May the source selection board had graded the proposals. The three Air Force members voted for Boeing, while the Navy member considered both proposals unacceptable since they did not meet Navy requirements sufficiently. He did, however, concur that the Boeing proposal came closer, and was therefore the better proposal.[76]

Given the difficulty in meeting both the Navy and Air Force requirements, on 1 May 1962 Secretary of the Air Force Eugene M. Zuckert and Secretary of the Navy Fred Korth asked for a second extension of the source selection to give the two contractors time to further improve their designs. McNamara asked his analysis team to study the

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* The voting members of the TFX Source Selection Board were: RADM F. L. Ashworth, BuWeps; Maj Gen T. Alan Bennett, AFLC; Brig Gen A. T. Culbertson, AFSC; and Brig Gen J. H. Moore, TAC. NASA Researcher John Stack served as an advisor to the board.

problem, determining tradeoffs between various levels of commonality and cost savings. They concluded that commonality standards, which had been set at 80%, could be relaxed and significant cost saving benefits could still be realized. McNamara concurred with the results of the study and allowed some relaxation, but reiterated that differences between the Air Force and Navy versions were to be kept to a minimum.[77]

With this concession, and having been given only two weeks to update their proposals, Boeing and GD resubmitted them for a third evaluation on 15 June 1962. Not surprisingly, most of the shortfalls in meeting the Navy requirements had not been fixed in this short period of time. The source selection board, however, again chose Boeing as the winner, this time unanimously. Despite the shortfalls, and forced to choose between the two designs, the Navy put its support behind Boeing, and strong consensus among the military leaders in both services was reached. The civilian leadership was less convinced, and Zuckert and Korth recommended yet another delay followed by a fourth evaluation.[78]

McNamara, who was frustrated by the failure of either contractor to submit an acceptable design, especially in the area of commonality, approved the recommended delay. Each of the contractors was put on contract for 60 days and paid $2.5 million to improve their design. On 13 July 1962 both contractors were instructed very clearly that "minimum divergence from a common design compatible with the separate missions of the Air Force and Navy to protect the inherent savings of a joint program" was a requirement for a successful proposal."[79] To further improve the proposals, both contractors were given the status normally reserved for prime contractors in that they could work closely with the evaluation team to resolve issues, get answers, and improve their proposed designs. Also during this period both the Air Force and Navy did analysis in efforts to be more prepared to conduct an informed evaluation of the proposals. The analysis also served to identify changes to the requirements that would improve chances for a successful proposal. Most of these were changes to justify less commonality, and were mainly in the areas of weapons and avionics.[80]

The revised proposals were submitted to the board on 11 September 1962 for the fourth evaluation. The evaluation board reported that both proposals were acceptable this time, but did not identify one as the winner, since they were so close. The GD design had a better structural design, a simpler fuel system, better supersonic dash capability, and high altitude maneuverability. The Boeing design had a superior ferry capability, conventional weapons carriage, loiter time, landing performance, and low altitude maneuverability. The Navy concurred with the results of the evaluation board. Although the two proposals were so close, on 2 November 1962 the source selection board members again voted unanimously that the Boeing design was better, and recommended it as the winner. All Air Force and Navy military leaders, up to and including the Air Force Chief of Staff and the Chief of Naval Operations, concurred.[81]

In an unprecedented move, notwithstanding unanimous military backing of the Boeing proposal, McNamara, with the consent of the civilian service secretaries, overturned the military decision. On 21 November 1962 he publicly announced that the TFX development contract, including the production of 22 prototype aircraft, would be awarded to General Dynamics, with Grumman as a partner. The importance of the contract was amplified because it put GD in position to receive the production contract for a projected 1700 aircraft, worth over $5 billion. McNamara explained that his decision was based mainly on the fact that the GD design had more commonality in the Air Force and Navy versions. He stated, "… General Dynamics proposed an airframe design that has a very high degree of identical structure for the Navy and Air Force versions. On the other hand, …in the two Boeing versions less than half of the structural components of the wing, fuselage and tail were the same. … Boeing is, in effect, proposing two different airplanes from a structures point of view." McNamara also cited technical feasibility issues with Boeing, centering mainly around the placement of the engine inlets, the planned use of thrust reversers in flight, and the extensive use of titanium in yet unproven ways. Finally, he took exception with Boeing cost estimates, which he considered too optimistic.[82]

Never before had civilian leadership overturned such a big procurement decision by those in uniform. Rumors began to circulate that the contract may have been given to GD because their Fort Worth, TX plant was about to become idle with the completion of B-58 production, whereas Boeing had plenty of work producing the B-52. The rumors also took into account the connection to Texas of ranking government officials, such as Vice President Lyndon B. Johnson, Deputy Secretary of Defense Roswell L. Gilpatric, and Secretary Korth, who were all from Fort Worth and active in business there. On 21 December 1962 Senator John L. McClellan, Chairman of the Senate Permanent Subcommittee on Investigations, sent a letter to McNamara asking him to delay signing the contract pending further investigation. McNamara disregarded the request, and one half hour after receiving McClellan's letter, the contract was signed. Nor was work on the project delayed, but went ahead at a feverish pace.[83]

Besides the military feeling like their needs were not being taken into account, now Congress felt like they had not been treated with proper respect. In reaction to the rumors and DoD's unusual behavior, McClellan's subcommittee called public hearings. The hearings received testimony from 26 February to 7 August 1963 and generated 2700 pages of testimony transcript from more then 90 witnesses, including Secretary of Defense McNamara, Secretary of the Air Force Zuckert, Secretary of the Navy Korth, and DDR&E Harold Brown. The investigation continued until 1971, and in the end it could not prove that any decisions were made for political or personal reasons. Neither did it uphold the decisions by McNamara and the DoD as correct. The final report called the program a fiasco and a failure, and delivered scathing criticisms of McNamara, his management of the program, and the resulting aircraft itself.[84]

Despite the fact that work continued during the investigation, it did have a negative effect on the program. Costly reports, in terms of man-hours and expense were continually being requested, and had to be prepared.[85] The most damage, however, may have been done in the area of public opinion, as the program received a large amount of negative press.

The TFX, which received the official designation F-111, first flew on 21 December 1964, two weeks ahead of schedule. After a relatively successful initial development, it later had some major technical problems that, while not central to this study, are relevant in that they shaped the perception of the program, and the resulting aircraft. They will be touched on only briefly.

Every development program faces technical challenges, especially when they incorporate new technologies. The desired multi-mission capability of the F-111, and the uniqueness of some of those missions, made this especially true for the F-111. The fact that mission success depended on revolutionary technologies, as opposed to simply being enhanced by them, meant that very few design relaxations could be tolerated. This pushing of the limits of technology led to two of the major subsystems, the engine and the variable geometry wing mechanism, causing some difficult development challenges.

The Pratt and Whitney P-1 engine, production version of the TF-30, was the first production jet engine to put an afterburner on a turbofan engine. Although the developmental and production versions had been thoroughly tested, the first several F-111A aircraft to fly with them experienced numerous engine stalls, especially when flying at high Mach numbers and high angles of attack. The problem was never completely solved in the A model. The combination of an improved engine and a redesign of the engine intakes improved the problem enough that it could be avoided, but not without some program delays. The new engine, the TF-30-P-3, was an upgrade to the P-1 and included an air diverter to allow the air to flow more directly into the first stages of the engine.[86]

Early in its development, the variable geometry wing mechanism presented some difficulties as failures occurred during testing. Analysis was done to determine the causes of the failures, and solutions were found. Although the variable geometry wing functioned without problems initially, after the aircraft had been flying for five years problems began to surface once more. The first indication was the crash of an F-111 at Nellis Air Force Base, NV on 22 December 1969, which was found to be caused by material failure of the lower plate of the wing pivot assembly. An investigation found that the forging process left some microscopic cracks in the part. Because it was made of very high tensile strength steel, when experiencing flight loads these cracks extended until failure occurred. The Air Force, in collaboration with its Scientific Advisory Board, began a demanding inspection of all parts made with similar material using a similar process. Any part that was in doubt was corrected through polishing, or was replaced. The Air Force also conducted a ground proof test, putting the wings under high stress, using hydraulic jacks, in a -40 degrees F environment. Only when all aircraft were certified safe were they allowed to fly throughout the full flight envelope. While the problem was corrected successfully, it was very costly, and reflected negatively on the program.[87]

During the period of testing of the F-111 the military situation in Vietnam had escalated. Operations there had moved from the role of military advisors training and advising the Vietnamese military to fight their enemies to the north, to one of active combat by American forces. Operation Rolling Thunder, a sustained aerial bombardment campaign against North Vietnamese forces, began on 2 March 1965, and was ongoing throughout F-111 testing. As the war heated up there was pressure to take advantage of the new capabilities offered by the F-111, especially its night/all weather conventional bombing capability.[88]

In the spring of 1967 the Air Force conducted a test called “Combat Bullseye I,” to evaluate the combat capability of the F-111. The results demonstrated that the bombing systems worked very well, and would substantially increase combat capability in Vietnam. Although overall system testing was incomplete, a decision was made to add some modifications, such as increased electronic counter measure capability and other avionics, and send it to Vietnam for evaluations and experience in actual combat.[89]

During the rest of 1967 and the beginning of 1968 preparations were made for the deployment. Besides the aircraft modifications, crews were trained and facilities were prepared in the theater. On 17 March 1968 six F-111s arrived at Takhli Air Base, Thailand to begin Operation Combat Lancer. On 25 March the aircraft began flying missions, but only three days later one of the aircraft crashed. The crew and aircraft were never found, and at the low altitude and rough terrain they were flying in, there would have been little chance for ejection. With no crew or crash site, investigation into the cause of the crash was limited. Only two days later a second aircraft crashed enroute to the target, but this time the crew managed to eject. They reported that the aircraft had been flying on a stable course and attitude when it suddenly rolled violently and dove at the ground. Due to the steep angle of impact and violence of the crash little evidence was recovered from the crash site, and the cause remained unknown. Two replacement aircraft arrived from the states and after a brief stand-down operations resumed. Less than a month after the second crash, a third aircraft disappeared, and again neither crew nor aircraft were recovered. After the third crash, and with no firm cause discovered, the operation was terminated and the aircraft were brought home.[90]

Operation Combat Lancer was a major setback because an important combat capability was lost at a critical time in the war. It was an even bigger setback for the F-111 program, however, because it only highlighted a larger problem with the aircraft. Between 19 January 1967 and 18 May 1968 nine aircraft crashed resulting in eight fatalities. Besides the crashes in Vietnam, other crashes occurred under similar circumstances, including the 18 May 1968 crash – less than a month after the third Combat Lancer loss. That crash was found to be caused by a failed actuator rod connected to the horizontal stabilizer. The fleet was inspected and almost half of the rods were faulty. The rod was redesigned to eliminate the weld that was prone to fail, and all completed aircraft were retrofitted. Another possible explanation for the Vietnam crashes was the terrain following radar. While it had passed a series of tests, it was known to have substandard performance in heavy rain and extremely varied terrain, both of which were prevalent in Vietnam. At the same time the actuator retrofit was done, several other design improvements were made and retrofitted, including improvements to the terrain following radar. There is still disagreement as to the cause of the Combat Lancer crashes.[91]

While the program was suffering from technical problems, and the crashes resulting from some of them, the biggest problem from a programmatic standpoint was the inability to meet Navy requirements. From the February 1961 decision to develop a single plane to meet both Air Force and Navy needs there was skepticism that it could be done. Analysis performed by the Air Force and Navy, as well as by the contractors revealed many challenges in doing so. McNamara and members of his staff produced analysis that indicated otherwise, with size, weight, speed, and other design characteristics that were more optimistic than those of either service. After much coaxing both contractors, especially GD, produced conceptual designs that could meet the requirements of both missions with a high degree of commonality. However, when concept was turned into reality the task proved more difficult.

The biggest constraints for the Navy were those needed to make the airplane compatible with aircraft carrier operations; namely aircraft weight, overall dimensions, and wind over deck requirements for landing.* Although the dimensions of the F-111B were maintained within acceptable limits by folding the nose and other design features, as development progressed it became apparent that the aircraft could not be built at the predicted weight. With each new modification to correct a problem the weight increased. This in turn increased required flying speed, which adversely affected wind over deck requirements. The original requirement for maximum basic mission weight for the B-model was 55,000 pounds. Despite numerous attempts to control the weight, by 1967 the actual weight was over 75,000 pounds. If the Navy were to fly the aircraft in combat it would have to decrease payload or fuel load in order to operate off of existing carriers, or modify the carriers themselves. Of course with the modifications and increased weight, the cost of the system increased (from $3.5 million per F-111B in 1962 to $8.7 million at the time of cancellation). Other requirements were compromised also, but were deemed less critical.[92]

The Air Force was interested in keeping Navy participation in the program in order to increase the total buy of aircraft, and thus decrease the per aircraft cost, but they were unwilling to accept excessive degradation of performance of the Air Force mission. While performance standards were not being met for the Navy, the percentage of commonality continued to fall. Commonality in airframe and structure, which started almost identical in the two versions and which provided much of McNamara's rationale for choosing GD over Boeing, remained at nearly 98% in June of 1967, but then dropped precipitously as engineers tried to correct the deficiencies in the Navy version. By March

* Wind over deck refers to the amount of headwind the aircraft experiences on final approach to landing. Since flight depends on airspeed, a slower landing speed in relation to the carrier deck (upon which stopping distance depends) can be achieved by a stronger headwind. That headwind can be the result of an actual wind, or be effectively "created" by the forward movement of the ship.

1968 it had dropped to 67%, thus erasing many of the anticipated savings that enticed McNamara to order a single multi-service airplane.[93]

In November 1967 McNamara, the driving force behind commonality, announced that he would resign as Secretary of Defense the following March to take a position at the head of the World Bank. Support for commonality in Congress was never enthusiastic, and was weakened by a dislike and a distrust of McNamara by many of the members as a result of his behavior toward Congress with the TFX contract disagreement and during the ensuing McClellan hearings. Congress became further disenchanted by the technical problems and numerous crashes. With McNamara out of the picture, with Navy insistence that their mission was not being met by the F-111, with the benefits of commonality evaporating as the Navy version continued to be changed, and with the Air Force unwilling to accept any more compromises to preserve commonality, on 3 July 1968 Congress disapproved DoD's request for $460 million for procurement of 30 F-111B production aircraft. Two days later the Navy formally terminated the F-111B program. On 9 July 1968 the Air Force issued a stop work order to GD, and production efforts halted the following day after delivering only two production F-111B aircraft (seven total).[94]

Even though the Navy program was terminated, the effects of Navy involvement had a marked effect on the Air Force version. Having already completed development efforts and being well into production there was no way for the Air Force to reverse efforts to achieve commonality. The main features imposed on the F-111 by Navy requirements, and their effect can be summarized as follows.

Design Feature	Reason	Effect	Result
Length	Carrier length limit	Reduced from 85' to 73'	Supersonic dash requirement reduced from 400 NM to 200 NM (approximately 25-50 NM achieved)
Cockpit configuration	Carrier length limit	Side by side instead of tandem	Same as previous
Tail surface area reduction	Weight and deck area reduction	Small loss of maneuverability and directional control	Less agility
Inlet redesign	Weight reduction	Top speed Mach 2.2 achievable at 42,000' vs. 35,000'	More limited speed envelope
Operational date	Requirements coordination	4 source selection boards, other negotiations and analysis	2 year delay of operational capability

Table 3.2. The main features imposed on the F-111 by Navy requirements, and their effects.[95]

With the Navy pullout, the increased per-aircraft cost, the cost of modifications to eliminate problems that emerged in testing and combat, the realization that the airplane would not adequately fulfill all the missions it had been designed to perform, and loss of Congressional support, as well as a growing feeling that the airplane was not the fighter TAC needed, the Air Force decreased the production run from over 1700 aircraft to only 530.*

Many of the programmatic issues presented had an impact on the public perception of the TFX program, and the F-111 aircraft, which was an important factor in the level of success they achieved. Gaining approval for the development of a major

* Of the original number, 235 were to be B-models for the Navy. Of the 530 produced for the Air Force, 76 were the FB-111 bomber version, purchased by SAC as a stopgap measure pending the procurement of its new strategic bomber, which much later became the B-1.

weapon system requires the backing of many people in various positions of responsibility. Many of them, as government officials in a democratic system, derive their power from the public, whether directly through elections, or indirectly through appointment or employment. Ultimately all of the money comes from the public. While the people of the nation do not have direct influence over an acquisition program, when strong public opinion lines up either for or against a program, government officials must take that into account. Elected officials who represent the public can only ignore public opinion so long before they are replaced. As a result, public opinion is an important factor in the development of a weapon system.

Despite the turbulent beginnings of the TFX program, the public took little notice of the program until the controversy erupted over the source selection decision, especially as Congressional hearings convened. As with most controversies most of the publicity was negative. Except for a brief period when the program enjoyed the success of the aircraft's early first flight, news of the program continued to be negative. Technical difficulties and the inability to meet requirements that led to schedule slips and cost overruns continued to tarnish the aircraft's image. The numerous crashes also soured public opinion toward it.[*] Finally, with the Navy's withdrawal from the program after almost seven and a half years of development and millions of dollars invested, the image of waste characterized the program in the public eye. It began to be referred to with terms such as "the world's most controversial warplane," "McNamara's Folly," and the "Flying Edsel" (with reference to McNamara's former position as President of Ford

[*] There were 14 crashes through April 1970. Although this is high, of the seven Century Series fighter aircraft that were produced, only the F-106 lost fewer aircraft during the first combined 50,000 hours of flight time. This fact, however, was not well publicized, and it seems that the F-111 was held to a higher standard, as it had the reputation of having a poor safety record. See Congressional Record – House, April 8, 1970 p. H2763.

Motor Company). Derogatory political cartoons began to appear, as well as disparaging articles.

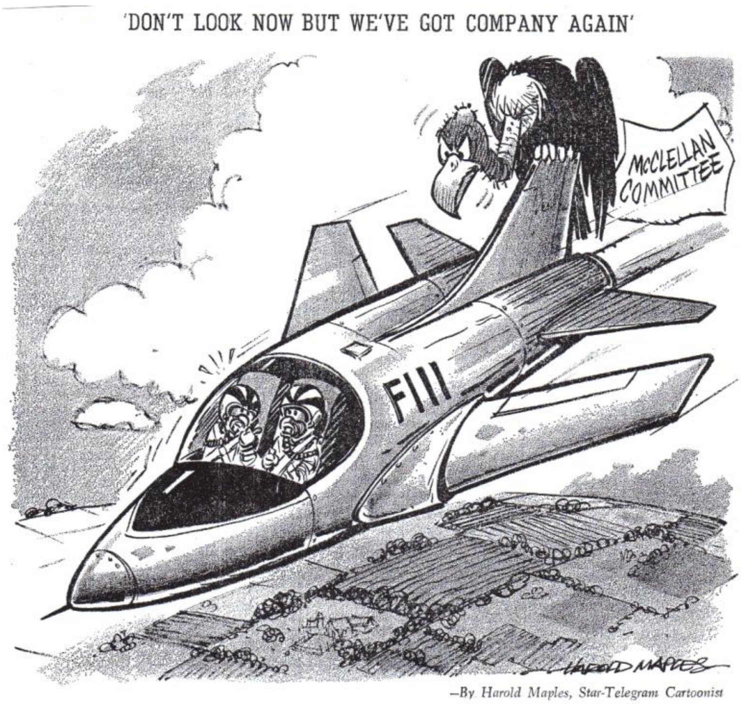

Figure 3.1. Political cartoon featured in the Tuesday, 17 March 1970 issue of the Fort Worth STAR-TELEGRAM showing the negative attention received by the F-111 program.

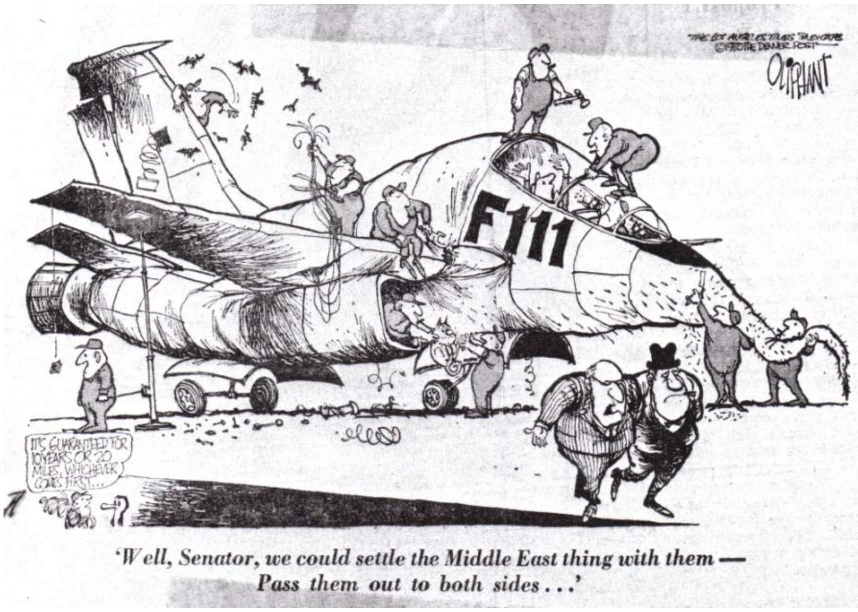

Figure 3.2. Political cartoon featured in the Saturday, 18 April 1970 edition of the Miami Herald showing the negative image of the F-111.

In response to the negative publicity that appeared in newspapers and the negative opinions about the aircraft and its beginnings, the Air Force and GD did their best to salvage public support by embarking on an effort to sell the airplane to the public. By this time the next Air Force fighter, the FX which was being sold as a single-purpose air superiority fighter, was already being developed so the F-111 was being reinvented as a bomber. Numerous speeches, interviews, press releases, and news articles, as well as testimony to Congress were produced by Air Force active duty personnel and civilian leaders, and General Dynamics officials to boost the image of the program and its product.

It was during this period that the decision was made to send F-111s to southeast Asia to enhance the bombing capability. It is clear that the deployment was not done solely out of military necessity. After all, the six aircraft that participated in Combat Lancer could not have made more than a superficial contribution to the war effort. The deployment was also designed to boost the flagging support of the aircraft. This is made clear in a letter from Air Force Vice Chief of Staff, General Bruce K. Holloway to Lieutenant General William W. Momyer, Commander of the Seventh Air Force, which provided all tactical airpower in Vietnam. General Holloway wrote, "I am … pleased to know that you feel the F-111 deployment is a good idea. I certainly think it is, and the sooner we get some real results with this bird, the sooner we are going to depreciate some of the teapot dome character of its upbringing."[96]

A few months later, during the busy training and preparation period leading up to the Combat Lancer deployment, the F-111 unit at Nellis Air Force Base, NV took time out from their war preparations to host Senator Howard Cannon, a former fighter pilot, a major general in the Air Force Reserves, and a member of the Senate Armed Services Committee. They provided Cannon with a full orientation of the aircraft, culminating in a flight. The senator, who was obviously impressed by the aircraft, later wrote a very complimentary article describing the airplane and his flight. He made a point to include all of the talking points in support of the F-111, made more credible by his general officer rank, his 5000 hours of flying time, and his impressive record and decorations from World War II, all of which were made apparent in the article.[97]

General Dynamics officials, who for most of the period of development chose not to get involved in the debate, realized a robust production contract depended on public support. In December 1968 Frank W. Davis, President of GD's Fort Worth Division, which designed and produced the F-111, agreed to let the Fort Worth Star-Telegram ask him any questions they wanted, with the agreement that they would report his written responses verbatim. The result was an entire section of the Sunday newspaper filled with dramatic photos and Davis' responses promoting the F-111 and responding to criticisms.[98]

With the release of the McClellan report in early January 1970 another wave of negative opinion appeared in the press, and again the Air Force responded. Among those who were given flights in the airplane were Senator Barry Goldwater, and Brigadier General Chuck Yeager (who was still on active duty). Senator Goldwater, once one of the harshest critics of the airplane testified to the Senate Armed Services Committee in February 1970, "I have flown this airplane and I am a great believer in it." He added that he was still critical of McNamara's management of the program, and earlier efforts to attempt to fulfill too many missions with the aircraft, but approved of the bomber role. He testified, "I prefer to call this plane the B-111 …it is a bomber for strategic purposes and a bomber for tactical purposes."[99] Yeager also defended the aircraft, calling it a "pretty good weapon system," and blaming the controversy on a desire to sell news.[100]

The Air Force was able to gain the support necessary to fund all of the F-111s it needed, based on its more limited role as solely an interdiction bomber. With plans for new fighters already in place, efforts eventually shifted to the support of other programs. In the end, the Air Force was given 12 more F-111s than it had asked for.[101][*]

Alternatives to the TFX

In an effort to avoid asymmetry in the study of the origins of the TFX it is necessary to address the alternatives that were considered. The objective is not to trace the development of the F-111 aircraft, which was the solution chosen to meet the

[*] This was a move by Congress to keep the assembly line open longer for political reasons, despite Air Force reluctance to release more money for the aircraft.

requirements of the TFX program, but it is to study the decisions made during the TFX program. For completeness, decisions regarding proposals other than a new Air Force aircraft must be considered. It should be noted, however, that the range of alternatives considered were limited by the constraints of the service. As one long-time acquisition official familiar with the program summed up the attitude, “We’re going to do this with airplanes because that’s our business.”[102] In fact, nothing but an airplane solution was seriously considered. While there were those, such as General Norstad who were pushing for surface-to-surface missiles to augment fighters, no one suggested that missiles completely take the place of an aircraft solution. One of the stated goals of Everest when he conceived the TFX was to modernize TAC’s fleet of aircraft, which precluded other alternatives from being considered.

Another alternative was to fulfill the mission with bomber aircraft. While there was competition for resources between TAC and SAC, the debate over the existence of TAC and the role of tactical aircraft was not debated at this time. While there was not always agreement on which command should receive more of the available resources, never was it seriously considered that bombers replace fighters altogether. Therefore, when General Everest began campaigning for a new fighter there was no evidence of significant debate about having bombers take over the proposed fighter mission.

Accepting that the range of alternatives was limited to a fighter aircraft, the list of alternatives becomes quite narrow. The Air Force could either use an existing fighter or develop a new one. Both of these options were considered, and in fact the decision was made to do both, although the existing aircraft (Navy F-4s, discussed below) were bought as an interim solution until the TFX could enter the inventory.

In 1960, after conferring with his staff, Air Force Chief of Staff General White made the decision to ask Congress for funding to extend production of the F-105. Recognizing an immediate need for increased, and more capable, tactical bombing capability that would last at least into the late 1960s, they considered alternatives that could be available relatively soon. These consisted of modified versions of the older F-100 and the F-101 interceptor, along with the F-105. The F-105 was the clear favorite since it had been designed for the role, and was the newest of the three. Furthermore, there was a lot of bias toward it in TAC, since it had been the only tactical fighter they had been able to develop somewhat independently during the 1950s.[103]

When McNamara became Secretary of Defense his Project 34 studied the future of tactical aircraft, and he considered options outside the Air Force. At the time, the F-4, developed as a Navy fleet air defense interceptor and ground attack aircraft, was already in production. He decided it would be the best immediate solution for the Air Force, based on the performance of the aircraft, which was impressive, but also on his vision of commonality. Citing development problems that the F-105 was experiencing, some of which had led to crashes and fatalities, McNamara used safety concerns to convince Congress to disapprove extended production of the F-105, and instead fund expanded production of the F-4. While some individuals in the Air Force had considered the F-4 prior to this, as an institution the Air Force was not interested in a Navy plane, and most people felt like the F-4 was forced on the Air Force. Once pilots began flying the aircraft, however, the improved performance of the aircraft won them over, and it became very well accepted. This was especially true after subsequent modifications yielded the improved E-model.[104]

As previously stated, the Project 34 study also recommended a joint tactical fighter, which would fulfill the longer term requirement for the Air Force, and which was fulfilled by the TFX. In doing so it recommended the termination of the Navy's follow-on fleet air defense aircraft, which was still in the concept development stage, and the reorientation of the Air Force TFX. These two programs, a strictly Air Force TFX with a Navy fleet air defense fighter, were the alternatives to the joint TFX program, since they had already been decided upon. The joint TFX program, however, was not a solution. It was a program full of options that would result in some weapon system that would fulfill the requirements, the genesis of which has been presented.

Predetermined TFX Decisions and Origins

This study seeks to understand how the Air Force determines its needs for a new weapon system. To that end, the preceding narrative of the events surrounding the program was given to provide data from which understanding can be gained. These data from the TFX case will be analyzed in order to consider those main expectations of the system that were decided upon outside of the documented requirements process. It is from this analysis that conclusions and theory will be derived in later chapters.

By the time a system is developed there are pages of specifications that in turn come from detailed requirements that are the result of analysis, threat assessment studies, tradeoff studies, and other parts of the documented requirements process. Many of the requirements are decided before this process begins, and many during the process come about as a result of judgment calls based on factors outside the documented process. Those have been termed "predetermined decisions" for this analysis, and it is those decisions that are of interest. Though there may be more, ten major decisions have been identified in the TFX case that fit the description of predetermined decisions. Each will be explored to ascertain its origin and rationale.

Emphasis on the Interdiction Bombing Mission

From the very beginning the TFX program was going to focus on the interdiction bombing mission. While it was conceived and designed to perform several different missions, the first priority was interdiction bombardment. This was articulated by Everest, and was never seriously questioned. While the capability and need to perform other missions, such as CAS or air superiority were called into question and had to be defended, the interdiction capability was always considered obvious.[105]

This predetermined requirement originated with General Everest when he first conceived the idea for the TFX, and appeared in every expression of requirements thereafter. But the idea cannot be attributed to him alone. By the time Everest penned his initial thoughts on a new fighter he was already heavily influenced by the mindset in TAC, and generally accepted throughout the Air Force, that the primary mission of TAC should be bombardment. The fact that the TFX program was started as a follow-on to the F-105, another aircraft with nuclear bombardment as its primary mission, supports this.

The origin of the idea of bombing as TAC's primary mission can be attributed to four main reasons. The first is that the Air Force, as well as the nation, put emphasis on the mission of nuclear bombardment. The decision was made to base the country's post World War II security strategy on the ability to retaliate against aggression with nuclear weapons, and that mission took precedence over all others in terms of priority. The general acceptance within the Air Force of the validity of this strategy led to a belief that TAC could support that mission by providing a bombardment capability to augment that of SAC. This was especially true with the invention of tactical nuclear weapons, which they believed would have the same effect as larger weapons, while reducing the chances of escalation. Smaller weapons could be assigned to battlefield military targets with less chance of collateral damage. Even in the case of a general war, while they could not deliver the same level of destruction, TAC could provide a quicker, more accurate delivery with enhanced survivability than SAC could offer with its slower, high altitude bombers that were based in North America.[106]

The second reason TAC had come to emphasize support of the bomber mission through participation in it, was that they viewed it as the only way to receive funding for new equipment. Since nuclear bombardment was the top priority, weapons and organizations that supported it received priority for resources along with the mission. There were those in TAC that, while recognizing the usefulness of its contribution to the bombardment mission, thought that that should be TAC's secondary mission, or an even lower priority. They believed TAC's other traditional missions of air superiority, conventional ground attack, and even CAS should receive as much or more emphasis as nuclear bombardment. However, they were willing to support the change in priority because they believed that was the only way TAC would receive any funding at all. These ideas were consistent with those outside of TAC as well. SAC officers were willing to support funding for a new fighter because it would be capable of contributing to the nuclear bombardment mission. Some, including SAC commander, General LeMay, resented the taking away of resources from SAC for a new fighter, but even he had to admit that TAC offered a capability his bombers could not. By placing emphasis on the bombardment mission, TAC was able to receive funding for new aircraft, including the TFX.[107]

Related to receiving funding is maintaining relevance as an organization, which is a third reason TAC accepted nuclear bombardment as its primary mission. While resources are necessary to exist, the organization also had to have a recognized purpose for its existence – that is, recognized by other parts of the Air Force. Without this there was little incentive for the Air Force to keep the organization. Since the most important recognized purpose for any organization in the Air Force was to support or execute the nuclear bombardment mission, TAC adopted it. As one general noted, "If you weren't in [the nuclear bombardment] business, you weren't in business."[108] LeMay expressed his opinion on occasion that other than the fact that TAC contributed to the nuclear bombardment mission (which he would have liked SAC to take over completely if he could have convinced enough people), TAC should have been given to the Army to provide CAS for them. While it is difficult to know how serious he was, it does provide insight to his opinion of TAC's overall relevance, and its dependence on the ability to deliver nuclear weapons to maintain that relevance.[109] Several other people who were involved with TAC during that period stated that it had little choice but to focus primarily on nuclear bombardment if it was to continue to exist.[110]

Finally, a fourth reason TAC emphasized the nuclear bombardment mission was that many within TAC as well as outside TAC believed that new technology had made the traditional missions of TAC obsolete, or at least less important. There were, of course, many who did not believe that. Some felt that TAC's traditional missions were justification enough for its existence, and that TAC should have been able to make the case more effectively to the Air Force to procure funding based on the importance of the traditional missions. They were not able to convince enough people to agree to that position, however.* Of particular importance were the views of Everest, whose experience in Korea convinced him that it was no longer necessary to emphasize the air superiority mission. Furthermore, he believed the nuclear bombardment mission to be the most challenging, so that if an airplane could accomplish it, it would also be capable of accomplishing the air superiority, conventional ground attack, and CAS missions sufficiently well.[112]

It is impossible to know the level of influence each of these reasons had on the positions espoused by various individuals, but in combination they offered reason enough to convince enough decision makers that TAC's primary mission should be that of nuclear bombardment. The choice of the F-105 design, and the virtually undisputed aspect of the TFX requirements demonstrates this.

De-emphasis on Air-to-Air Mission

The importance of air superiority, or control of the airspace over which the battle is taking place, was advanced beginning with the earliest airpower theorists. Douhet, the first person to articulate airpower theory, advocated control of the air as the first step to the successful use of airpower.[113] World War I and World War II both demonstrated the necessity for air superiority in order to succeed in both surface battle or when attacking from the air. Lack of air superiority is commonly held as the reason Hitler

* For example Lt. Gen. Arthur C. Agan and Charles E. Myers, Jr., were two people who did not believe that the importance of the air superiority mission was diminished, and worked to convince others. Their efforts did influence the design of the F-X (follow-on to the F-111).[111]

decided not to invade England during the Battle of Britain. Air-to-air combat received much of the attention in both of those wars, beginning with the invention and glamorization of the fighter “ace” in World War I, a tradition that has continued to the present. With the actual and symbolic importance placed on air superiority, and air-to-air combat specifically, it is interesting that it was de-emphasized not only by TAC, the organization that was responsible for the mission, but by the whole Air Force, whose primary mission of nuclear bombardment depended on it, at least to some degree. The de-emphasis of the air superiority mission was discussed briefly in the last section, but it was such a departure from earlier thought, and played such a role in the development of the follow-on aircraft to the TFX, that it is worth examining separately.

Even though airpower was used in World War I, aircraft and technology had not yet progressed to the point to allow it to be a decisive factor in the outcome. By World War II that had changed, especially by the end of the war. The strategy adopted was that of High Altitude Precision Daylight Bombing. It was based on the fact that technology for bomber aircraft advanced more quickly, and they were able to fly at higher speeds and altitudes than fighter aircraft. The premise was that bombers would fly over enemy territory, unreachable by defenses due to their altitude and speed, and be able to destroy the enemy’s ability and will to fight.

By the time the war began and the strategy was employed, fighter aircraft technology had also advanced, along with that of ground based defense systems (anti aircraft artillery). Bomber aircraft were not invincible and in fact suffered significant losses. They defended themselves by arming themselves and flying in close formation for mutual protection. Eventually, as fighters with adequate range became available, the fighter, as an escort, became an important enabler of the bombing strategy. By the end of the war the allies had almost complete control of the air again, both in the European and Pacific theaters. There are many reasons for this, and which one was decisive, is still debated. The result is that for much of the war bombers were able to carry out their missions with impunity.[114]

In Korea air superiority again had to be won and maintained, but the Communist forces were so outclassed that many took air superiority for granted. Again, there was debate as to the explanation of how air superiority was achieved. Many point to the superior skill and training of American pilots, but others give credit to the bombing of enemy aircraft and airfields. Again, the main lesson learned was that air superiority was readily attainable.[115]

Despite the importance of achieving air superiority, the experience gained from the earliest beginnings of flying led to three conclusions by decision makers in the U.S. Air Force. The first is that, if necessary, bombing can be achieved even without the support of fighters. While there was a period of great loss during World War II when unescorted bombers conducted missions, the fact that targets were destroyed, coupled with the ability later in the war when bombers flew uncontested in both theaters reinforced this idea. With the advent of jet bombers that could fly at increasingly higher altitudes, the threat from ground defenses was also minimized.[116]

The second conclusion was that air superiority could be achieved through bombardment. By destroying aircraft, airfields, and aircraft production facilities on the ground, the enemy would not have the ability to challenge American air superiority. The fact that the Germans, Japanese, and North Koreans could not maintain a credible air-to-air threat was attributed by many to bombing efforts.[117]

The third conclusion drawn from previous experience was that air superiority was relatively easily obtained, and therefore, the Air Force would always have it. While no one openly expressed that they took air superiority for granted, it was manifested in exercises and simulations that had no air superiority component. It was often given as one of the initial assumptions.[118]

Of course there were people throughout TAC and the Air Force who disagreed with some or all of these conclusions. Others, especially those who had flown fighters in World War II and Korea, believed that air superiority was won in the air, that it would continue to be, and that if it was not, other missions such as bombing would not be possible. Everest expressed a belief in these conclusions, and based his initial ideas for the F-111 on them. The fact that the concept of the F-111, as conceived with a minor role as an air superiority fighter, was so readily accepted shows that a sufficient number of people believed one or more of the conclusions enough to de-emphasize that mission to the point that it was given to a bomber (the F-111).

Another factor that led to the de-emphasis of the air-to-air mission was the development of new technologies. The jet engine, air-to-air missiles, and tactical nuclear weapons all led to this change in emphasis.

The aerial engagements with jets in Korea were far fewer and far shorter than those of World War II. Those that did occur were often limited to one pass, or at the most a few turns, and success was often a function of initial position at the time of enemy detection rather than combat ability.[119] Many saw this trend continuing to the point that there would never again be aerial combat. The prevailing attitude was that “the dog fight was a thing of the past.”[120]

This attitude was reinforced by the invention of air-to-air missiles. If a pilot could detect the enemy at long range and fire a missile, there was no need to engage in aerial combat. Missiles would be maneuverable, and not aircraft. Even though missiles were not very reliable until after the Vietnam Conflict, the attitude prevailed.[121]

Tactical nuclear weapons strengthened the argument that air superiority could be achieved by destroying the enemy on the ground. Increased fire power meant that even with marginal accuracy enemy bases, aircraft shelters, and other targets could be bombed with a higher probability of destruction. Putting a tactical nuclear warhead in an air-to-air missile further decreased the need to have a maneuverable fighter that emphasized air-to-air combat.[122]

Multi-Mission Capability

In response to later efforts to use the F-111 for the Navy fleet air defense mission, Everest claimed that he was not interested in an aircraft that would fulfill multiple missions, but that his primary interest was making the aircraft survivable for its interdiction bombing mission in Europe.[123] Whether or not he was interested in a multi-mission fighter, that is the fighter he chose to propose. The earliest requirements documents and operational concepts specify the capability to perform more than one mission. Everest and TAC, with agreement from most of the Air Force, initially conceived a multi-mission airplane because there would not have been resources for more than one aircraft, and they were satisfied with less capability for the secondary missions.

Later the Navy mission was added as yet another mission, as a result of McNamara's goal for commonality.

With increasing costs of new technologies, and the ongoing build up of strategic forces, it has been shown that TAC was a lower priority for resources. Most people in TAC were skeptical that they would get funding for any new aircraft, so the idea of requesting more than one single-mission aircraft was not considered. This was a major factor in the decision to develop a multi-mission aircraft.[124]

It has been stated that the nuclear bombardment mission was the first priority, and that TAC had accepted that position as well. The corollary to that is that the other missions were not considered very important. The reasons for the de-emphasis of the air superiority mission have been given, but the other two missions were given just as little emphasis, or even less. The CAS mission was accepted with enthusiasm by almost no one in the Air Force. The Air Force often got blamed for keeping the CAS mission only to keep the Army from competing for aircraft funding, and many people in the Air Force would agree with that assessment. The Army often expressed dissatisfaction with the lack of Air Force interest, and adequate equipment, for the CAS mission. Therefore, relegating it to a low priority mission for the TFX was acceptable to the Air Force.[125] Similarly, the Air Force was enamored with nuclear weapons, and had not completely accepted the conventional bombardment mission. Certainly decision makers were not willing to trade away nuclear bombardment capability for conventional, especially when they believed they could have both.[126]

The idea of de-emphasizing missions other than nuclear bombardment was further accepted by TAC and the Air Force because it was felt that if the aircraft was capable of accomplishing its primary mission, it would be more than capable of performing the other missions. The air superiority mission, for example, could be accomplished with the primary mission by dropping tactical nuclear weapons on targets such as enemy airfields, and by launching air-to-air missiles. With the prevailing view of the role of air-to-air missiles in the air superiority mission, a large stable missile platform would be very well suited for that function. Characteristics such as high speed, high altitude capability, and large payload made the TFX ideal for this view of the air superiority mission. Similarly, the TFX was considered by many people in the Air Force to be very suitable for the CAS mission as well (as expressed in General White's testimony), although this requirement was eventually removed in favor of a separate joint Army and Navy attack aircraft.[127] It was recognized that the conventional bomb delivery mission would require greater accuracy, but this was to be accomplished through new radar and avionics technology, which would also enhance the primary mission.

Perhaps the most apparent requirement for the TFX to be a multi-mission aircraft resulted from McNamara's February 1961 decision to reorient the program to include Navy requirements for the fleet air defense mission. While the idea of using a single aircraft for both services was not new, McNamara firmly adopted the idea as a way to meet President Kennedy's Flexible Response strategy. The strategy would require a significant amount of investment in new weapons, and McNamara was very focused on extracting the most combat utility from the money spent. Cost effectiveness became a defining theme of his tenure in the position of Secretary of Defense.[128] The arguments of the previous paragraph were upheld by McNamara's Project 34 Study. The study had provided evidence, which convinced McNamara of the feasibility of meeting the requirements of both services with a single aircraft, and that money would be saved by doing so. Although the Navy and Air Force never fully agreed, the revised SOR from which the F-111 was eventually developed, was heavily influenced by the decision to include the Navy mission. Therefore, the added requirement to fulfill the Navy mission of fleet air defense was another input into the predetermined requirement for the TFX to be a multi-mission aircraft.

High Speed

Everest's initial concept of the TFX was an attempt to increase survivability by increasing its speed and altitude capabilities. This was decided unilaterally by Everest prior to accomplishing any significant analysis. It was accepted by TAC, and then the Air Force.

The correlation of speed with survivability is not difficult to establish, and therefore it may not seem significant that Everest wanted a high speed aircraft. Speed, however, is not the only way of achieving survivability. Stealth technology, standoff weaponry, and improved countermeasures can also be just as effective. While these technologies may have been somewhat immature at the time, the same is true of variable geometry wings and afterburning turbofan engines, which were required for Everest's exacting speed and altitude requirements. The attempt to limit radar cross section and the use of countermeasures were both applied to the TFX, but there is little or no mention of them before the formal requirements generation process. Conversely, the aircraft top speed was specified at greater than Mach 2 at high altitude and near or greater than Mach 1 at low altitude before any other work was done.

That TAC and others in the Air Force were in agreement with Everest's vision of a high speed fighter is evident from the fact that when the first written set of requirements was written in SDR No. 17, the specified top speed had increased from Everest's targets of greater than Mach 2 and near or greater than Mach 1, to Mach 2.3-2.5 at high altitude and Mach 1.2 at low altitude. There is no public record of any debate or analysis accompanying this change, but a convincing explanation is a general desire for greater speed in each new aircraft.

The Air Force's fixation on high top speed was not wholly unfounded, however, since this was the accepted solution to the problem of survivability. The ability to fly faster had been sought after since the Wright brothers' first flight. This pursuit was given increased motivation during periods of combat, when the ability to catch up to an enemy to put it in weapons range, or to outrun an enemy when on the defensive had obvious advantages.

Given the emphasis placed on speed, it was difficult to gain support for an aircraft if its top speed was not higher than that of the aircraft it was to replace. Accordingly, with few exceptions, each new fighter was faster than its predecessor.

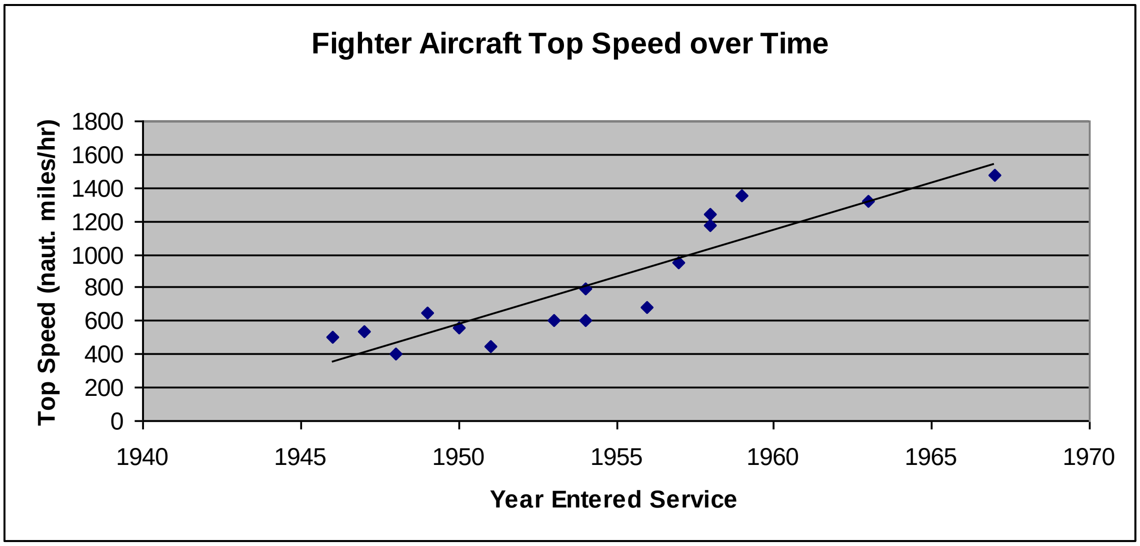

Figure 3.3. In general each fighter aircraft had a higher top speed than its predecessor.* When there is an exception, there is usually an explanation. In some cases the slower aircraft was begun earlier and remained in development longer than its predecessor, for example. Such was the case with the second to last data point, which represents the F-4 (the final data point is the F-111). The F-4 was developed in the early 1950s by McDonnell as an unsolicited proposal that was eventually chosen by the Navy for development. It is improbable that the aircraft would have been used by the Air Force if it had not been pushed by the Secretary of Defense. Despite such anomalies there is a clear trend in the data.[129]

This was the case with the TFX as well, and Coulam suggests that the main reason for the increase in top speed was to give the TFX a clear improvement over the F-105 in order to aid in the approval process. Even if that wasn't the primary reason, it is clear that the Air Force had a bias toward faster aircraft.[130]

High and Low Altitude

The reasoning for high altitude is similar to the desire for greater speed. It had long been a measure of performance because of the difficulties encountered when attempting to achieve greater altitudes. Again war experience demonstrated that

* It is not completely straight forward to compare reported top speed across aircraft. Some sources use reported design speed, some sources report top speed achieved in specialized tests which may not be achievable by production versions, the speed capabilities of all aircraft are subject to altitudes and atmospheric conditions during which speed is measured, which are not known for many of the reports. Attempts were made to compare data as consistently as possible. Because the point of the figure is to show the trend, the limitations of the data are acceptable.

increased distance from the ground also meant distance from ground-based threats, and increased altitude capability compared to an enemy aircraft yielded a similar advantage. Similar to speed, it was easier to gain approval for a new aircraft that had a higher ceiling.

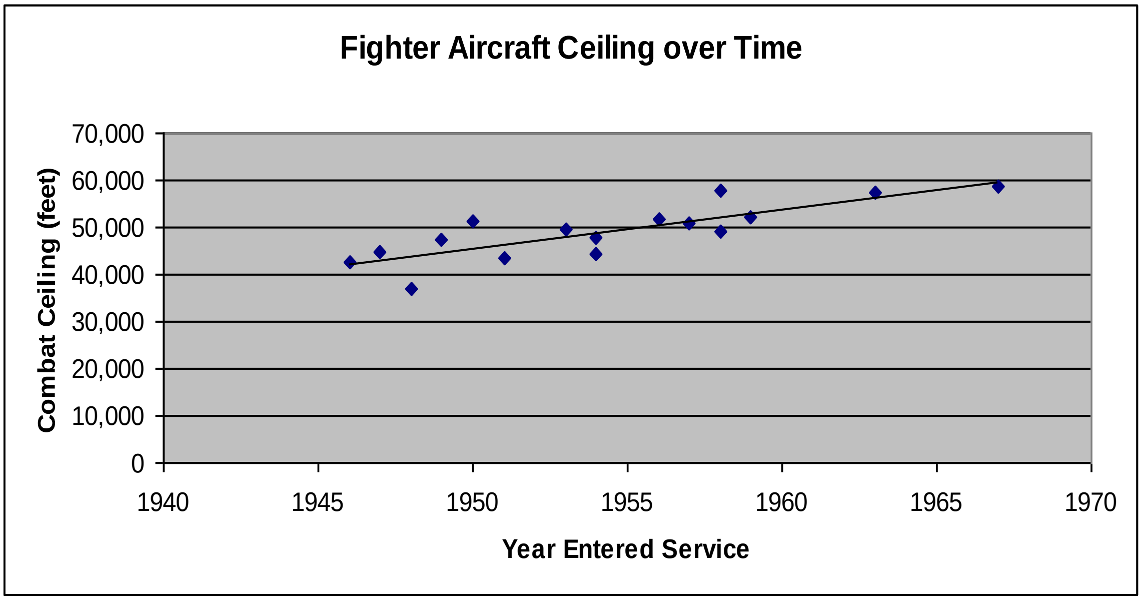

Figure 3.4. In general each fighter aircraft had a higher ceiling than its predecessor.* There are exceptions, but there is a clear trend in the data. The final data point is the F-111.[131]

There is no record of debate or discussions regarding a ceiling requirement for the TFX. When SDR No. 17 was issued the ceiling was set at 70,000, which as can be seen from the graph is more than a 10,000 foot increase from any earlier aircraft. This was later relaxed to 60,000 feet when SOR-183 was released (with 70,000 feet desired). This requirement was kept through production despite the fact that it had little to do with the

* It is not completely straight forward to compare reported ceiling across aircraft. Some sources use reported design ceiling, some sources report highest altitude achieved in specialized tests which may not be achievable by production versions or with mission fuel loads and or payloads, the altitude capabilities of all aircraft are subject to aircraft and atmospheric conditions during flight, which are not known for many of the reports. Attempts were made to compare data as consistently as possible. Because the point of the figure is to show the trend, the limitations of the data are acceptable.

primary mission of the aircraft. A bias toward high altitude capability was recognized by participants, and is evident.[132]

The low altitude component was specified by Everest, and was a deliberate attempt to avoid enemy radar detection. Surface-to-air missiles were in their infancy at this time, and although bombers were still basing survivability on high altitude flight, as exemplified by the B-70 which was in development up until the early 1960s, with a ceiling of over 77,000 feet, Everest specified a low altitude approach. Attacking at low altitude had been used for years for various reasons, and Everest did not articulate why he based the TFX conceptual mission on the low altitude option. It may have been based on his experience in World War II where he often flew at low altitude to avoid detection. He recounts one experience where he was directed to fly at a higher altitude and three of the six aircraft he was leading were shot down. Had they been able to fly higher they would have been unreachable by the enemy guns, but their B-24 aircraft could not fly high enough with a full bomb load. If they had flown their normal low altitude tactics they would have had increased probability of achieving surprise and avoiding the ground threat.[133] When confronted with a similar scenario with the TFX, he specified a high speed low altitude approach. Another explanation is that it was simply a continuation of the approach employed by the F-105, which was also designed to approach the target at high speed and low altitude. A third explanation is the eventual need to be at low altitude for bomb release, for greater accuracy, although that would not require the entire 400 nautical mile ingress leg to be flown low. Regardless of the reason, there is no record of discussion about the low altitude approach once it was put forth by Everest.

Variable Geometry Wings

As previously noted, there was never an explicit requirement for variable geometry wings. The acceptance of Everest's initial mission concept, and Stack's feasibility study which yielded the conceptual design that included the feature, however, virtually locked this feature in as a requirement. No other design approach was seriously considered, and it was generally accepted that the mission was not possible without the feature. There is also evidence that there were those who were enamored with the technology itself, and did not consider other alternatives for that reason.[134]

One of the reasons given for the conclusion of the Project 34 Study that the TFX could satisfy both Air Force and Navy mission requirements was the fact that the Navy was considering a variable geometry wing aircraft as well, and that it would enable a single aircraft to be used by both services. Thus, McNamara's push for commonality also pushed the design toward a variable geometry wing that would allow it to fulfill the varied missions of both services.[135]

Two Crewmembers

Everest planned on his new aircraft being operated by a crew of two, and Stack's conceptual design included a two-place cockpit with tandem seating. There is no evidence that anyone ever considered a single-seat aircraft, and SDR No. 17 and all later requirements documents specified a crew of two pilots for the Air Force version of the TFX. This requirement is a result of proposed mission duration, as well as the existing view that to perform the all-weather mission a second person was required to operate the radar and other avionics. This requirement appears to have been uncontested.

Everest's concept was for the aircraft to be based in the United States, out of range of enemy aircraft and missiles, and then to be flown unrefueled across the ocean to deploy to the theater when needed. SDR No. 17 does not specifically address pilot fatigue, but SOR-183 specifies that the cockpit will include "crew comfort provisions for flights in excess of 10 hours."

Another reason for the requirement was a consensus that adequate technology did not then exist to allow a single person to both fly the airplane and operate the avionics necessary for accurate all weather bombing. While it was acknowledged that a technological solution could have been developed to make this possible, SDR No. 17 states that the crew should be used to decrease system complexity and avoid the need for automatic sophisticated subsystems. Thus a conscious decision was made to favor a second crew member over technology. If there was anyone who favored a technological solution they did not have a significant or lasting voice in the debate.[136]

Two Engines

The debate over using one engine versus two is an ongoing one. Dilger, who conducted a study on the subject observed, "Ask 100 fighter pilots [which is better, a single or twin engine fighter] and you'll get 100 different opinions."[137] Those who favor one engine tout the savings in cost and weight, while the reason given most often for two engines is safety and survivability in the event of engine failure. Of course there are rebuttals for each of those reasons. The twin engine advocates would ask if the cost of training a new pilot, not to mention a human life, is worth the savings of an extra engine, while the single engine advocates question how much safety an extra engine provides, especially in combat, when the loss of an engine is likely to be catastrophic and cause the second engine to fail at the same time. According to Dilger, neither peacetime statistics or combat statistics provide conclusive evidence that one option is any safer than the other. Then there are the engineering arguments. Harry Hillaker, the designer of the F-16 claims that the only consideration for deciding how many engines to put on an airplane is how much thrust you need, and how many engines you need to provide that thrust.[138]

The requirements documents simply specify that there will be at least two engines, and offer no rationale. Despite the apparent controversy, there does not seem to be significant debate on the subject for the TFX. From discussion that occurred just a few years later on the FX program, a bias toward twin engine aircraft appears to have existed at that time. Another possible reason for choosing two engines is that expressed by Hillaker. The most demanding thrust requirement was the low altitude 400 nautical mile supersonic leg. The large amount of drag created by an airplane large enough to carry the substantial payload and the required two crew members, would certainly require more thrust than one engine could produce at the time. This is especially true for such a long supersonic leg, which precluded the use of full afterburner to achieve the required thrust. When Stack produced his initial design concept it was a twin engine aircraft, and the WADD study, which verified his work, supported that concept. From the initial concept design, two engines became a requirement. Similar to the case of variable geometry wings, the requirement for two engines was never significantly questioned. Whether or not a smaller aircraft with one engine could have performed the mission was never studied seriously after Stack produced his design.

Large Aircraft

The decision to make the TFX a large aircraft was not articulated until the September 1961 revision of SOR-183, but it was clear from the beginning that it would be. The initial concept design had an estimated weight of approximately 75,000 pounds. This was a substantial increase from the F-105, which weighed around 53,000 lbs. When a weight was specified it was given as "approximately 60,000 lbs" with full internal fuel and 2,000 pounds of internal stores. It further specified that the Navy version could not exceed 55,000 pounds without concurrence of the Navy.[139]

The technical reasons are compelling as justification for a large fighter, and in fact efforts at weight reduction for the Navy version were attempted unsuccessfully. Air Force decision makers seemed to have little concern about the large size of the aircraft, and in fact many thought the size was a positive characteristic. There were many in the Air Force who were biased toward big airplanes. There was a saying that asserted, "a good big airplane is better than a good small airplane."[140][*] Others were willing to accept a large aircraft for increased capability, which at that time equated to higher speed, larger payload, and longer range.[141] The pursuit of these characteristics made fighters increasingly bigger, which was the trend from the time the Air Force was first established.

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[*] Former Air Force Chief of Staff General Larry told of an experience when he and John Boyd were briefing a general who offered this opinion. John Boyd, who was not afraid to speak his mind, responded, "No, General, that's football players, that's not airplanes."

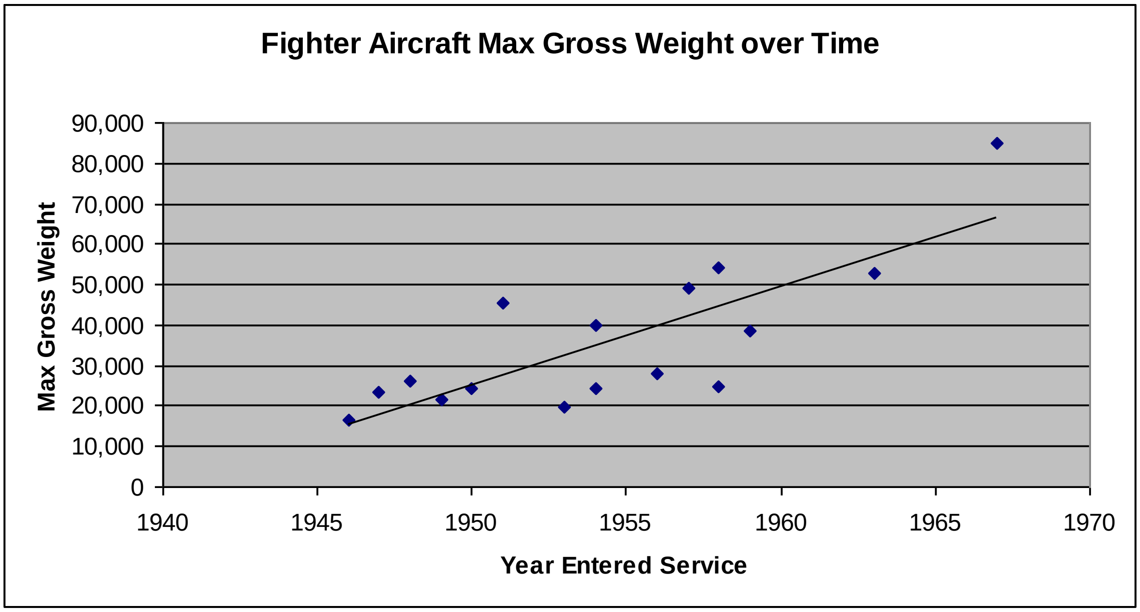

Figure 3.5. Over time the size of fighters has tended to increase.* The final data point is the F-111.[142]

Navy Specific Requirements

This category of predetermined requirements is included because even though there may have been clear cut technical reasons for Navy requirements, which were arrived at through the Navy's documented requirement generation process, from the time McNamara dictated that the TFX would be a joint program he also determined that any subsequent Navy requirements would be included in the Air Force version, insofar as possible. Table 3.2., above, provides a summary of those features that were imposed on the aircraft as a result of this decision. As previously stated, these specific requirements were not the result of a calculated effort to design the best aircraft for mission

* It is not completely straight forward to compare reported maximum gross weight across aircraft. The maximum design weight may or may not be indicative of useful operational limitations, for example. Attempts were made to compare data as consistently as possible. Because the point of the figure is to show the trend, the limitations of the data are acceptable.

accomplishment; they were a byproduct of McNamara's goal to save money through commonality.

Summary of Predetermined TFX Requirements and Origins.

The following is a recap of the main predetermined requirements that were established for the TFX, along with their source, and reasons for them, summarizing the last ten sections.

Decision	Who	Why
Emphasis on interdiction bombing mission	Everest, TAC, most of USAF, and later McNamara	Supported the nation's top priority mission of strategic bombardment, allowed TAC to gain relevance and compete for resources, adaptable to conventional bombing in support of new administration's goals
De-emphasis on air-to-air mission	Everest, TAC, and most of USAF	Experience was interpreted to show that the air-to-air mission was outdated due to new technology, and the ability to destroy airfields and aircraft through bombardment
Multi-mission capability	Everest, TAC, most of USAF, and later McNamara	Everest/TAC: Survivability, ability to keep mission/relevance, could only get one plane so it had to do all missions, others not as important or demanding USAF: Supported strategic bombardment emphasis which was main goal McNamara: Commonality, save money to build up conventional forces
High speed	Everest, TAC, USAF	Enabled mission accomplishment (especially air superiority), fulfilled need to improve on previous systems, bias for speed
High and low altitude capability	Everest, TAC, USAF	Survivability (enabled mission accomplishment), fulfilled need to improve on previous systems, bias for high ceiling
Variable geometry	Everest, Stack, McNamara applied technology to mission and goals	Enabled mission, though no other options (mission or system) were considered, took advantage of new technology and enabled commonality
Two crewmembers	Everest, TAC, most of USAF	Perceived need to achieve all weather operations, which came from experience (choice to use people versus technological solution)
Two engines	Everest, TAC, most of USAF	Thrust requirements given chosen constraints, perception of increased safety based on upbringing and bias (analysis inconclusive)
Large	Everest indirectly, USAF agreed - Not Navy	The mission as defined, with other constraints, imposed suggested a large airplane, allowed for an improved payload, was readily accepted by Air Force due to bias toward bigger systems (Navy wanted smaller for carrier ops)
Side by side seating, limited length, other Navy constraints	Navy, and indirectly McNamara, since he imposed jointness	Navy requirements came from mostly valid constraints (elevator size, deck strength, etc.) but were introduced to the USAF version as "predetermined" because they were based on imposed commonality

Table 3.3. Summary of predetermined TFX requirements and their origins.

Preliminary Conclusions from the TFX Case

The F-111 is considered by many to be an unsuccessful weapon system, although the concession is often added that after development was complete it did perform well as an interdiction bomber. It did very little of what it was conceived to do. The F-4 was produced in large numbers and became the primary ground attack aircraft. The E-model of the F-4 also took on the role of air superiority fighter until it was replaced by the FX, which was originally planned as the replacement for the F-111. With the development of a reconnaissance version and a surface-to-air missile suppression ("Wild Weasel") version, the F-4, Navy-designed stop gap fighter, overshadowed the F-111 as a true joint multi-mission aircraft.

The assessment of reasons why the F-111 turned out to perform such a limited role compared to that envisioned must take into account that the emphasis placed on the various missions changed. As noted, the F-111 performed admirably in the interdiction bombing mission, which was what it was primarily conceived to do, albeit with nuclear weapons rather than conventional. While it was still under development emphasis was shifted from nuclear bombardment to conventional operations. The missions that were once considered peripheral, and for which it was not well equipped, became central.

Beginning in the late 1950s the reliance on nuclear weapons began to be called into question. General Maxwell Taylor, the Army Chief of Staff, began criticizing Eisenhower's New Look policy in favor of a more balanced approach. In 1960, after retirement, Taylor wrote the influential book, *The Uncertain Trumpet*, which outlines his vision of a strategy of Flexible Response. It called for a mix of conventional forces that could be used in limited war, while the nuclear forces could deter nuclear war.[143] The incoming Kennedy administration adopted this strategy, eventually bringing Taylor back on active duty and appointing him as Chairman of the Joint Chiefs of Staff. The administration, and specifically McNamara, began to rebuild conventional military forces in order to have options for dealing with lower level Communist aggression.

The TFX was able to contribute to the conventional mission. Although the F-111 experienced technical problems during Operation Combat Lancer, after being modified to correct the problems it returned to Vietnam and flew successfully in Operations Linebacker I and II. The strategy involved in conventional interdiction, however, did not require the extreme measures imposed by the nuclear mission. For example, the aircraft did not need to be based on a separate continent. Also, most limited war scenarios did not include the threat of airfield destruction by surface-to-surface nuclear missiles, such as in general war in Europe. This rendered the soft field dispersion capability superfluous as well. This change in emphasis to the conventional mission left the F-111 with costly extraneous capability. Even though it proved capable in Vietnam, it did so at higher cost.

The air-to-air lessons of Vietnam made it clear that the F-111 was wholly inadequate as an air superiority fighter. Political considerations precluded destroying airfields and fulfilling the mission through bombing. Also, poor missile performance coupled with the inability to identify enemy aircraft at long range demonstrated that an air superiority fighter had to be maneuverable, and capable of close-in combat. This represented a weakness for a fighter that was expected to fight its way to the target.

The F-111 was maligned by many, including Everest, as being ruined by the quest for commonality and the inclusion of Navy requirements.[144] It is true that certain capabilities were lost because of the inclusion of Navy requirements, but it is not clear that the resulting loss of capability degraded the ability to adequately perform the conventional interdiction mission that it was ultimately needed to do. It is also doubtful that a pure Air Force F-111, untainted by Navy requirements, would have performed any better at any other mission, other than the original transatlantic dispersed nuclear delivery mission, which turned out not to be needed.

Other criticism of the aircraft focuses on its troubled development, but it was not the first system to go over budget, have schedule slips, and experience technical problems. Many aircraft considered more successful had similar problems.* The inadequacy of the F-111 to perform those missions expected of a fighter, which really constitutes its failure, was caused be changing mission expectations; that is, a different mission emphasis from that for which the aircraft was conceived.

* The F-105, the predecessor of the F-111, which was considered quite successful, is one example. It experienced numerous program delays, cost overruns, technical problems and fatal crashes. Major problems were still being corrected while the Air Force was requesting a production extension. The F-106 was basically a continuation of F-102 development which attempted to correct the numerous problems. Nor were these two isolated cases.[145]

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87. Report on the F-111 Structural Certification Program (31 Aug 1970. Robert C. Seamans, Jr. and Gen John D. Ryan, Air Force Chief of Staff), in the USAF Collection, AFHRA; Robert C. Seamans, Jr., interview by author, Beverly Farms, MA, 10 June 2008.

88. Anderton, 173-175.

89. Ibid., 204.; Giraudo Interview, 339-340.

90. Anderton, 204.; Giraudo Interview, 344-348; Conceptual Phase to F-111B Termination, 53.

91. Ibid.; Disosway Interview, 270; Oral History Interview of Brig Gen Frank K. Everest, USAF (Ret.) by Hugh N. Ahmann, 23 September 1988. Typed transcript pp. 38-39, K239.0512-1844 Iris No. 01114730, in USAF Collection, AFHRA.

92. Conceptual Phase to F-111B Termination, 55-56; Program Cost Change History for WS-324A/B (F-111A/B, RF-111A) (Aug 1964.), K146.0034-77 1962/02/01-1964/08/01, IRIS No. 01002700, in the USAF Collection, AFHRA; Special F-111 Back-Up Book (15 Jan 1968. SAFGC), IRIS No. 01087399 in the USAF Collection, AFHRA.

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94. Ibid., 57.

95. F-111 Changes to Meet Navy Requirements, K168.82-166 1961-1964, IRIS No. 01087588, in the USAF Collection, AFHRA. Declassified on author’s request, 26 Jun 2008.

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98. “General Dynamics Answers the Questions: This is the F-111 Story,” *Fort Worth Star-Telegram*, 29 Dec 1968, pp. H1-H8.

99. “Goldwater Now Backs F-111 Fighter,” *San Diego Union*, 29 Mar 1970.

100. “Gen. Yeager Calls F-111 'Pretty Good Weapon System',” *Aerospace Daily*, 1 Apr 1970.

101. Knaack, *Post-World War II Fighter*, 259.

102. Myers Interview, 2008.

103. Oral History Interview of Lt. Gen. John J. Burns, USAF (Ret.) by Hugh N. Ahmann, 5-8 June 1984 and January 1986. Typed transcript pp. 164-168, K239.0512-1587 Iris No. 01085466, in USAF Collection, AFHRA; F. F. Everest Interview, 349-355.

104. Coulam, 49,107; Spangenberg Memo; Burns Interview, 1986, 164-168; Oral History Interview of Gen F. Michael Rogers, USAF, by Lt Col Gordon F. Nelson and Lt Col John N. Dick, Jr., 1 February 1977. Typed transcript pp. 14, 16-17, K239.0512-1069 Iris No. 01034266, in USAF Collection, AFHRA; Oral History Interview of Eugene M. Zuckert, by Col John L. Frisbee, 1 September 1965. Typed transcript p. 18, K239.0512-763 Iris No. 01000323, in USAF Collection, AFHRA.

105. Oral History Interview of Lt Gen Arthur C. Agan, USAF (Ret.) by Lt. Col. Vaughn H. Gallacher, 19-22 April 1976. Typed transcript p. 356, K239.0512-900 Iris No. 01033136, in USAF Collection, AFHRA; Myers Interview, 2008.

106. This assertion is supported in numerous interviews. Examples include: F. F. Everest Interview, 309-310; Flax Interview, 1973, 21-22, 229; Martin Interview, 1978, 370; McNickle Interview, 60.

107. This assertion is supported in numerous interviews. Examples include: Oral History Interview of Gen David C. Jones, USAF, (Ret.) by Dr. Lt Col Maurice Maryanow and Dr. Richard H. Kohn, 5 August, 15-17 October 1985; 20-21 January, 13-14 March 1986. Typed transcript p. 76, K239.0512-1664 Iris No. 01105219, in USAF Collection, AFHRA; Oral History Interview of Gen Curtis E. LeMay, USAF, (Ret.) by John T. Bolen, 9 March 1971. Typed transcript pp. 45-46, K239.0512-736 Iris No. 01001829, in USAF Collection, AFHRA; Oral History Interview of Gen John D. LaVelle, USAF (Ret.), by Lt Col John N. Dick, Jr., 17-24 April 1978, Typed transcript p. 263, 265, K239.0512-1036 Iris No. 01042082, in USAF Collection, AFHRA; McNickle Interview, 60.; Rogers Interview, 1977, 23.

108. Burns Interview, 1986, 110.

109. McNickle Interview, 56.

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111. Agan Interview, 1970, 36-37, 43; Agan Interview, 1973, 21; Myers Interview, 1973, 8-9.

112. F. F. Everest Interview, 172-178, 324.

113. Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari (New York: Coward-McCann, 1942), 24-25.

114. Franklin Cooling, ed., *Case Studies in the Achievement of Air Superiority* (Washington, DC: Air Force History and Museums Program, 1994), 313-314, 416.

115. Ibid., 496-497; F. F. Everest Interview, 172-178.

116. Agan Interview, 1970, 9-10.

117. F. F. Everest Interview, 178; Flax Interview, 1973, 21-22; Oral History Interview of Maj Gen Edward A. McGough, USAF, by Jack Neufeld, 26 September 1973. Typed transcript pp. 3-4, K239.0512-860 Iris No. 01006825, in USAF Collection, AFHRA; Myers Interview, 1973, 25.

118. Agan Interview, 1970, 10-12; Agan Interview, 1973, 21; Myers Interview, 2008.

119. Cooling, 496.

120. Oral History Interview of Maj Gen F. C. Blesse, USAF, (Ret.), by Lt Col Gordon F. Nelson, 14 Feb 1977. Typed transcript pp. 58-58, 62-63, K239.0512-1077 Iris No. 01104963, in USAF Collection, AFHRA; Burn Interview, 1986, 200-201; Flax Interview, 1973, 21-22; LaVelle Interview, 339-340.

121. Blesse Interview, 59-60; Burns Interview, 1986, 14-15; Rogers Interview, 1977, 16-17.

122. Oral History Interview of Peter R. Murray, by Hugh N. Ahmann, 10-11 July 1973, Typed transcript p. 271, K239.0512-679 Iris No. 01016272, in USAF Collection, AFHRA.

123. F. F. Everest Interview, 310.

124. McGough Interview, 3-4.

125. Agan Interview, 1970, 27; Oral History Interview of Brig Gen William F. Georgi, USAF, by Jack Neufeld, 5 June 1973. Typed transcript p. 23-26, K239.0512-964 Iris No. 01021507, in USAF Collection, AFHRA; Myers Interview, 2008; Sprey Interview, 19-20.

126. Oral History Interview of J. T. Cosby, by Lt Col Robert G. Zimmerman, 3-4 December 1973. Typed transcript p. 145, K239.0512-693 Iris No. 00904831, in USAF Collection, AFHRA; LeMay Interview, 1965, 21; Myers Interview, 1973, 5-6.

127. Georgi Interview, 23-26.

128. Charyk Interview, 6, 8, 11-12; Oral History Interview of Gen Jack J. Catton, USAF, (Ret.) by Dr. James Hasdorff, 19-20 July 1977. Typed transcript p. 102, K239.0512-952 Iris No. 01070732, in USAF Collection, AFHRA; "McNamara on TFX."

129. Data for this graph was taken from Jones; Knaack, *Post-World War II Fighter*; Various volumes of *Jane's*; Various Fact Sheets from the National Museum of the Air Force.

130. Oral History Interview of Gen Lew Allen, Jr., USAF (Ret.) by Dr. James C. Hasdorff, 8-10 January 1986. Typed transcript pp. 102-103, K239.0512-694 Iris No. 01105260, in USAF Collection, AFHRA; Oral History Interview of Thomas Christie, by Jack Neufeld, 3 October 1973. Typed transcript p. 2, K239.0512-962 Iris No. 01019854, in USAF Collection, AFHRA. Declassified on 31 Dec 1981; Coulam, 41, 95; Oral History Interview of Lt Gen F. Michael Rogers, USAF, by Jacob Neufeld, 17-18 July 1974. Typed transcript p. 27, K239.0512-965 Iris No. 01020174, in USAF Collection, AFHRA. Declassified on 31 Dec 1982.

131. Data for this graph was taken from Jones; Knaack, *Post-World War II Fighters*; Various volumes of *Jane's*; Various Fact Sheets from the National Museum of the Air Force.

132. Burn Interview, 1986, 7; Christie Interview, 2; Hildreth Interview, 231; Myers Interview, 1973, 12; Rogers Interview, 1974, 27.

133. F. F. Everest Interview, 156-157.

134. Burns Interview, 1986, 37; Davis Interview, 35; F. F. Everest Interview, 311-312.

135. Conceptual Phase to F-111B Termination, 13.

136. SDR No. 17; SOR-183.

137. Robert G. Dilger, “One Hole or Two?,” *USAF Fighter Weapons Review* (1975): 10.

138. Harry Hillaker, interview by author, Fort Worth, TX, 21 September 2007.

139. Revised SOR-183, 8 September 1961.

140. Gen Larry Welch, USAF (Ret.), interview by author, Alexandria, VA, 27 April 2008; Sprey Interview, 21; Speech “Tactical Hardware Briefing” by Brig Gen James F. Kirkendall, TAC Asst. DCS/Ops, at TAC Commanders Conference, Shaw AFB, SC, 7 May 1968, in USAF Collection, AFHRA Declassified at authors request on 1 Jul 2008. References about bias for large aircraft: Oral History Interview of Gen Paul K. Carlton, USAF, (Ret.) by R. Cargill Hall and Charles Dickens, 23 Sep 1980. Typed transcript p. 18, K239.0512-1277 Iris No. 01044841, in USAF Collection, AFHRA; Hillaker Interview; Oral History Interview of Gen Louis L. Wilson, Jr., USAF, (Ret.) by Lt Col Arthur W. McCants, Jr., 7-8 November 1979. Typed transcript p. 73, K239.0512-1178 Iris No. 01049783, in USAF Collection, AFHRA.

141. Sprey Interview, 6, 21; Welch Interview.

142. Data for this graph was taken from Jones; Knaack, *Post-World War II Fighters*; Various volumes of *Jane’s*; Various Fact Sheets from the National Museum of the Air Force.

143. Maxwell D. Taylor, *The Uncertain Trumpet* (New York: Harper, 2003).

144. F. F. Everest Interview, 319.

145. Knaack, *Post-World War II Fighters*.

Chapter 4
Case Study: The FX

The Fighter-Experimental, or FX, was a program to develop a follow-on fighter for the F-111. The need for a replacement was anticipated by TAC planners even as the TFX program was just beginning to get underway, but it was not clear what the new aircraft would be. Beginning with those who were never convinced that the F-111 was what TAC or the Air Force needed, and spreading as the F-111 encountered problems and failed to provide the capabilities envisioned, the idea began to develop that the new fighter would not be "another F-111." What finally resulted was in many ways the opposite of the F-111. It was significantly smaller, although not small; it was optimized for a single mission, and promoted as a single-mission aircraft; it was a maneuverable, air-to-air, single seat fighter; and it was a single-service program. Also unlike the F-111, the F-15 was, and still is, considered one of the most successful fighter aircraft ever produced.

Background Leading Up to the FX Program

As with the TFX program it is impossible to understand why decisions were made without understanding the environment that existed leading up to, and during, the decision-making process. While there was a strong consensus favoring the Everest concept of the TFX, there were those who disagreed, and would have chosen a different fighter. As established in the previous chapter, many of those people chose to back the Everest design for a variety of reasons even though they did not consider it the optimum solution. As the situation changed, those advocating a different kind of fighter chose to present their ideas more conspicuously. Because of events that had occurred they were able to gain support for those ideas, which had an influence on the next fighter.

Roots of Fighter Emphasis

Soon after returning from World War I American airmen began thinking about how aircraft should be used in warfare. The central figure in this pursuit was Brigadier General William "Billy" Mitchell, who had developed strong personal beliefs that strategic bombardment offered a war-winning capability. Besides Mitchell's own vociferous efforts to convince the nation of this, his ideas were taught, beginning in 1920, at the Air Service's first official school on the subject, the Air Corps Tactical School (ACTS), the commandant of which was Maj. Thomas DeWitt Milling. Milling had served as Mitchell's Chief of Staff in World War I while he was commander of all American air assets in France, and had become a devoted follower of his ideas. These ideas were taught at the school as well as being written into the first airpower doctrine, the creation of which was another purpose of the school. The result going into World War II was a doctrine that called for unescorted bombers to destroy the enemy's ability and will to conduct war by attacking the web of industry that supported it.[1]

There were, however, those who saw a role for fighter aircraft; perhaps even the dominant role. Claire Chennault, Chief of Pursuit Training from 1931 to 1937 at the ACTS, found himself increasingly at odds with the rest of the faculty. He believed that not only could bombers be stopped by fighters, but that a force dominated by fighters, with the aid of a limited number of bombers, could win a war by disrupting the enemy's logistics and preventing supplies from reaching the front. Chennault failed at advancing his ideas at the ACTS, and in frustration, as well as due to some health problems, he retired in 1937.[2]

Chennault's influence may have been lost had it not been for the reputation he later developed as leader of the Chinese American Volunteer Group (nicknamed the "Flying Tigers"). The group had an inordinate amount of success against the Japanese despite the fact that they were undersupplied and their P-40 aircraft represented outdated technology. Chennault was later called back to active duty and given command of the Fourteenth Air Force, which covered the China-India-Burma theater of operations, and was eventually promoted to lieutenant general. During and after the war several books were written about his exploits. According to one reviewer, most were "wartime propaganda" and "adventure stories" which added to his reputation.[3]

All of Chennault's ideas regarding the employment of fighters were not sound, nor were they ever fully tested during World War II. The initial heavy losses suffered by American bombers did serve to validate his assertion that bombers were vulnerable to defenses. While bombers were able to inflict damage, their efforts were hampered, and it was not until later in the war, when air superiority was established, that strategic bombardment was conducted as envisioned by the ACTS theorists.[4]

The lessons from World War II differed depending on who analyzed the results. While the most widely accepted view was that strategic bombardment, especially with nuclear weapons, could win wars, those who flew fighters came out of the war with an appreciation for the need to earn air superiority in the air. They would contend that while bombing can eliminate enemy air defenses, those targets cannot be reached by bombers until air superiority exists, which requires fighters. They would point out that this lesson was relearned in Korea, especially given the political constraints that allowed enemy aircraft to operate safely from sanctuaries that were off limits to American bombers for political reasons.[5]

Throughout the 1950s, as tactical airpower was neglected in favor of strategic airpower, there were people who maintained the belief that a fighter should be maneuverable and have the capability of fighting other aircraft in the air. They decried the consolidation of the aircraft designations that lumped all small aircraft under the generic label of "fighter." Instead, they thought attack aircraft, bombers, and pursuit aircraft should all be designated as such. During the development of the F-111 some of these people were those who dissented, or would have dissented if they had thought they could have made a difference. When it became more apparent that the F-111 would not meet the needs of the Air Force they began to build support for a fighter that, in their opinion, would meet the needs.[6]

Advocacy of Fighter Aircraft

Of those who disagreed with the direction fighter development had taken, or who spoke out on behalf of a different mission emphasis, a few seem to have been more effective at convincing others to act. One of these was Lieutenant General Arthur C. Agan, who served as Assistant Deputy Chief of Staff for Plans and Operations from 1964 to 1966. Agan had flown and commanded fighters his entire career, beginning prior to World War II, and had strong feelings about the need to gain air superiority, which would require a high performance fighter.[7]

When Agan arrived at the Pentagon he was concerned by the lack of emphasis on the air-to-air mission. Emphasis was strong on the bombing mission, both in the Air Force in general, but even in TAC. The Secretary of Defense and his staff were not so concerned about mission, as numbers of fighters. Their method of analysis was influenced by the emphasis placed on ground troops in support of Kennedy's Flexible Response strategy, and it traded off numbers of fighters with ground troops to gain the most combat effectiveness for the cost expended.[8] At that time the Air Force lacked a credible quantitative analysis capability that could compete with that of OSD, so Agan decided to put together a qualitative study.

In order to overcome the credibility of OSD's computer analysis, in October 1964 Agan assembled a group of high-profile fighter pilots and aces (some multiple times). The study, referred to as the Thyng Study drew on the combined experience of this varied and accomplished group to determine the future fighter needs of the Air Force.[*] The conclusions were that the Air Force lacked the ability to gain air superiority against the Soviet forces in Europe, and that a high performance air superiority fighter, that was not completely reliant on missiles, was needed if the deficiency was to by rectified.[9] At the time of the Thyng Study the F-4 was in production and the F-111 was in development, so no concrete action was taken other than to continue to study the problem.

Agan used the results of the Thyng study to raise awareness of the need for air superiority, and to start the Air Force to move in that direction as a matter of policy. One of his efforts was to draft a formal Policy Statement on Air Superiority for signature by the Air Force Chief of Staff. In January 1965 General John P. McConnell replaced

[*] Members who worked in the study, called the "Ace's Study", or the "Thyng Study" after its chairman, were: Brig. Gen. Harrison Thyng, Col. Francis S. Gabreski, William Dunham, Winston W. Marshall, George Laven, Jack Holly, and John J. Burns.

General Curtis LeMay as Chief of Staff, and although McConnell was a bomber pilot, he was not as single-minded in his emphasis of the bomber mission as was LeMay. McConnell supported Agan in his views on air superiority enough to sign the policy statement in May 1965 and circulate it through the Air Force. Besides defining air superiority and stressing the importance of "winning" it, the document stated the need for at least one, but preferably more of the following advantages: numerical superiority, tactical superiority, and technical superiority.[10]

Other efforts were ongoing during the early 1960s as well. Charles E. Myers, Jr., who was a test pilot for the F-106, and who had held the position of president of the Society of Experimental Test Pilots, was very active in promoting a change in mission emphasis to that of air superiority. After his test pilot career, Myers worked for Lockheed as a requirements analyst and then as a marketer. Besides his professional interest in selling air-to-air fighters (the F-104), he also had strong convictions that the air superiority mission had been lost in bombardment, and that there was a need to re-educate those in Washington, including those in the Air Force, as to how the mission should be accomplished. He emphasized the air-to-air aspect of mission, and even organized an informal group of sympathizers, which they named the "Air Superiority Society."[11]*

Myers saw his efforts toward the advocacy of the air superiority mission as a precursor to selling fighters, and his company agreed and gave him wide leeway in this pursuit. With that backing, and the access gained by his reputation and that of his company, Myers prepared a briefing on the subject which he gave to as many decision

* The name was chosen because of the irreverent nature of the acronym it created. Female members were dubbed "assets".

makers to whom he could gain access. He also wrote an accompanying paper, which he "passed out like chewing gum." The message was that all fighters are not alike. There are fighter-bomber, interceptors, and what he called fighter-fighters, or fighters designed to kill other fighters in air-to-air combat. He contended that this last category of aircraft is vital, and yet it was missing from the inventory. The evidence suggests that his message was very well circulated, throughout 1964 and 1965, and that it had an influence on the ideas espoused.[12]

Another effect the efforts of Agan and Myers seemed to have was the opening of the debate on the subject of fighter mission emphasis. Not only was it being discussed within the Air Staff, but it was also receiving attention in publications with wider dissemination.[13]

The Vietnam War*

The efforts that were underway to promote the air superiority mission in the early 1960s were strengthened by events that unfolded during the Vietnam War. Even though the Air Force still embraced the mission of strategic bombardment with nuclear weapons, involvement in Vietnam further highlighted the need to be able to fight a conventional war. The F-111 was designed based on those priorities. Leading up to the development of the FX, however, it became clear that greater emphasis would need to be placed on conventional roles.

* While officially operations in Vietnam were not part of a declared war, leading to it being referred to as the "Vietnam Conflict", the term "Vietnam War" has been used deliberately to highlight the fact that lessons were being learned from the combat environment that the military would be facing in actual wartime. This was the new face of war, as opposed to that often envisioned by military leaders of the time, which was usually referred to as "general war", and which implied total nuclear war.

From the beginnings of U.S. involvement in Vietnam CAS aircraft were seen as inadequate. While the Air Force initially touted the TFX as a solution to that problem, the removal of that requirement by OSD, and the subsequent lessons from Vietnam prompted the Air Force to complete a study to assess the needs for ground attack aircraft. The so called "Bohn Study," named for its chairman, Lieutenant Colonel John W. Bohn, Jr., was begun in August 1964, and completed on 27 February 1965. It found that a large high performance aircraft like the F-111 was too expensive to justify putting in the high risk ground attack environment, and the study therefore looked at less expensive options. The conclusion was that a mix of low-cost tactical aircraft with higher cost, high performance aircraft would be the best way to strengthen the force.[14]

Vulnerability in the air superiority capability, which had been allowed to develop, was also exposed early in the war. While on a bombing mission over North Vietnam, two F-105s were shot down by Korean War era MiG-15s on 4 April 1965.[15] Not only did this event serve to dispel the attitude that air superiority could be taken for granted, but also exposed the current fighter aircraft as being ill-suited to take on the mission. The fact that Air Force leaders grasped the significance of this event, at least to some extent, can be seen from the reaction it prompted. Immediately F-4 aircraft were sent to Vietnam to provide air cover for the F-105s. It also helped to persuade McConnell to sign and distribute the previously mentioned air superiority policy letter prepared by Agan. Finally, the event generated much support for studies to begin addressing the need for a new fighter, although most of the early efforts saw air superiority as only one of the missions of which such a fighter would be capable.[16]

As the war progressed into the late 1960s results continued to be poor. Up through December 1966 the kill ratio (MiGs killed versus American planes killed) was 2.4 to 1.[17] The Air Force was not used to being challenged in this area, having had a kill ratio four to five times greater than this in Korea. American air superiority had been taken for granted during the interim, and the early results were especially surprising, given the outdated equipment the enemy was using (mainly MiG-17s) and the fact that the Air Force considered its equipment to be much more capable. The trend reversed briefly in the first few months of 1967, but then over the next year, during much of the concept development work of the FX, the ratio fell even lower to an even 1 to 1 exchange.[18]

Aircraft Leading Up to the FX

Most of the aircraft that were procured during the period leading up to the FX program have already been discussed. The F-105 was a nuclear fighter-bomber, and was the frontline fighter at the beginning of the Vietnam War. The F-111 was still in development as the follow-on to the F-105. The F-4 was procured from the Navy as an interim fighter bomber until F-111 development was completed. Two other aircraft which influenced the procurement of the FX, the F-5 and the A-7, were procured at this time.

The F-5 began development during the 1950s as a Northrop-funded, low cost, unsophisticated fighter that could be provided to U. S. allies under the Military Assistance Program and foreign sales. By 1964 the aircraft was just becoming operational, and the U. S. sent a squadron to Vietnam for combat testing, as well as procuring some two-seat B-models in which to train allied pilots.[19]

The A-7 grew out of the Navy-led effort to develop a low-cost, low-technology ground attack aircraft after the requirements for that mission proved too divergent from the SOR-183 requirements of the TFX. The Navy awarded a development contract for the aircraft to Vought in March 1964, with a projected initial operational capability in early 1967. The aircraft was a subsonic single seat aircraft capable of carrying a large payload, optimized for the conventional air-to-ground mission.[20]

When it was decided that the TFX would not provide a CAS capability for the Air Force, the Army began putting pressure on the Air Force to provide another solution. The previously mentioned Bohn Study was commissioned, and recommended these two aircraft, the F-5 and the A-7 as the only ones capable of fulfilling the mission, within the required cost constraints. It recommended the F-5 be selected from these two choices.[21] OSD, however, saw another opportunity to simplify logistics and save money through commonality, and pushed the Air Force to accept the A-7.[22]

Further studies were conducted to compare the F-5 with the A-7, but none of the analysis was conclusive. Depending on what entry parameters, going-in assumptions, or characteristics were given priority the analysis could show either airplane as the better choice.[23] Although the Air Force in general was not enthusiastic about a low-technology aircraft, there was a broad consensus that the F-5 was the more desirable airplane, because it fit the Air Force paradigm of supersonic capability.[24] In the end, General McConnell chose to back the A-7 against the wishes of most of the Air Force. Besides relieving the pressure being exerted by OSD and placating the Army, who was pushing for a slower speed aircraft which it considered to be better suited for the CAS mission, McConnell also saw this as a way to justify an air superiority fighter. It was accepted by all participants, and the analysis confirmed, that the A-7 had little if any air-to-air capability, while the F-5 had a modest capability in that mission. By choosing the specialized air-to-ground aircraft, Air Force leaders left the air-to-air need unmet, thus creating an opening for a new aircraft procurement.[25]

New Commander of TAC

One person does not have the ability to dictate the characteristics an aircraft will have, but some people, especially those in positions of authority, can exercise more influence than others. It is significant, then to note that in the period leading up to the FX program the commander of TAC was replaced by General Gabriel P. Disosway, who was a career fighter pilot, and who played an important role in the development of the FX. Even more significantly, Disosway replaced General Walter C. Sweeney, Jr., who was not only a career bomber pilot, but held high positions of authority within SAC, and was appointed by LeMay to bring SAC influence to TAC. While Sweeney was cooperative with TAC efforts to procure a new fighter, the airplane that would have resulted with a bomber pilot in command may have been quite different.

Systems Analysis

When McNamara became Secretary of Defense he brought a new management philosophy to the job. Throughout the nation's history the services were, in essence, given an allowance of resources based on a budget ceiling set by Congress. Little oversight was exercised over how the individual services chose to spend that money to fulfill their military requirements.[26] McNamara questioned not only the requirements, but the ability of the military to determine those requirements. He did not believe there were any pure military requirements, but that all requirements involve political, economic, diplomatic, and technical factors, as well as military considerations. He also believed that the Secretary of Defense should make the final decisions about requirements and systems, since the individual services only have expertise in military matters, in his opinion, and they are susceptible to institutional biases.[27]

While McNamara had the authority to make decisions about weapon systems, he was not satisfied that he had the management tools. To remedy this he established the office of Systems Analysis. Alain Enthoven, who was in charge of Systems Analysis, described it as:

> …A recent approach to highly complicated problems of choice in a context characterized by much uncertainty; it provides a way to deal with differing values and judgment; it looks for alternative ways of doing a job; and it seeks, by estimating in quantitative terms, where possible, to identify the most effective alternative.[28]

The office was staffed with young highly educated civilian analysts, who had little or no experience in military matters, and often demonstrated contempt for those who would cite military experience as a basis for decision-making. One general described his relationship with Enthoven as follows.

> I was dealing with a gentleman who was a good analyst, a good mathematician, and a very fine intellect. However, he didn't know a … thing about an airplane. He didn't know a … thing about a crew, he didn't know a …thing about training, and he didn't know really anything about the Air Force. I spent hours and hours reiterating and responding to his doubts and his challenges. For months I did this before we came to a conclusion. It was amazing, you see, and I was a three-star general. I had

> been in the Air Force for over 30 years or something like that, I had a lot of experience, but I was challenged by this young man who had never done anything except go to school.[29]

On the other hand, the level of education for military officers, while increasing, was not very high, and many of them did not understand or appreciate the methods used by the OSD analysts. They often had to fall back on "military judgment," or experience. This led to briefings being more on the level of propaganda at times, and in general quite shallow.[30] This situation led to two different decision-making mentalities; one held by the Air Force and one by OSD. The result was not only a mutual lack of credibility, but often mutual disrespect.[31]

Air Force Studies and Analysis

In response to the greater demand to justify decisions with quantitative analysis the Air Force made a concerted effort to develop a more robust analysis capability. In the past the Air Force had relied on ad hoc groups formed from officers assigned to those offices with an interest in the study, as well as anyone who could provide the needed expertise to answer the question or questions being studied. Often the analysis was qualitative in nature, and was a statement of the best judgment of the group.[32]

The person who was tasked to build up the Air Force's internal studies and analysis capability was Lieutenant General Glenn Kent, who had proven himself in the DoD's Office of Research and Engineering. Kent was chosen to lead this effort, first in AFSC, and then as the Assistant Chief of Staff for Studies and Analysis. He handpicked a group of extremely capable officers to help him, and had a strong team in place leading up to the FX program. Two important members of the team were Lt Col (later General) Larry Welch and Major (later Colonel) John Boyd.[33]

Each of these officers helped develop an important analysis capability that was used extensively to define and refine the FX, and programs beyond that. Welch, an accomplished fighter pilot, was tasked to lead the development of a computer simulation called TAC Avenger that modeled one-on-one fighter engagements. Besides a performance comparison of the aircraft, it attempted to incorporate the decisions a competent pilot would make in such an engagement. Welch and his team then went about calibrating it, and convincing people that it was a valid representation. Since it was the first of its kind that produced credible results it became a very valuable tool leading up to, and during the FX program.[34]

John Boyd was also a fighter pilot who had studied engineering, and had committed a great deal of thought to the representation of aircraft states during aerial combat. Boyd discovered a way to quantify the amount of energy an airplane had at each point in its envelope. This Energy-Maneuverability (EM) theory, as it was called, allowed aircraft to be compared throughout their envelopes, and not on a point by point basis. Previous to the development of EM theory aircraft were compared one parameter at a time, such as speed and altitude. The real value of EM, especially after the results of calculations were presented on easy to compare colored charts, was that engineers and pilots could communicate more easily with each other. Pilots often felt like they knew what they wanted in an airplane, but they were incapable of communicating such characteristics as “the ability to stay with an enemy,” which was more than top speed or ceiling, in terms an engineer would understand. Similarly, engineers could show designs with characteristics such as wing area, thrust, and drag, but those meant little to pilots. Boyd's EM theory showed that fighter maneuverability was mainly a function of thrust-to-weight ratio and wing loading. By changing these two characteristics a new EM profile, based on excess energy throughout the envelope, was created, and could easily be compared with other designs or threat aircraft.[35]

Setting the Stage for the FX Program

While there was consensus within the Air Force that there was a need for a new fighter, there was not a high degree of agreement beyond that. Some believed the new fighter should be another multi-mission fighter, while some thought it should focus on the air superiority mission. All agreed that it should be high performance, but there was not agreement on a definition of that term, or which aspects of the new airplane's performance should be emphasized.

Genesis of the Concept

With the momentum generated by the unsuccessful aerial engagements in April 1965, General Ferguson, the Deputy Chief of Staff for Research and Development, was able to procure approval from Harold Brown, the DDR&E, to begin development of an FX, along with the acquisition of an interim air-to-ground airplane (at this time the Air Force requested the F-5, but that was later changed). No funding accompanied the approval, so internal discretionary funds were used, and a study group was assembled within the Air Staff to conduct early concept studies. Ferguson directed the studies, and requested the group to study an aircraft in the range of $1-2 million for a buy of 800-

1000, and that would have a superior all-weather air-to-air capability, with an aided visual ground attack capability. He envisioned a single-seat, twin-engine fighter that could sacrifice speed for maneuverability.[36]

As he began these studies, Ferguson wanted to consolidate the various existing requirements, many of which included the need for vertical/short takeoff and landing (V/STOL) capability. He sent a memo to TAC asking them to clarify their V/STOL requirements, presumably to see how they might fit into the FX concept. At this time (then) Colonel Burns, who had participated in the Thyng Study, was the Assistant Director of Requirements at TAC, and a strong advocate of the air superiority mission. He took advantage of this request to begin laying the groundwork for an official requirements document specifying an air superiority fighter based on his ideas. That same day he drafted a message stating that TAC had no requirement for a vertical takeoff and landing aircraft, but it did for a short takeoff and landing (STOL) aircraft, and he added the characteristics he thought it should have. After clearing the message with the TAC deputy commander for operations, he sent it off that evening. His hope was to access money designated for STOL research to advance this idea.[37]

This initial exposure was well received, or at least it was not dismissed, so Burns took that as encouragement to write the requirements he had submitted via message into a Qualitative Operational Requirements document (QOR) for the new fighter. It asked for a fighter with the following characteristics.

- Weight: 30,000 – 35,000 pounds, reversing the trend toward bigger fighters
- Radar-equipped: Burns specified a radar "similar to the F-4's"
- Maneuverability: It should be capable of outperforming the enemy in the air
- Thrust-to-weight: specified as "high," though no target was given

- Speed: Mach 2.5 maximum, reversing the trend toward faster fighters[38]

While many gave Burns the credit for coming up with the QOR requirements, he acknowledges that they came out of the Thyng Study, which was simply the combined wisdom of a group of aces and fighter pilots. The document was not based on any quantitative analysis.[39]

Technology

Technology did not play nearly as central of a role in defining the FX as it did the F-111. The resulting aircraft did include technological advances, such as new higher thrust engines, avionics that allowed a single pilot to perform the air-to-air mission in a non-visual setting, and a radar that would allow a look down, shoot down capability. None of these technologies defined the airplane the way the variable geometry wing defined the TFX program. While the initial concepts were not dictated by the technologies, the final design was of course heavily influenced by the technologies used.

Selling the Program

Even though Burns submitted a requirements message to the Air Staff, that did not mean that everyone in TAC agreed with his conclusions. There were also many in the Air Staff that had a different idea of what the Air Force needed in a new fighter. OSD was split too in their views of what the next fighter should be.

The first hurdle was to consolidate backing within TAC for the QOR, which was written in May 1965. One of the first allies Burns enlisted was Lieutenant General Gordon Graham, who was on the TAC staff, and became the Deputy Commander for

Operations in August. He was a triple ace fighter pilot with 16.5 kills in World War II, and then had gone on to fly fighters in SAC. His past experience no doubt played a role in his support for the new air-to-air fighter. Graham helped acquire the needed approval within the command.[40]

At this time General Sweeney was commander of TAC, but he was in the final stages of pancreatic cancer. No one expected him to act on the new fighter given his health, and because of his SAC bomber background, although Burns claims he was open to the idea.[41] He retired on 1 August 1965 and was replaced by General Disosway, who was enthusiastic about the new fighter. Disosway had been a fighter pilot his whole career, but that alone is not enough to make someone support the air-to-air mission. Agan claims he spent hours discussing the subject with Disosway when he was the Vice Commander of TAC and on the Air Staff (1961-1963).[42] Whatever motivated Disosway, he became one of the strongest advocates for an air superiority fighter. He assumed command on 1 August, and by October the QOR had been signed and forwarded to the Air Staff.[43] There were still those in TAC who were not convinced of the need for an air superiority fighter as Burns described it, but with the top leadership behind it, the QOR was submitted.

Convincing those on the Air Staff was the next step. Several visits were made from TAC to the Pentagon to explain the requirements and answer questions. One of the important allies TAC was able to make at the Air Staff was General Jack J. Catton, who served as Director of Operational Requirements, and later Assistant Deputy Chief of Staff for Programs and Resources. Besides these influential positions, he had an additional duty as chairman of the Air Staff Board, an organization of top decision makers on the

Air Staff that considered decisions that cut across functions. Although Catton had a bomber background and was a close associate of LeMay, he understood the need for a fighter, especially in light of the F-111s projected inability to succeed in the air-to-air close-in combat that was re-emerging in the Vietnam War. Catton and Agan had spent time together on a study for the A-7 program that addressed the issue, and he was also one of the first among the Air Force leadership to pay attention to Boyd's EM theory. With Ferguson and Catton as allies on the staff, Burns and Disosway were able to start making some progress.[44]

It was also during this time that the Air Force made the decision to procure the A-7. There are many who claim the decision was based on political pressure from members of Congress from Texas, where the A-7 was produced. These insinuations received more strength since some of the top leaders who had been pushing for the F-5 changed their position just before the decision was made.[45] Whether that played a significant part is unknown, but a more likely explanation was that the Air Force leaders knew that having the F-5 in the inventory would curtail their efforts to procure a new air superiority fighter, given that the F-5 had an air superiority capability, although much more limited than that envisioned in the FX. Given that the Air Force was already procuring the F-111, if it chose the F-5 the entire inventory would have been made up of aircraft with which it was not satisfied. This explanation is supported by the fact that Harold Brown, who supported the F-5 as DDR&E where he arguably would have been closer to administration pressure working directly under McNamara, switched his support to the A-7 within a month after becoming Secretary of the Air Force (on 1 October 1965). Disosway's efforts to convince others to support the procurement of a subsonic ground attack airplane, and his statements that it would open the way for approval of the FX air superiority airplane, also support it.[46]

Disosway also set out to remedy the divided voice of the fighter commands that had weakened attempts to procure past fighters. PACAF, USAFE, and TAC all fly tactical fighters, but only TAC procures them. As a result, two of the three tactical fighter commands are underrepresented in the procurement arena. To correct this, Disosway sent Burns to the other two commands to brief them on FX requirements and to try to build consensus. He also set up a series of "Tri-Commanders Conferences" with the other two commanders to discuss the issue. The first was held in February of 1966, and the three commanders were able to agree on the requirements as put forth in the QOR. They drafted a letter over all three signatures to send to the Chief of Staff stating their urgent requirement for an "FX optimized for the air-to-air mission." That the so-called "Twelve Star Letters" influenced the Chief is evidenced by his response to the letters stating his ongoing support.[47]

Along with continued efforts to shore up support within the Air Force, efforts were already being made to build support in other organizations. The A-7 compromise was one such effort. Congress was the target of efforts as well. Major General Roger K. Rhodarmer was given the job of coordinating all information flow to outside agencies, including Congress. This allowed the Air Force to focus advocacy efforts, as well as to control what was being advocated. Major General John C. Giraudo, who spent five years in the Air Force Legislative Liaison office, and who "had a personal love affair with the soon to be born F-15," was a good point of contact for efforts with Congress as well. All of these efforts, within the Air Force and in other organizations were ongoing, especially as the program went through an exhaustive definition phase.[48]

Defining the Concept

The concept of a new air superiority fighter was slowly being accepted, especially by those in key leadership positions. Despite this, there were many people who were still pushing for another multi-mission fighter. Among those that did accept the idea of a single mission aircraft, or at least one whose primary mission was air superiority, there was a wide range of what, in their minds, constituted an air superiority fighter. Some who wanted such a fighter recognized their need for more information before the decision could be made. The ongoing problems of negative image and eroding support for the F-111, coupled with the worry that Air Force interests could again be threatened by turning the FX into another joint program, steeled Air Force leaders' determination to be as thorough as possible in their efforts to build a feasible program with strong consensus. To accomplish this, several efforts were undertaken to provide answers to questions that arose.

Much expertise, especially technical, resides with the contractors who design and build weapon systems, so one of the early efforts to determine how the FX might be conceptualized was to ask for inputs from industry. In December 1965 the Air Force sent RFPs to thirteen aircraft companies asking for design options based on specification they had derived from their interpretation of the QOR. Eight companies returned bids, and of those, three were put on contract to conduct parametric studies in March 1966, with a fourth participating using their own funds. The companies conducted tradeoffs of five parameters: avionics, maneuverability, payload, combat radius, and speed. The deliverable for each was a very cursory conceptual design, along with weight and cost. The four studies yielded approximately 500 designs, which ASD evaluated in July 1966.[49]

The idea of a single mission aircraft, or even having the air-to-air mission dominate the others, had not been fully accepted in ASD. Many who worked there still believed that a multi-mission aircraft was what the Air Force needed. As a result, the specifications provided to the contractors, and the criteria used for evaluation, were based on the ability to perform both the air-to-ground mission and the air-to-air mission, with more emphasis on bombing. This resulted in a conceptual aircraft that was similar to the F-111. It had a variable geometry wing with high wing loading, a moderate thrust-to-weight ratio (.75), the top speed was Mach 2.7 which would require extensive use of exotic materials such as titanium, and it weighed 60,000 pounds. Not surprisingly it was going to be very expensive.[50]

The concept proposed by ASD did not agree with the idea many people in the Air Force envisioned for an air superiority fighter, and therefore it was not readily accepted. General Ferguson, who became commander of AFSC on 1 September of that year, tasked the Air Force's best analyst, Lieutenant General Glenn Kent, to tackle the problem. As stated, he recruited Boyd, Welch, and others, and began working on the problem.[51]

Kent recognized that the lack of general acceptance of the ASD design resulted from a problem with the requirements, as they existed. Because they were still in a qualitative format it left an opening for those of every persuasion to introduce requirements. Some lamented this as "gold plating," but Kent recognized it as the natural process of each group trying to have their perceived needs met. Although a conceptual aircraft design had been put forward, it was obvious that it was incapable of actually performing all of its missions satisfactorily any more than the F-111 was. There was a technology limit over which the requirements had tried to step. Kent recommended a complete "scrub down" of the requirements. Before this occurred, however, Kent conducted the analysis required to provide the answers that would allow informed requirements decisions to be made.[52]

The analysis began by addressing the requirement in the QOR that the aircraft would outperform the enemy in the air. The first step was to define the enemy. Using available threat data, and projecting into the future, a notional composite threat aircraft was defined, against which options would be compared. Next they conducted a parametric study of FX concepts that went from a 32,000 pound day visual fighter with no air-to-ground capability; to an 81,000 pound, multi-mission, all weather, day/night, air-to-air and air-to-ground aircraft. They constructed a large matrix with all of the possibilities in between those limits.[53]

Three methods of analysis were used to create the concept options. The first was the TAC Avenger model developed by Welch and his coworkers, the second was Boyd's EM theory, and the final method was the traditional method of point comparison. This consisted of comparing top speed, range, payload, missile ranges fired at various points, and other static comparisons.[54]

Kent's philosophy of analysis was that the analysts should provide the answers to questions, and the users should make the final choice. Based on this philosophy Welch and Boyd presented their findings, including their matrix of options, to decision makers in AFSC, TAC, and on the Air Staff, as well as other informational briefings. When they gave the results to the Chief of Staff, based on the analysis and advice from Disosway, Boyd, and others, he chose a concept that was a 40,000 pound aircraft with a 36 inch pulse Doppler radar, which gave it a look down shoot down all weather day/night air-to-air capability. It had a low wing loading of 65 and a high thrust-to-weight ratio of 1.1. The top speed had been dropped from Mach 2.7 to Mach 2.3. No air-to-ground capability was specified, although it became apparent that a significant capability could be added with little penalty.[55] After making that decision he later stated that if anyone tried to increase the weight over 40,000 pounds he would find him and remove him from the Air Force, so he was very decisive on the point.[56]

While Kent's group was working on their analysis, efforts were underway by AFSC throughout 1967 to develop a Concept Formulation Package (CFP). It was completed and submitted to the Air Council on 23 June, and to the Chief of Staff the following day. It was approved, and in July Secretary Brown submitted it to the Secretary of Defense. The CFP explained the rationale for the new fighter, its general characteristics and functions, as well as proposed programmatic data. The document presented justification for a maneuverable air-to-air fighter based on the emerging threat, and contained the requirements from the QOR. As an example, it included some conceptual design parameters based on the ASD design, although it did specify a 40,000 pound weight instead of 60,000 lbs.[57]

Another issue that had to be addressed, beginning in May 1966, was that of commonality. Similar to the Air Force, the Navy also had requirements for follow-on aircraft. An 18-month study concluded that the requirements were too divergent to be met by a single airframe. Efforts continued in attempts to identify subsystems that could be used by both services. Given the negative experience the services had been through with the F-111 program, both the Air Force and the Navy were adamantly opposed to introducing commonality into their programs. There was even an unofficial agreement that neither service would attempt to push its aircraft on the other, although when it became apparent that the two programs might be in competition for the same money, there were concerns that the Navy might make such an attempt anyway. Although much effort and significant resources were expended to produce analysis proving that commonality would have a negative effect, in the end the push for commonality was a factor only in forcing the Air Force to decide on the aircraft's primary mission.[58]

Disagreement persisted within the Air Force as to the mission emphasis the FX should address. Some still asserted that it should be a multi-mission aircraft, which would degrade maneuverability and the air-to-air mission capability. Others accepted the air superiority mission, but felt the level of "fall out" air-to-ground capability should be more than others thought it should be. Still others agreed with the concept of an air superiority fighter, but thought that should mean bombing aircraft and facilities on the ground. All of this was the case despite the insistence on an air-to-air emphasis by the commanders of the three fighter commands, and the Chief's decision that it should be a highly maneuverable air-to-air fighter. In early 1968 there was a growing concern among those in the Air Force involved with weapons procurement that the Navy was planning to unveil an airplane program that was further along than the FX program. The feeling was that if the Navy was far enough ahead, Congress might expend available funding on that program, and force the Air Force to procure the resulting aircraft. With the threat of being forced to take another Navy airplane came a feeling of urgency which compelled the Chief to try to consolidate the Air Force position.[59]

To help strengthen a united position, in February 1968 TAC released an updated requirements document to replace the 1965 QOR. "Required Operational Capability TAC No. 9-68" (ROC 9-68) specified the following:

> - Weight: Unspecified, but "as small as possible commensurate with performance requirements"
> - Radar-equipped: Look down shoot down capability
> - Maneuverability: It should be capable of outperforming the enemy in the air, specifying a maneuverable aircraft unhampered by ground attack requirements
> - Thrust-to-weight: 1.1 to 1
> - Speed: Mach 1.1 at sea level (1.2 desired), and at altitude speed was unspecified, but Mach 2.7 maximum was desired
> - Crew size: Specified as one pilot
> - Load factor: 7.33G capability with 80% internal fuel and 4 missiles
> - Avionics: All weather air-to-air, with a minimal aided visual air-to-ground delivery system (once there is no more air-to-air threat), that would not penalize the air-to-air performance[60]

In order to consolidate the Air Force position, McConnell assigned Major General Rhodarmer the task of putting together a briefing that explained that the F-15 would be a single mission airplane, the mission being maneuverable air-to-air combat. There was to be no mention of any air-to-ground mission. Rhodarmer, with the help of Brigadier General Robert Titus, John Boyd, and Colonel Everest Riccioni put together a five-hour briefing and gave it to all the four star generals. Then they proceeded to give it to the lower levels. They also prepared a written document that communicated the Air Force's common position. Besides trying to convince everyone of the validity of the mission, their main goal was to unite them around that position in order to avoid being forced to take another Navy airplane. They also showed that the air-to-air mission was demanding enough, that if an airplane were capable of doing it, it would be more than capable of taking on an air-to-ground role at a later time. The time to discuss that was after the airplane was approved. Finally, it allowed the Air Force to point to the new Soviet MiG-25 Foxbat Mach 3 fighter as an immediate air to air threat that needed to be countered, thus justifying the new aircraft.[61]

After McConnell was satisfied that he had a united position within the Air Force, in May 1968 he testified in front of the Senate Arms Services Committee and gave the following statement.

> We had a very difficult time in satisfying all the people who had to be satisfied as to what the FX was going to be. In fact, we had a difficult time within the Air Force. There were a lot of people in the Air Force who wanted to make the FX into another F-4 type of aircraft. We finally decided – and I hope there is no one who still disagrees – that this aircraft is going to be an air superiority fighter.[62]

When McConnell was asked if there was a possibility the airplane could be used for CAS, he responded, "It would be over my dead body."[63]

The strategy was to present the image of a sound program that would proceed unhampered by controversy. It was also presented as the antithesis of the Navy program, the VFAX, which was planned to replace the F-111B, which the Navy had succeeded in cancelling. The Navy cancelled the VFAX one month later and concentrated on a different aircraft, which later became the F-14. The result was that the FX had been designated a single mission aircraft, and was free from commonality encumbrances. The resignation of McNamara earlier that year also helped pave the way for the latter result.[64]

After the Air Force established a unified position, and the commonality issue was resolved, progress toward the establishment of a program accelerated. In May 1968 McConnell assigned top priority to the FX program and pledged all necessary manpower and resources for its support.[65] In June results from a second round of design studies were completed by contractors. These results were evaluated and used by a team to revise the requirements and prompted a decision to conduct a prototype approach to three major subsystems; the engine, the radar, and the gun.[66]*

The revised requirements were formalized in a revised version of the CFP in August 1968, and then incorporated into the FX Development Concept Paper (DCP), prepared by the DDR&E's staff, with Air Force assistance. This was released on 18 September 1968. The DCP stated that the FX would be optimized for the counter-air mission and meet the following requirements:

- Weight: Specified as 35,000-40,000 lbs
- Radar-equipped: Look down shoot down capability
- Maneuverability: It should be capable of outperforming the MiG-21 and its follow-on
- Thrust-to-weight: Desired greater than future threat (possibly 1.3 to 1)
- Wing Loading: Desired less than future threat (possibly 60-65 lb/sq-ft)
- Speed: Mach 1.2 at sea level, Mach 2.3 at altitude (Mach 2.7 desired)
- Crew size: Specified as one pilot
- Engines: Twin turbofan engines
- Load factor: 7.33G capability with 80% internal fuel and 4 missiles
- Avionics: All weather air-to-air, with a minimal aided visual air-to-ground delivery system (once there is no more air-to-air threat), careful consideration should be given before adding any weight for air-to-ground equipment[67]

The day after the DCP was completed, John Foster, Jr., the DDR&E approved contract definition to begin the program. It was approved by Secretary of Defense Clark

* Contracts for the analysis and design studies had been awarded on 1 December 1967 to General Dynamics-Fort Worth Division and McDonnell Douglas. Fairchild-Hiller, Grumman, Lockheed, and North American had conducted internally funded studies as well. The gun program was later cancelled as the caseless ammunition technology failed to mature. An existing gun was used instead.

Clifford, who had replaced McNamara, on 30 September 1968, and the Air Force released the RFP, which it had previously prepared.[68]

The FX Development Program

Like the aircraft that resulted from the two programs, the FX program was in many ways the polar opposite of the TFX program. While the latter was maligned as one of the poorest run programs ever, the FX program was seen as a model for others to follow. The management of the program is not the focus of this research, but some information provides insight into the perception of the program and the resulting aircraft, and is therefore relevant.

To manage the program, an FX Special Projects Office was set up in ASD at Wright-Patterson Air Force Base, Ohio, and it was to manage the FX program during the early stages.* This office became a System Program Office (SPO) in May 1968. On 11 July 1969 Brigadier General (select) Benjamin N. Bellis was appointed as the director that would lead the development effort. That same month three competing contractors, Fairchild-Hiller, McDonnell-Douglas, and North American submitted design proposals, followed 2 months later by cost proposals.[69]

Programmatics

After the TFX program received formal approval, with its reorientation as a joint program, much work remained to establish joint requirements and choose a development contractor. As presented in the last chapter, that was a long, painful, and in many ways

* The special project office also had responsibility for the AX program, which eventually produced the A-10.

detrimental, process that caused delays, led to cost overruns, and left the program with a very negative image. In order to address the problems, the TFX program received unprecedented amounts of oversight, to the point that McNamara himself was making program decisions normally made at the program manager level.[70]

The Air Force was determined that the FX program would not repeat the problems of the TFX. While the efforts to establish FX requirements were somewhat drawn out, the Air Force utilized the time to solidify consensus around the concept that came out of the process, so that when the program got underway there would be less chance of controversy. There was a concerted effort to anticipate questions and research the answers in advance. When the program was ready to begin, Air Force Vice Chief of Staff, General Bruce K. Holloway stated regarding the FX program, "Without exception, this is the best job I've seen in concept formulation for a new weapon system."[71]

The poor results of the total package contracting strategy used for the F-111, as well as the C-5, convinced the Air Force to look for a new option. Major General Harry E. Goldsworthy, the ASD commander, was given the task. He determined that although no one part of the F-15 was high risk, the integration of all subsystems into a working aircraft posed a risk. To contract for the entire project up front, locking the contractor into a fixed cost contract, inhibited creativity that might change initial cost estimates, as well as requiring an accurate cost estimate at the very initial stages of a program, which was nearly impossible. Instead, Goldsworthy proposed a mixture of cost reimbursement and fixed price type contracts, each with associated incentive fees. To exercise control over costs, however, he introduced a series of technical development milestones. At each milestone the Air Force would evaluate contractor performance to determine accomplishment before progressing to the next step, or paying incentive fees.[72]

Other changes were implemented to remedy the problems experienced with the F-111, such as the Secretary of Defense being involved in the day to day management. The Air Force took steps to consolidate control in the program director. Deputy Secretary of Defense David Packard, with the concurrence of the Secretary of the Air Force, the Chief of Staff, and the Commander of AFSC, told Bellis that he had complete authority on the program. He was to be able to run the program, in accordance with the development plan, without interference from anyone else. He was also relieved of much of the oversight by creating a streamlined chain of command. Bellis bypassed the commander of ASD and his staff, the AFSC staff, and reported directly to the AFSC commander. The next step in the chain was the Chief of Staff and Secretary of the Air Force. Bellis stated that he made efforts to communicate with concerned parties, but he did not feel compelled to do so, and most importantly he did not need their approval for program decisions.[73]

In order to consolidate so much authority in one person, that person must be competent, and the leaders above him must have confidence in him. In the case of Bellis, he had previously been program director for the SR-71 program, which due to a number of reasons, including its revolutionary capabilities, was seen as a very successful program. Because the SR-71 program was classified and compartmentalized, it too received little oversight, and some credit for the success of the program can be attributed to the ability of very few people to make changes. Bellis was able to use his authority as FX program director to limit the constant attempts by people and organizations to make program changes. However, it was the credibility that he had, both with those whose changes he refused as well as with the leaders that supported his decisions, that allowed his approach to be successful. A competent and respected program director played a significant role in the success of the FX program.[74]

Source Selection

With the memory of the problems of the TFX source selection still fresh, the Air Force took exceptional care to avoid any perception of mismanagement during the FX source selection process. A source selection evaluation group evaluated the proposals in the categories of technology, logistics, operations, and management. They used a well defined grading scale, and submitted their results, which did not include a recommendation to the source selection advisory council, comprised of representatives from ASD and the using commands. The council members used a predetermined and agreed upon weighting scale to assign each proposal a score. Again, without selecting a winner they forwarded their scores through the Air Staff to Secretary Seamans, who was the Source Selection Authority.[75]

Despite the careful nature of the process, there was concern among members of the House Armed Services Committee that the source selection could be improperly influenced by the Secretary of Defense. So set on making sure the process was above question, Seamans agreed to provide a sealed copy of his signed decision to one of Representative Mendel Rivers' staff members to put in his safe until after the public announcement was made. In this way they could verify that it had not been changed by the Secretary of Defense for political reasons. Obviously there were lingering doubts about the TFX selection.[76]

After some cost cutting efforts and resubmission of cost proposals, the source selection was carried out as planned. On 23 December 1969 Secretary Seamans announced that McDonnell-Douglas had won the contract. The political questioning did not end with the announcement, however, and Seamans and others had to defend their actions in Congressional hearings. A GAO investigation was conducted as well, but neither found any wrongdoing, and in fact most people considered the process exceptionally fair and professional.[77]

Milestones

The F-15, as the McDonnell Douglas FX design was called, had some technical problems with its new engines, but much fewer than some critics predicted. Developing a new airplane and a new engine simultaneously has inherent risks, and these were made worse by collaboration with the Navy that was left over from the McNamara tenure. The services were directed to use a common engine core, which led to delays as requirements were agreed upon. While some cost increases resulted, the engine was ready for the scheduled first flight, and residual problems were later resolved.[78]

The rollout occurred on 26 June 1972, followed by the first flight on 27 July. Initial operational capability was achieved in early 1976, just six months later than programmed almost eight years earlier in the DCP. The F-15 is still in service today.[79]

Public Opinion

The FX program did not command near the amount of media attention that the TFX did, which is partially attributable to the fact that at the time the FX was going through the conceptual phase, media stories about the F-111 received most of the attention. When the FX did get attention it was generally positive. The aircraft did have its detractors, but most of the stories refer to it and the program in glowing terms. "Remarkably trouble free" and "far better than… expected" are typical of media descriptions.[80]

It was not difficult for the F-15 program to outshine other programs that preceded it. All contractual milestones were satisfactorily met on or ahead of schedule, most of the test aircraft were delivered ahead of schedule, the flight test program proceeded at a faster pace than any previous modern jet fighter, manufacturing proved more economical than predicted, and the aircraft met or exceeded performance targets. While cost is difficult to track (based on what is included in a reported cost and what year dollars are used) the cost was close to that specified in the DCP ($8.4 million in FY66 dollars). During its service life no F-15 has ever been shot down in air-to-air combat, while it has destroyed 104 enemy aircraft.* It is difficult to find any sources that describe the F-15 as unsuccessful.[81]

Alternatives to the FX

Like the TFX, the FX program was born out of the idea that TAC was seeking a new fighter aircraft, in large part because of the realization by many that the F-111 was

* This kill ratio includes all F-15 variants and all nationalities.

not going meet all their needs, as well as the ever-present need to modernize their equipment. Most in TAC and many in the Air Force accepted this assumption and ensuing efforts to procure the FX were based on it. The only non-aircraft solution mentioned was in a section of the CFP which addressed alternatives to developing an air-to-air combat capability. It offered surface-to-air missiles (SAMs) as a competing idea, but quickly dismissed them as being too localized.[82] The idea could also be dismissed on cost grounds based on a study the Army had done which investigated the possibility of attaining air superiority through the use of SAMs but found it too expensive.[83] There is no further evidence that any consideration was given to a solution other than a fighter aircraft.

Another alternative that must be addressed is that of not buying anything. During the early beginnings of the FX program the F-111 had barely had its first flight, and there were still those who believed it could fulfill the air superiority mission. Many of these were in the Air Force, with the bulk of them being in the OSD. Much of the analysis conducted within the Air Force during the first couple of years was not considered to be of great practical value because it was done to define an airplane for which many saw no need. While there was agreement in principle to a follow-on FX fighter at the time of the A-7 decision, when it came to committing resources, the term “follow-on” assumed a much more futuristic connotation. Even Air Force Secretary Zuckert was unwilling to begin pushing for a new fighter until the need was justified. In fact the idea was not pushed outside the Air Force until after he was replaced. People in the Systems Analysis office, the DDR&E, and McNamara were also among those opposed to undertaking development of a new air superiority fighter until the F-111 had been used in the role.

Those pushing for the FX saw it as a replacement for the F-4, while those who advocated waiting saw the FX as a replacement of the F-111 in the more distant future.[84]

Along with defining the characteristics of a new fighter, there was a broader set of alternatives as to how to provide them. Given that it would be a tactical fighter, the alternatives were reduced to the modification of an existing fighter, or a new purpose-built fighter. A study considering possible modifications was undertaken and determined that none would satisfy the requirement. As presented above, the need for an air superiority aircraft was finally established. Using that as the criteria the Air Force addressed and dismissed the A-7, the F-111, the F-4, and the YF-12. The A-7 was dismissed on the grounds that it was designed only for air-to-ground, as the trade-off studies between it and the F-5 had shown. While the F-111 could function in the air superiority role when the emphasis was placed on bombardment of air assets or as a missile platform, it was shown to be inadequate based on Boyd's new EM theory, which addressed the close-in air combat that was then being emphasized. The F-4, which was being used in the air-to-air role in Vietnam was deemed to be old technology since its development had taken place years before the Air Force procured it from the Navy. This early development had produced a design incapable of being improved enough to fulfill the role as it was now being defined, even if it received new wings, engines, and avionics.[85] The YF-12 was designed as a high speed interceptor based on a CIA spy plane. It had almost no maneuverability due to its high speeds and large supporting structure. Also, because of its extensive use of exotic materials, such as titanium, in order to achieve a Mach 3+ top speed, it was extremely expensive which eventually led to its cancellation.*

The alternatives for developing a new air superiority fighter included using a Navy aircraft or an Air Force fighter. The idea of the Air Force use of another Navy aircraft has already been discussed. It is fair to conclude that it was given no consideration within the Air Force, and a concerted effort was made to convince those in the OSD to abandon the idea. The option was addressed and the analytical basis for its dismissal, which is summarized in the DCP, was based on a divergence of mission emphasis of the Navy from that of the Air Force, as well as cost.[86]

With the assumption that the FX would be a new Air Force tactical fighter, there were numerous alternatives as to what that fighter would be. The process of making that determination based on the alternatives, and the emergence of the resulting aircraft are addressed as the primary focus of this research.

Predetermined FX Decisions and Origins

As with the TFX case, the FX case exhibits some defining decisions that were influenced by inputs not accounted for in the documented requirements process. It is impossible to know what all of those were, but ten major decisions have been identified for analysis. Even though these ten are not exhaustive, they provide sufficient opportunity to learn about the decision making process.

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* The design was modified slightly to be a reconnaissance platform, which was fielded in limited numbers as the SR-71 spy plane.

Emphasis on the Air Superiority Mission

As shown in the last chapter, the bombing mission was central not only to the Air Force, but to the entire national defense posture, and had been adopted by TAC. Therefore it was a drastic departure from previous ideas to design an aircraft that emphasized what was considered a peripheral mission only a few years prior. While there were many influences on this decision, no individual influence can be singled out as the reason. All of them worked together to cause the mission emphasis to evolve, resulting in an aircraft that would meet the demands of the new mission emphasis.

An important catalyst for the change in emphasis was the shift in national defense policy from a reliance on nuclear weapons to one that would rely heavily on conventional weapons. President Kennedy stated that he intended to have "a wider choice than humiliation or all-out nuclear action."[87] One of the most important changes this brought about was the availability of funding. Since Kennedy already had the nuclear option, money was made available to provide him with the conventional option. The administration saw fighters as an important part of a conventional warfare capability, so it was willing to provide funds for their development since they had long been neglected. Increased funding led to a situation where TAC felt like it did not have to accept what was offered, but that it could be more selective in what it procured.[88]

The change in national strategy to one of flexible response provided the opportunity to pursue a mission that many in the Air Force already believed to be valid. This included many of those who had fought a limited war in Korea, especially in fighters, and then had seen the lack of flexibility unfold during the strategic build up of the 1950s.[89] Obviously more than just a shift in policy was needed to cause the change in emphasis to the air superiority mission. In fact long after Kennedy took office there were still people who thought Kennedy's desired flexibility could be attained through the use of tactical nuclear weapons. Still others rejected the premise outright that the threat, or use if necessary, of nuclear weapons yielded insufficient options.[90]

Whether those in the Air Force agreed with the flexible response strategy or not, it soon became clear that they would be implementing it. Actually participating in the resulting combat operations in Vietnam, a limited conventional war, demonstrated the implications of the flexible response strategy, and caused many to evaluate where mission emphasis should be placed when procuring new systems. Those evaluations, whether based on rigorous analysis or simply "gut feel," led many to conclude that a change in mission emphasis was in order. They believed the nation entered Vietnam with a general lack of preparedness for the war due to inadequate investment in fighter aircraft. During the 1950s and early 1960s the money that had been invested went toward fighters that supported the strategic mission. As a result America entered the war with bombers and interceptor, but no real air superiority fighters. This was made evident by the difficulties experienced defeating MiG-21s and even the older MiG-17s. The previously mentioned air-to-air combat results provided proof that the air superiority mission had been neglected and needed to be addressed.[91]

Related to the lessons being learned in Vietnam was a belief held by some that the F-111, the new fighter then under development, was not going to improve the situation. Although the F-111 was conceived to fulfill the air superiority mission, it was going to do so with an emphasis on the bombing mission. It assumed that air superiority could be won with bombs and missiles. Actual combat results showed that the battle for air superiority was actually being fought in the air, with close-in combat. That aspect of the air superiority mission had not been emphasized, and therefore the F-111 would perform just as poorly, if not more poorly, than the existing aircraft if it were to engage in air-to-air combat. This feedback from the previous development program prompted a change in emphasis as the Air Force began working on the FX.[92]

With emphasis on the bomber mission the threat aircraft would be destroyed on the ground, or at long range using missiles. This approach allowed a large fighter with an emphasis on the bombing mission, like the F-111, to be considered an air superiority fighter. With the beginning of the Vietnam War some realities of limited war, as well as lessons learned about the equipment being used, revealed some shortfalls in this approach.

In the Korean War aircraft were not allowed to bomb north of the Yalu River, which created sanctuaries for the enemy, and guaranteed bases of operation. Air superiority was achieved, but that happened through air-to-air combat using the F-86. This suggested that in limited wars it may not always be possible to gain air superiority by bombing, especially using nuclear weapons. However, the Korean War was seen as an anomaly; something that would not be repeated, and therefore the lessons could be ignored. There was a widespread attitude that dogfighting was a thing of the past. From Vietnam, which had even more political restrictions than Korea, people in the Air Force began to accept that bombing could not be relied upon to destroy enemy aircraft, and that air-to-air engagements were still a part of modern war.[93]

As combat experience began to accumulate it also became apparent that air-to-air missiles could not be relied upon to destroy enemy aircraft before they got close. Early missiles proved unreliable and difficult to employ, which resulted in dismal hit probabilities.* Furthermore, fighter aircraft designed with an emphasis toward the bomber mission relied on firing the missiles while the enemy was still far away. In Vietnam the inability to determine if an airplane detected with radar was an enemy or not made necessary the requirement to visually identify a target before firing.** This requirement removed the effectiveness of a long range missile and led to close-in combat.[95]

One reason that is often given for the FX's emphasis on air superiority is that it was a reaction to the Soviet threat. While the projected threat was a factor in defining the requirements, it had not changed significantly since the TFX program. Fighter aircraft had always been designed to meet the projected threat. What had changed was the approach the Air Force chose to employ when addressing the threat. The threat was also an important factor for gaining support for the FX program.

The early results of the Vietnam War, coupled with the ability to project those results onto a European war scenario, began to convince people of the value of an air superiority fighter. Despite the bombing and missile capabilities provided by bomber oriented fighters, air superiority would ultimately have to be won in the air. Analysis, especially that done by General Kent's team using TAC Avenger simulations and EM theory, showed that with current equipment the Air Force would not be able to successfully compete with current Soviet fighters in Europe, much less future threat

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* Even by the end of the war the AIM-7 Sparrow radar missile had only been successful ten percent of the time. The shorter range AIM-9 Sidewinder heat seeking missile was about the same. The older AIM-4 Falcon was never successful and was quickly withdrawn from service in favor of the newer AIM-7.[94]

** The challenge to "identify friend or foe" (IFF) beyond visual range (BVR) has been the focus of much technology development research, and the problem still has not been adequately solved.

aircraft. This was especially true given the change in strategy that emphasized conventional warfare. In the European theater plans went from a conventional force that would have to survive no more than 30 days, acting as a tripwire for the introduction of nuclear retaliation, to one that could last at least 90 days, and conventional forces were expected to defeat enemy forces.[96]

Threat aircraft that drove the change to emphasis on air superiority included the MiG-17 and MiG-21, which were being used in Vietnam, and were known to be in every other potential theater. Even though they were not cutting edge technology, their small size and maneuverability made them difficult to defeat. The future threat aircraft which the FX would encounter, as identified in the DCP, included the Mig-25 Foxbat, the SU-7 Fitter, the SU-9 Fishpot, the SU-15 Flagon, the YAK-28 Firebar, and the TU-28 Fiddler. Also considered was the MiG-23, which was in development to replace the MiG-21. Interestingly, while the maneuverability and small size of the current threat seemed to be the characteristics that made them effective, the future threats followed a trend that imitated American aircraft. All of the future aircraft were large fast missile platforms. Some were designed to be multi-mission, such as the SU-7 which had a variable geometry wing. The MiG-23, though an air superiority fighter, also had a variable geometry wing, and weighed twice as much as the MiG-21 it replaced. The SU-15 imitated the F-106, and even had an automated intercept system associated with it, comparable to the SAGE system. The TU-28 ended up being the world's largest production fighter ever built.[97]

Evaluation of the threat led some within the Air Force to move toward the air superiority mission, and it was also used extensively to convince others, within the Air

Force and outside, of the need for an air superiority fighter. Despite the fact that the perceived need was in large part a reaction to the small size and maneuverability of current threat aircraft, the threat that captured the most attention was the new MiG-25, which was a very large, very fast (Mach 3+) fighter with limited maneuverability. Reaction to, and even fear of, this plane was a factor in gaining support for the FX program, especially from Congress.[98]

Another event that refocused emphasis on the air superiority mission was the "Six Day War." On 5 June 1967, in response to an Egyptian build up of troops, Israel launched a preemptive airstrike against Egyptian air assets. Employing a mixture of French-built fighters, the Israeli Air Force achieved complete surprise, destroying 309 of the total 340 Egyptian aircraft on the ground. This set the tone for a brief war in which Israel maintained complete control of the air, allowing them to support their advancing ground forces, while interdicting enemy reinforcements. The few aircraft that did manage to get airborne were destroyed. By the end, 416 Arab aircraft had been destroyed, the Egyptian and Jordanian air forces were virtually destroyed, and only about one third of the Syrian Air Force remained.[99]

Air superiority not only allowed the Israelis to attack at will from the air, but it provided a very permissive environment for their ground troops to advance. The significance of this war was not lost on the U.S. Air Force, who sent a team to Israel after the war to gather information. Besides the official reports, the war was widely cited as evidence of the importance of air superiority in future wars.[100]

All of the reasons given so far for emphasizing the air superiority mission were used by advocates to promote it. The efforts of those advocates, such as Agan and Myers had some effect on the thinking of people. This was especially true as other events, such as the Vietnam War, the apparent inadequacies of the F-111, and the appearance of new threat aircraft gave advocates more credibility. As the climate began to change, and advocating a change of emphasis was not seen as heresy, as it was at the turn of the decade, more of those people who had leanings toward air superiority felt inclined to lend support.[101] Concerted efforts were made to recruit advocates that would command respect, attention, and credibility. The Thyng "Aces" Study was an effort to do that. General Titus believes he was recruited onto Rhodarmer's briefing team because he had scored three aerial victories in Vietnam. Rogers, who was recruited onto Kent's analysis team, and who was an ace, was told by Ferguson to let Kent do the analysis, and he (Rogers) should do the advocacy.[102] Aces such as Blesse and those in leadership positions, such as Hollaway began to advocate more openly through articles. Boyd, who had always been a strong advocate of air superiority, received attention and was influential thanks to his EM theory, as well as his reputation as one of the best fighter pilots in the Air Force.[*] This advocacy was a critical factor in changing views about mission emphasis.[104]

Another reason the air superiority mission was emphasized is that many saw that as the most effective means of acquiring a new fighter. Even though more money was

[*] John Boyd's reputation as one of the best fighter pilots is well-known, dating back to his assignment on the faculty of the Fighter Weapons School at Nellis Air Force Base, NV during the 1950s. The reputation is based on stories of Boyd betting everyone he flew against that he could defeat them (meaning achieve a simulated kill by having his aircraft in firing position behind his adversary within the correct parameters for long enough to take a shot) within 40 seconds. The story continues that Boyd never lost, thus acquiring the nickname "40 Second Boyd". Though Boyd's biographer, Robert Coram, claims to have interviewed people who experienced simulated combat with Boyd, and vouch for the story, much of its dissemination comes from Boyd's telling of the story himself. The story has been perpetuated by his close associates and repeated by those who have heard it. General Wilbur Creech, who was on the faculty with Boyd disputed the story, and called it a fabrication. Others who have served (and flown) with him later also doubt the veracity of the story. Whether the story is true, it is accepted that Boyd had credibility based on the story, which is the important factor in advocating his beliefs about air superiority.[103]

available for fighters than had previously been available, there was always competition for funding. By choosing to emphasize the air superiority mission, an opportunity was created to acquire another airplane. This would translate into more budget share, more influence, more relevance, and more control over air assets. It would also mean the ability to modernize. The Air Force would have a more difficult time justifying a new aircraft other than a superiority aircraft because it was already procuring two new aircraft that fulfilled the other missions of ground attack and interdiction (in the A-7 and F-111). As shown, the A-7 was procured with this purpose; to help justify a new acquisition. By establishing the need for the air superiority mission, the Air Force was establishing the need to acquire a new fighter.

The decision to emphasize the air superiority was not unanimous, however. While momentum was building for the air superiority mission, there were those who held, or at least advocated a different view. The dissenting view was that a multi-mission aircraft could adequately perform the air superiority role, along with its other roles. This was the view that had produced the F-111, which was still under development at this time. In the face of all the influences presented, there were very few who did not believe there was a need for a greater air superiority capability. Some of those were people who were invested in the F-111, either career-wise or ideologically. Even if they saw a need for a greater air superiority capability, they worried that it would jeopardize acquisition of the F-111. This faction was not very strong inside the Air Force, but had more support in the OSD, especially since the F-111 was the embodiment of the commonality ideology.[105]

Close-in Air-to-Air Combat versus Missile Platform

Consensus was growing for an emphasis on the air superiority mission, but air superiority still meant different things to different people. Studies, past experience, current events, technology and other factors could all be used to back whichever position one was inclined to take. For example, some people still felt that air superiority was gained primarily on the ground based on World War II experience and Israeli experience, and that the bombing restrictions in Vietnam would not exist in a war such as Europe. Others conceded that air superiority would have to be won in the air, at least to some extent, but they foresaw technology solving the problems of unreliable missiles and the identification of friend or foe (IFF) beyond visual range (BVR), which would suggest that a large fast missile platform would be ideal. Still others felt like the fight would always evolve into a close-in dogfight, and therefore a small, simple, inexpensive, maneuverable, day, visual, fighter was sufficient. One group could point to the threat of the MiG-25, while another could point to the MiG-21.

Because of the conflicting messages taken from the same data, the decision of how much close-in combat capability, versus missile platform capability, to design into the airplane was a social process dictated by the winning of converts to one point of view or another. The norm, leading up to the FX program, had become the view that an air superiority aircraft was a missile platform, and many accepted the emphasis on air superiority with this type of aircraft in mind. This was reinforced by the way fighter performance was compared, which was point analysis. Since American aircraft could outrun, out accelerate, and out climb any threat aircraft, many believed they were also superior at close-in combat. The reason the FX did not follow the previously accepted view can be attributed to the fact that many of those who advocated the strongest for the air superiority mission believed that it implied close-in combat, and that a different design was required to achieve that. In the end the FX was a compromise of the two approaches: a maneuverable dogfighter with a very capable radar for combat with missiles.

Among the outspoken air superiority advocates that also advocated a close-in combat capability were Agan, Burns, Boyd, and Myers. Agan, citing his experience escorting bombers in World War II, asserted that the even if bombing can contribute to air superiority, the fighters have to gain enough local air superiority to allow the bombers to reach their targets. He also believed strongly that some percentage of airplanes would not be stopped by missiles (a technology he had little faith in), which would necessitate close-in combat, most likely with a gun.[106]

Burns was influenced by Agan, and in fact was chosen by Agan to participate in the Thyng study, which Agan commissioned. Burns acknowledges that his ideas for the initial FX requirements were inspired by that study. As an up-and-coming fighter pilot he was no doubt influenced by the opinions of the venerable aces on the panel with him. Although the QOR he wrote was not detailed or quantitative, it specifically asked for an aircraft that could defeat the threat aircraft, including the MiG-21 in a maneuvering fight.[107]

Boyd had flown fighters his whole career and was interested only in the air-to-air mission. He liked the challenge of competing against another reasoning opponent, rather than being subject to the probabilities associated with getting shot down by ground fire associated with the air-to-ground mission. While on the faculty of the Fighter Weapons

School he spent considerable time thinking about ways to improve air-to-air combat. Specifically he studied the reason the F-86 had such an impressive kill ratio against the MiG-15, which was superior in every category of the prevailing comparison criteria. It was faster, it could fly higher, and it could even turn tighter. He came to the conclusion that the key to success was the F-86's ability to maneuver, that is change its attitude, more quickly. Boyd worked on this problem for years, between his other professional and family responsibilities, and at length, aided by an advanced engineering degree*, he concluded that maneuverability was a function of wing loading and thrust-to-weight ratio. Furthermore, instead of point analysis, he devised a way of using the design parameters of an airplane to determine the energy state throughout its envelope, thereby making it possible to compare aircraft in a way that would describe actual aerial combat capability.

This EM theory, which Boyd came up with and used to analyze current aircraft, was instrumental in convincing many people that a different mission emphasis was required to be competitive with the existing and future threat. The Thyng Study group was the first formal use of the theory, although in a rudimentary form. As Boyd improved the theory, working with Thomas Christie, who at the time was a weapons analyst at Eglin Air Force Base, FL, where Boyd was stationed, and as people became more aware of it, use of the theory snowballed until it was very well-known. Other advocates began using it, including Myers, Burns, Rhodarmer's advocacy group, and Kent's analysis group of which Boyd became a part. Working in Kent's group, the theory was used in concept design analysis to determine the maneuverability of various designs, and to compare them with EM plots of threat aircraft. This analysis was very

* The Air Force sent Boyd to the Georgia Institute of Technology where he studied thermodynamics, and earned a masters degree.

effective at explaining to people why older MiG-17s and -21s were defeating newer and "better" (using point analysis) American aircraft, and then convincing them that emphasis needed to be placed on the close-in air combat mission.[108]

Myers advocacy has been addressed. In his presentations he often used pictures that represented the rationale for the close-in air superiority mission. One was of two people in a phone both, one with a rifle and the other with a pistol. The message was of course that long range weapons are sometimes not useful. Another showed an aircraft firing a missile with the caption, "A Hit – on What?" referring to the limitations imposed on missile warfare due to IFF deficiencies. These helped explain and convince people of the importance air superiority, with an emphasis on close-in combat.[109]

Figure 4.1. Charles E. Myers, Jr. used this poster in his air superiority advocacy briefing titled "Air Superiority in Non Nuclear War"

Another factor in convincing people of the need for a close-in combat capability was the TAC Avenger simulator created by Welch. The ability to compare not only equipment and its performance, but also likely tactics and actions, allowed decision makers to experiment with parameters and gain insights on the results of various decisions. While simulation analysis is commonplace today, this early influential model was a pioneering effort that had a big impact.[110]

Another advantage to advocating the close-in combat capability for the FX was that the Navy did not have or want such a capability. During efforts to stave off another Navy fighter, the Air Force could point to the vast differences between a maneuverable close-in air superiority fighter, and a long range missile platform air superiority fighter. The Navy was developing the F-14 at the time, and EM theory and TAC Avenger simulations could be used, and were used, to prove that more close-in capability would be needed to defeat the Soviet fighters, and that the FX would give more capability.

Those who opposed the close-in capability in favor of the missile platform approach were some in OSD, as well as Kelly Johnson. OSD, of course was pushing for the Air Force to take the missile platform approach since that would align them more closely with the Navy mission, allowing a common platform. Clarence "Kelly" Johnson, was the famous aircraft designer from Lockheed, and he had enormous credibility in Washington based on his past successful designs. His most recent project was a Mach 3+ spy plane, the A-11, which he hoped to modify into a fighter (the YF-12) and sell to the Air Force. Of course such a large fast airplane would be useless in a close-in engagement, but it could intercept any existing or projected aircraft, even the MiG-25.

Johnson testified to Congress, and anyone who would listen, about the dangers of the MiG-25, and the ability of the YF-12 to combat it.[111]

High Thrust-to-Weight Ratio, Low Wing Loading

The requirements for a high thrust-to-weight ratio and a low wing loading came as a direct result of the close-in combat capability requirement. Boyd's EM theory was used to determine what values would be appropriate for the desired level of performance, and were emphasized. Low wing loading and high thrust-to-weight ratio give an aircraft greater ability to change its flight path direction, thus making it more maneuverable. EM theory was used in the Thyng Study, and while Burns did not give specific targets in the initial QOR, he asked for enough maneuverability to defeat the enemy in the air, and a "high" thrust-to-weight ratio. By the time the ROC came out three years later, after inputs from Boyd doing EM analysis in Kent's group, the thrust-to-weight was specified at "1.1 to 1." Later that month when the DCP came out more exacting numbers were given, suggesting that the FX should attempt to beat a threat aircraft with a possible thrust-to-weight ratio of 1.3 to 1, and a wing loading of 60-65 pounds per square foot. Besides being aggressive targets, it was also a new approach to define a new aircraft with such parameters. The following table is provided for comparison purposes.

Aircraft	Wing Loading (lbs/sq ft)	Thrust-to-Weight Ratio
MiG-17F	50.1	0.57
MiG-21	77.8	1.13
F-100D	103.2	0.42
F-105	136.4	0.5
F-4	78	0.86
F-111	126 (spread) 158 (swept)	0.61
FX ROC 9-68	Unspecified	1.1
F-15	73.1	1.12

Table 4.1. Wing loading and thrust-to-weight comparisons for various U.S. and Soviet fighters during the 1960s.[112]

Not a Pound for Air-to-Ground

This rhyming slogan was the battle cry for those who wanted a single-mission air superiority aircraft, and which eventually became the unified Air Force position for the FX. There is much evidence that only the purest fighter pilots, and not even all of them, actually accepted the idea of a truly single-mission aircraft. Adopting it, however, served the purpose of avoiding competition with other Air Force and Navy aircraft, thus preserving the program. It also insured that the resulting air-to-air capability would be sufficient, and unhampered by other mission requirements. Finally, those who were in favor of some air-to-ground capability believed that if the FX was designed as a capable air-to-air single-mission fighter, an air-to-ground capability could always be added later. In fact, that is what occurred, although the capability was never used until a modified version, the two-seat F-15E, was developed much later.

Despite the consensus that the FX would be an air superiority fighter, virtually everyone took that to mean that that would only be its primary mission. The question then became, how much air-to-ground capability should be included. Some favored absolutely no provisions for air-to-ground, literally not a pound. These included Boyd and Disosway, although later he relaxed his position, most likely having been influenced by Momyer, who Disosway respected, and who had served as Seventh Air Force Commander in Vietnam, and saw more value in the air-to-ground mission. Others wanted a robust radar bombing capability and even a terrain following system to be included in the avionics. The ASD engineers at Wright-Patterson fell into this category. As the tradeoff data became available, consensus began to form around a high performance air-to-air capability with limited (visual) air-to-ground capability.[113]

When the threat of a joint program with the Navy was seen as more likely, McConnell took great efforts to unify the Air Force position to strengthen the case for the Air Force program. The position he chose to solidify was the single-mission air-to-air fighter advocated by Disosway, as early as 1966 in his 12-star letter. Disosway was very energetic and persuasive, especially with his access to Kent's analysis results. Beyond this, however, Disosway and McConnell had a long and close personal relationship stretching back to when they were teammates on the West Point football team. McConnell was known to trust his judgment.[114]

McConnell's position, that which would allow a strictly Air Force program to be approved, was clearly based on expediency, at least in part. Even as he was preparing to testify to Congress that a ground attack capability would be added only over his dead body, he was mollifying those who wanted an air-to-ground capability with the message that it could be added later. This was the message Rhodarmer was using in his briefing, as well, to gain support for the single mission concept. Only four months after his testimony to Congress the ROC specified a visual air-to-ground capability.[115]

Most people didn't mind acquiescing to the single-mission position because the conceptual designs that would provide the required air-to-air capability would be able to provide a substantial air-to-ground capability as well. Many believed that the FX would be capable enough at the air superiority mission that in most wars, especially limited wars, it would soon clear the skies of enemy aircraft, and could then be employed in the air-to-ground mission. This is suggested in the DCP as well.[116]

There was also a backlash from the F-111 experience. Many people, including Secretary Seamans, favored the single-mission concept because they did not want "another F-111." They considered it an airplane that had tried to do too much, and was mediocre, but not good, at any one mission. Whether that assessment was justified or not, they advocated a superior air-to-air capability in the FX, and if any air-to-ground capability was added it should do so at no cost, or very minimal cost, to the air-to-air mission.[117]

Those who opposed the single-mission concept were primarily in the OSD, and were interested in a multi-mission aircraft to be used as a common platform with the Navy. There were those in the Air Force who favored a multi-mission emphasis because it was supported by the force structure ceiling. McNamara had imposed force levels on the services resulting in a maximum number of fighter wings the Air Force could field. If some of those were filled with single-mission aircraft, they argued, the overall level of capability would be degraded. The maximum amount of capability and flexibility could be achieved by filling all wings with aircraft that had as much capability as possible. They saw multi-mission aircraft as meeting that need. Whether or not they were convinced, they dropped these arguments when they became futile after McConnell's edict of unity.[118]

Radar

It was pointed out that the inclusion of a radar missile capability, along with close-in combat capability was a compromise between the two extremes. The compromise, which was later shown to be feasible and effective using the analysis, was included when the airplane was first conceived. When Ferguson requested the first concept studies he requested they study an all weather air-to-air fighter, which would require a radar. The Thyng Study also recommended a radar-equipped fighter, and Burns specified in the first QOR a radar comparable to that in the F-4. All of those involved in the initial conception of the FX included a radar-equipped airplane as a going-in assumption. This is understandable since warfare had been moving toward a night, all weather capability since World War II.

The question of whether to remove the radar was really the issue, and it was raised by a small, but influential group. The main proponent of a non radar equipped aircraft was Pierre Sprey, a civilian in OSD's Systems Analysis office. Based on the poor performance of air-to-air missiles and the dearth of IFF solutions, Sprey believed that aerial combat in conventional wars would be fought almost exclusively in a visual setting. If that was going to be the case, he reasoned, there was no need for a heavy and expensive radar. Absent this expensive equipment and the structure to support it, fighters could be made cheaply and in far greater numbers. Any deficiencies in performance could easily be made up for by outnumbering the enemy.[119]

The quantity versus quality argument had been around for a long time. Holley addressed this in 1953 and concluded that quality is more important. The U. S. Air Force has always favored technological solutions, beginning with General Arnold, and therefore the day, visual fighter concept did not gain very much support during the FX development. Threats such as the new MiG-25 Foxbat, for example, demanded an advanced technology response, according to accepted thinking. Boyd was one of the few in the Air Force at this time that agreed with the concept. Myers also adopted this view, but neither was very vocal about it until later, during the lightweight fighter program.[120]

Not only did the FX program include a radar, but it included a very advanced one for the time. The F-15 was the first aircraft in the inventory with a look down shoot down radar, which was deemed necessary to be fully effective in the modern combat environment with technologies like terrain following. The inclusion of the radar had a big impact on the aircraft design. Due to its advanced nature it was very large, driving the final product toward a bigger aircraft.[121]

Aircraft Weight of 40,000 Pounds

The Thyng Study recommended an air superiority fighter that could maneuver. While the study employed minimal use of the brand new EM theory, most of the recommendations were based on the experience and intuition of the members of the panel. One of their recommendations was a reversal of the trend toward larger aircraft. Burns captured this recommendation in the QOR by specifying an airplane that was 30,000-35,000 pounds, or less than half the size of the F-111.

The tradeoff for weight was capability and cost. In past aircraft it was a general rule that the more weight, the more capability, but the higher the cost. This was true when capability was synonymous with speed and payload. A bigger aircraft could carry more payload and more advanced avionics. It also allowed for more structure which could allow for greater speeds. This accounts for the attitude that bigger was better. With the shift in emphasis to the air superiority mission, however, extra weight not only added more cost, but also cut down on maneuverability. It would, however, allow for more advanced avionics and more payload. This complex relationship was modeled by

Kent's group using Boyd's EM theory and Welch's TAC Avenger simulation, resulting in the matrix of concept options previously mentioned.

With this data it became a matter of judgment to decide which criteria to use to decide which tradeoff provided the most attractive compromise. As previously recounted, advocates for close-in combat were very convincing in their assertion that the solution should favor maneuverability. There is evidence, however, that cost was also used to bound the choices.

While the various concepts were being debated, McConnell came to the conclusion that the aircraft would not weigh more than 40,000 pounds, and he was able to make the decree stick. His decision took into account the analysis that told what capability a 40,000 pound aircraft would have, but it was also influenced by many other factors making it appear to some to be completely arbitrary.[122]

It is impossible to know who all McConnell talked to before making the decision, but they did include Disosway. He also had inputs from Kent's analysis team. In the end he decided that an all weather air-to-air capability with a visual air-to-ground capability would be acceptable. Since that was achievable, according to the tradeoff studies, without exceeding 40,000 pounds, and since that size would not incur excessive cost, he set the limit there. He worried that if the weight and cost grew it would put the program in jeopardy, and he worried that even a little over the limit would open the floodgates, and cause weight and cost growth as had happened with the F-111. For this reason he was very strict on the limit. From that point on there were tradeoff debates, but they were bounded by the imposed weight limit.[123]

Medium cost

All aircraft have cost limits, but cost estimation analysis is notoriously inaccurate, both because of limitations in the ability to project into the future, but also because of the manipulation that can be done to a program based on the cost imposed. In the case of the FX, analysis was done to provide costs on the various concept options, but given the questionable nature of the costing methods, experience and reputation played as much of a role as actual analysis.

Near the end of 1968, after the weight of the aircraft was set, the analysts in Kent's group and those in ASD at Wright-Patterson were getting cost estimates that disagreed, with those computed by ASD being significantly lower.* Because the Air Staff had to send someone to testify in front of the Armed Services Committee in order to obtain program approval there needed to be consensus on the cost projections they reported. Kent sent Welch to meet with Kelly Johnson, since he had a good track record with his past programs. Welch describes the meeting:

> I … sat down with Kelly Johnson, and he just took a [5x7] piece of paper. He said, "Okay, this is the thrust-to-weight you're looking for, you don't have an engine with that thrust-to-weight." … He said, "Those engines will cost you a million and a half dollars each." It had already been decided it would be a twin engine airplane, thus: three million dollars for engines. He looked at the avionics and said, "That's going to cost you a million and a half dollars each, and the airframe is going to cost you two and a half million dollars." He said, "The airplane will cost you seven million dollars."[124]

That was the cost data they used for the program proposal, and at the hearings it was accepted by the committee with no questions. The following year, as the program progressed the cost threatened to rise, and Deputy Secretary of Defense David Packard

* ASD computed a flyaway cost of $3.2 million, while Kent's group estimated a cost closer to $5 million.

threatened to cancel the program if it exceeded $7 million. He directed Project Focus, a scrub down of requirements to bring the cost back below $7 million, and once that was done the program proceeded and a development contract was awarded.[125]

Lower Top Speed than Predecessors

As with the weight, the top speed was lower than that of preceding fighters, thus reversing the trend. The idea of trading off speed for maneuverability was suggested in the early Ferguson Study, and put in the QOR by Burns. The decision was primarily based on cost because any requirement above Mach 2.5 would require the extensive use of exotic and costly materials. Referencing the above statement that the Air Force has a bias toward advanced technology, it was not a trivial decision to accept an aircraft that would be less capable than the state of the art, and even less capable than the preceding aircraft, at least in terms of top speed. The debate did not end with the written requirements, and in fact that probably marked its beginning. McConnell's imposition of a weight limit and Packard's imposition of a cost limit precluded a high Mach fighter, but before those limits could be imposed, the idea of lower speed had to be justified, and that justification had to be accepted.[126]

One thing that helped sell the idea of a slower aircraft was the application of experience to the issue. Myers was especially articulate on this matter, and spoke with much credibility. Having been a test pilot in the Mach 2 F-106, and having conducted tests to isolate high speed vibration, he had logged more flying time at or above Mach 2 than anyone he met. His extensive Mach 2 experience amounted to approximately twelve minutes total. It required so much fuel to accelerate to that speed that it was completely inefficient to fly there. Added to that, Myers had researched jet combat and determined that virtually all past air-to-air combat had occurred below 15,000 feet and at subsonic speeds. To develop an air superiority fighter with too much speed capability, he concluded, was not cost effective.[127]

Another factor was the introduction of EM theory. Under the old method of comparison, point comparison analysis, a faster aircraft was considered to be better. Using EM comparison charts, decision makers could clearly see that using these new criteria top speed increased turn radius and hurt maneuverability. The extra weight and high fineness ratio associated with high speed flight also decrease performance as measured using EM. In essence, EM theory provided quantitative data to prove what Myers was asserting. The development of EM theory was a key factor in gaining acceptance of a slower aircraft.[128]

There were many people who were not in agreement with this decision and tried to convince others to support a different design. Most of them had had it ingrained in them their entire careers that "speed is life," and it was one of the definitive measures of performance. Kelly Johnson, who has already been mentioned, held this attitude. Another was Colonel William Whisner who was Chief of Fighter Requirements at TAC in the early 1960s. Myers told of trying to convince Whisner, who was a quadruple ace, having shot down 15.5 enemy aircraft in World War II and 5.5 more in Korea. He had been flying in Germany when they introduced jet fighters which were much faster than any of the propeller-driven fighters in use, and he vowed never to allow pilots to be equipped with aircraft that could be outperformed by the enemy. To him that meant speed and altitude. Based on the emerging threat, he was convinced the next fighter had to have the capability to fly at Mach 3. It was very challenging for an advocate of lower speed in favor of maneuverability to fight against people like Johnson and Whisner. As Myers posed it, “Who can enlighten Whisner? Who WILL enlighten Whisner?” Whisner is representative of those who pushed for a high speed aircraft.[129]

Two Engines

Burns was the creator of the initial QOR for the FX, which contains the requirement for a twin engine aircraft. This is consistent with Ferguson’s concept as well. When the QOR was being written, burns told Titus, who was on his staff and who was tasked with helping to do the actual writing, that it would be a twin engine aircraft. When Titus asked why Burns replied, “The twin-engine airplane has always been superior to the single engine airplane.” Boyd also stated that the QOR requirement was Burns’ personal preference. Rogers, who was on Kent’s analysis team, acknowledges a bias for twin engine aircraft. Although he didn’t share the bias (he claims to have been biased toward single engine aircraft), he said he was probably the only one who only wanted one engine.[130]

The arguments of safety and cost arose during the debate of one versus two engines, but as was pointed out in the previous chapter, the analysis is inconclusive, and except for thrust requirements the decision can be left up to judgment. In this case, thrust requirements were dictated by the mission, which was also being debated. Had Sprey been able to convince enough people to support the day visual fighter, the thrust requirements almost certainly would have been met with one engine. Conversely, if Whisner had won the debate, his Mach 3 concept would have required two. Since the all weather air superiority mission lent itself to a mid-weight design it is likely the aircraft could have been designed either way. Given that the documented requirements called for two engines, most of the contractor studies concentrated on twin engine aircraft. Other than the day visual fighter proponents, the choice of two engines seemed to be one of the lesser debated decisions.

Single Seat

A single seat aircraft is another decision that was made very early on by Ferguson for his studies, and again by Burns in the QOR. The prevalent attitudes of those involved in the FX program were biased toward single seat aircraft at that time. That this was the case is supported by a survey conducted throughout TAC. Fighter pilots Air Force wide were asked, for various missions, if they would prefer a single seat aircraft or a two-seat aircraft. The response rate was very high and the consensus for the night all weather air superiority mission was for single seat by a margin of approximately 85% to 15%. If the mission was visual air-to-air combat the margin increased to 96% in favor of single seat.[131][*] Besides the obvious bias for single seat, there were practical reasons as well. Having only one pilot removed that weight, as well as that of the required structure. Also, visibility, which is important for close-in aerial combat is much better with a single seat cockpit. Both of these arguments came up in discussions.[132]

The desirability of a single seat aircraft was not disputed, but the ability to develop adequate avionics was questionable. A technological solution had to be devised that could reduce the workload to the point that one pilot could accomplish the all

[*] Myers, who at this time, around 1966, was working as a consultant for TAC, helped administer the survey and analyze the results. He said the written comments indicated that pilots who said a second crewmember might be useful preferred that the additional crewmember "keep his mouth shut".

weather mission while maintaining control of the aircraft. The solution arrived at was a computer that processed radar data and projected the information onto a heads-up display in the pilot's field of view.[133]

Summary of Predetermined FX Requirements and Origins

Following is a summary of major decisions that defined the FX program, along with information about their origins.

"Predetermined" FX Requirements and Origins

Decision	Who	Why
Emphasis on air superiority mission	Agan, Myers, Burns, Ferguson, Boyd, fighter pilots who had acquiesced to bomber mission, people convinced by advocates, Vietnam, etc.	Change in national strategy, poor initial results in Vietnam, MiG-17 and MiG-21 plus follow-on aircraft posed threat existing aircraft could not handle, Arab-Israeli War showed importance of air superiority, mission emphasis changed due to advocacy efforts, provided best acquisition opportunity
Close-in air-to-air combat vs. missile platform	Myers, Thyng study, Burns, Boyd, Disosway, some Korean war fighter pilots, people who saw lessons in Vietnam	Personal experience from WWII and Korea, bombing aircraft on ground not possible due to sanctuaries, nuclear weapons unusable in limited war, poor air-to-air missile performance, inadequate IFF, different from Navy acquisition
High thrust-to-weight ratio, low wing loading	Advocates of close-in aerial combat, Boyd	Enabled close-in aerial combat, EM showed them to be new measures of fighter performance for close-in aerial combat
Single-mission air superiority fighter	Disosway, Boyd, later McConnell, and unified Air Force	Ensured superior air-to-air performance, protected Air Force from Navy aircraft, created niche unfilled by A-7 or F-111, a good air-to-air capability will yield a good air-to-ground capability with minimal intrusion, air-to-ground capability could be added later
Radar	General consensus, except Sprey and some in OSD	Allowed all weather night air-to-air capability which was deemed a necessity in modern war, provided missile capability for future, provided missile option vs MiG-25 Foxbat
Aircraft weight of 40,000 pounds	Advocates of all weather air-to-air with minimal air-to-ground intrusion settled on this, McConnell set it as limit	Determined to be an affordable size, allowed a compromise of capability and cost
Medium cost	Determined by Kent's analysis group (with Kelly Johnson's help), limit imposed by Packard	Determined to be a feasible program cost based on informed calculations (based on successful experience), would allow program to avoid cancellation
Lower top speed than predecessors	Ferguson, Burns, Myers, Boyd	Saved on cost due to less use of exotic materials, superior air-to-air still possible based on new EM criteria, allowed for greater maneuverability
Two engines	General consensus, except Sprey and some in OSD, and Rogers	Bias for two engines in Air Force, allowed thrust for all weather radar mission (although a single engine design could have sufficed)
Single seat	General consensus	Bias for single seat fighters, decreased weight, increased visibility for air-to-air combat

Table 4.2. Summary of predetermined FX requirements and their origins.

Preliminary Conclusions from the FX Case

During the concept definition phase of the FX program a TAC Avenger simulation was conducted pitting the conceptual aircraft against an adversary flying a MiG-21. The results, an astounding 955 to 1 kill ratio, provoked ridicule for the audacious claims. One retelling of the event claims that General Ferguson's response was, "If I believed that story… we'd only need three F-15s: one in Europe, one in the Pacific, and one in the U.S. to train in."[134] Whether this legend is true or not, the F-15's actual performance in combat has been no less astounding. The two differences are that the aircraft has not yet met enough adversaries to have killed 955, and that the F-15 combat losses are zero, not one. Pictures of Iraqi fighters buried in the sand evoke the conclusion that potential enemies would rather hide than have to face the F-15. Given the importance of combat performance in judging the success of a system, the F-15 is seen by many as the most successful fighter ever produced. Beyond combat performance, the FX program was successful by programmatic standards as well. Its schedule remained virtually intact, the cost estimates were not overly optimistic, and its performance exceeded expectations.

The F-15 represented a significant departure from previous fighters that were developed when the emphasis was placed on the nuclear bombardment mission. While its success can be attributed to many factors, one of the primary reasons was that when it was used in combat, the mission that it was required to fulfill aligned very well with that emphasized during its conception. The high speed interceptor capability, emphasized during the 1950s, was never required. The residual interceptor capability which the F-15 possesses, as a result of its close-in dogfighter and all weather missile design, turned out to be enough to defeat any threat it encountered. Even though the emphasis placed on air-to-air combat as a single mission could almost be considered an overcorrection to the multi-mission capability envisioned for the F-111, the F-15 succeeded because the single mission it was designed for coincided with the mission needed when it was eventually employed in combat.

If the mission that the F-15 was required to perform had turned out to be different, it may not have performed so well, tarnishing its successful reputation. For example, if the air-to-air threat became dominated by very fast aircraft such as the MiG-25, the F-15 may not have been considered nearly as successful. Or, if terrorist-dominated insurgency warfare had become the norm before the F-15 was tried in combat, instead of the conventional battles fought in Iraq, the Balkans, and Afghanistan, it may not have fared significantly better than the F-111 in its perceived level of success. The alignment of the mission emphasized during FX conception, and that which it eventually fulfilled in combat was a primary contributor to the success of the resulting F-15 aircraft.

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129. Meyer Interview, 2008; Rhodarmer Interview, 36.

130. Titus Interview, 2008; Boyd Interview, 1973, 29; Rogers Interview, 1974, 5.

131. Myers Interview, 2008.

132. Neufeld, 14.

133. Bellis Interview, 154-155; Blesse Interview, 99; Disosway Interview, 296; Fitzsimons, et al., 100-105; Flax Interview, 1973, 32-33; Rogers Interview, 1974, 10-11.

134. Stevenson, 3-4.

Chapter 5
Case Study: The LWF

The Lightweight Fighter (LWF) program began as a technology demonstration prototype with no aspirations of becoming a production aircraft. The need for a less expensive companion fighter for the F-15, as well as the potential to provide an affordable fighter to allies led to the development of a "missionized" version of the prototype. The airplane that began almost as an afterthought of the mainstream Air Force became extremely successful. The small maneuverable multi-role fighter was designed with an emphasis on the close-in air-to-air combat mission, but has primarily been used in the air-to-ground role.

Background Leading Up to the LWF Program

As the FX concept was coming into focus, and it became clear what the airplane would look like, some of those who were pushing for a smaller, simpler, and less costly fighter began work on the next fighter in hopes that it would solve the problems they perceived. Unlike the FX, which had a long concept definition period during which the Air Force built a consensus regarding what the aircraft would be, the LWF configuration was decided mainly by those outside of the Air Force leadership, whose primary role was deciding whether or not to procure it. Neither TAC, nor the Air Force had a formal requirement for the new weapon system during its conception, and no formal requirements documents were produced prior to its development. As technology became available, a very capable lightweight fighter became a possibility, and during this period the occurrence of certain events presented the Air Force with the decision of whether or not to procure a new aircraft.

Force Structure and Cost Considerations

As new technology became available during the 1950s and 1960s aircraft became increasingly more capable, allowing for more combat effectiveness from each individual airplane. The capability, however, also came with increased cost, which limited the number of new airplanes the Air Force could afford. This tradeoff between quantity and quality presented an array of procurement options, compelling the Air Force and the Department of Defense to make a decision on the future make-up of the force; a choice that could not be based on analysis alone.

A major factor in force structure decisions was the perceived need to react to the Soviet buildup of weapons. As the 1970s began the Soviet Union began modernizing their military forces resulting in a buildup of both nuclear and conventional forces. It was an accepted reality that the Soviet Union and Warsaw Pact forces outnumbered U.S. and NATO forces, but this buildup came at a time during which U.S. forces were decreasing. The Vietnam War was coming to a close resulting in a reduction in conventional forces. F-111 procurement had been cut, and the F-15, which was an advanced technology, high performance fighter, was expensive enough to preclude the procurement of large quantities. This divergence of numbers made the imbalance more acute, or at least gave that impression. Figure 5.1. shows the balance of tactical aircraft during the 1970s. This situation during the early part of the decade was influential during the LWF program.

Tactical Aircraft

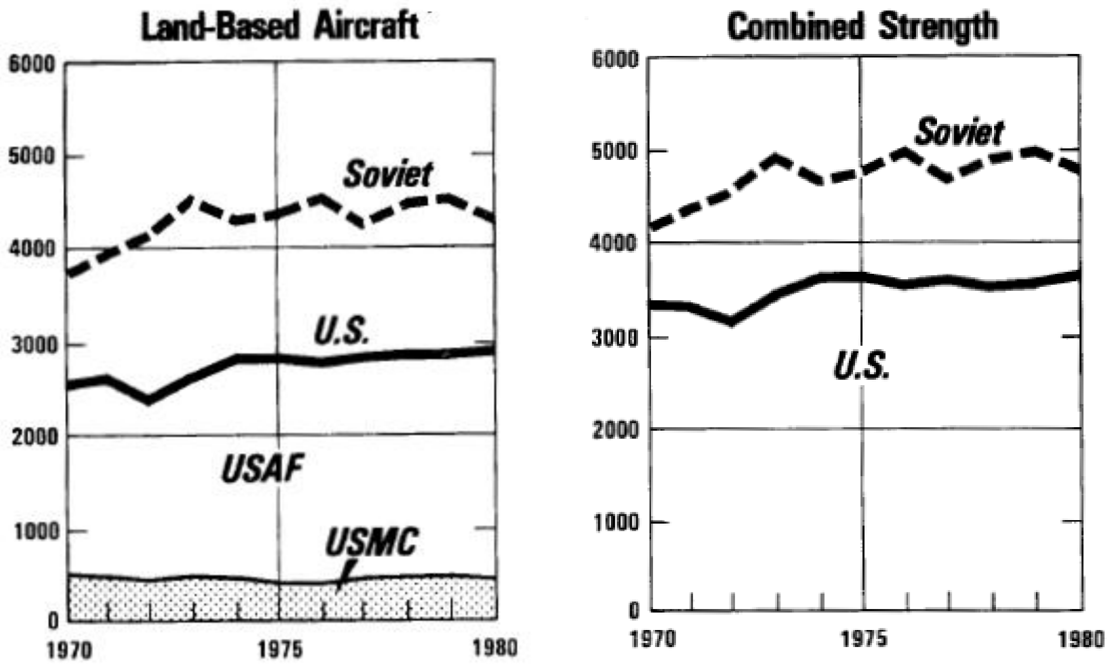

Figure 5.1. The U.S. – Soviet military balance of tactical (fighter, attack, and fighter-bomber) aircraft during the 1970s. U.S. numbers include Air Force Reserve, Air National Guard, and Marine Corps Reserve aircraft.[1]

Another important factor in force structure decisions was the increasing costs of fighter weapon systems. As technology increased in aircraft, the cost of procurement increased significantly. During the early 1970s this rising cost became a concern for many people, not only within the Air Force, but throughout the government. Articles began to appear expressing concern over the trend. Norman R. Augustine, who served as Assistant DDR&E leading up to this time later quipped,

> In the year 2054, the entire defense budget will purchase just one aircraft. This aircraft will have to be shared by the Air Force and Navy 3 ½ day each per week except for leap year, when it will be made available to the Marines for the extra day.[2]

In a 1973 article Stark suggested that a way to measure cost over time, while leveling the effects of different aircraft, is to track the cost per pound of an aircraft. This, he added, needed to be done in constant year dollars. In his article, published while the F-15 was in testing, Stark called attention to what he considered the alarming trend in the cost of advanced technology aircraft.[3]

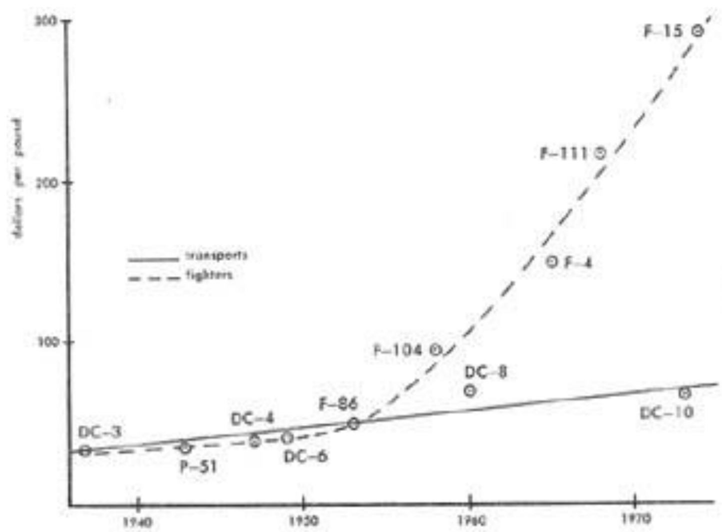

Figure 5.2. The rising cost per pound (in 1973 dollars) of fighter aircraft, compared with transports.

The rising cost of aircraft also made it difficult to fill the allotted force structure. The Air Force had a set number of wings authorized, many of which at the time were equipped with F-4 aircraft. Originally the plan was to procure more F-111s, but that number had been decreased. To replace all of the F-4s with much more expensive F-15s was a daunting task, which most people considered impossible given the economic situation. Even though the new aircraft were more technologically advanced, and therefore more capable, there was an inherent need for numbers of aircraft. No matter how capable an aircraft is, there is only a certain amount of geography it can effectively operate in, and that requires the dispersion of some minimum quantity of aircraft to provide air support for the entire theater of operations. Furthermore, the Air Force was reluctant to decrease its force structure, which they equated to budget share and relevance.[4]

As consensus solidified around a 40,000 pound, advanced technology FX fighter, those who favored a simpler less costly solution began to unite their efforts toward improving the next fighter, according to their ideas. At that time there was no follow-on fighter being discussed, so their work included generating interest for one. Three people became especially outspoken in support of a lightweight fighter, and they became known as the "Fighter Mafia." Boyd, Sprey, and Riccioni, each for different but related reasons, staked their reputations and careers on this pursuit.

As mentioned, Boyd was a career fighter pilot who was passionate about improving the profession. His early work focused on tactics and employment of existing aircraft, but even early on, in the mid 1950s he began thinking of how to improve the aircraft. After developing his EM theory, which gave him a way to measure and compare fighter performance, his next goal was to apply that knowledge to actual design. He was able to do some of that with the FX program, but it wasn't until he began thinking about a follow-on lightweight fighter that he refined the use of EM theory to improve fighter design. Despite the accolades for the F-15, Boyd was never happy with the final product. His motivation to work on a lightweight fighter was his career-long pursuit of the optimum dogfighting aircraft.[5]

Sprey had similar views on what a fighter should look like. He was advocating a light simple fighter which he called the FX^2, and which was a 25,000 pound, single engine, visual fighter with no radar, that would be much more maneuverable than the F-15, at less than half the cost. His motivation was cost effectiveness. He believed the advanced technology features of the FX, such as the sophisticated radar, complex avionics, and long range air-to-air missiles, would not be useful in combat, and therefore served only to make the airplane less maneuverable and more expensive. His design, he believed, would be far more capable than the FX and far cheaper, thus saving money for other programs.[6]

Sprey was able to convince Alain Enthoven that the concept had enough validity that it should be studied in more depth. In the fall of 1968 he was allowed to conduct a study, and accordingly put Northrop and General Dynamics on contract to validate his ideas by analyzing possible designs. At the conclusion of the FX^2 Study both contractors verified that such an airplane could provide more capability than the F-4, with half the weight.[7]

Riccioni was concerned about intelligence reports that showed superior numbers of Warsaw Pact fighters in the European theater. As early as the mid 1950s when he was stationed in Europe he worried about this imbalance. In 1968, for his Air War College thesis, Riccioni established that U.S. forces were badly outnumbered, and then provided a notional design of a "Modern Air Superiority Aircraft," or MASA, as he called it, that could remedy the situation. The MASA was to be a small, maneuverable, single seat fighter with good visibility. It would sacrifice top speed for maneuverability, and would have a radar sufficient to allow it to employ radar guided air-to-air missiles. It would be designed strictly for air-to-air, with any air-to-ground capability being derived from the existing design. This paper summarizes Riccioni's views when he arrived at the

Pentagon in 1969, although he admits that he was influenced by Boyd and Sprey after he arrived.[8]

An important concept that emerged during the debate over quantity versus quality in the building up of force structure was the "high-low mix." During the TFX program as the Air Force, Army, and Navy were trying to reach an agreement on what the requirements should be, the Army was able to make the case that the F-111 would be too expensive to procure enough of the airplanes to effectively fulfill the CAS mission. Even if there were enough TFX aircraft dedicated to CAS, because of their expense and extra capability there would be reluctance to use them in the high threat CAS environment. A study was conducted to determine if a lower cost, lower technology aircraft could be introduced into the inventory as a CAS aircraft. In late 1964 the "Force Options for Tactical Air Study" (the Bohn Study) concluded that mixing lower cost aircraft in the inventory with the more expensive F-111s would be a cost effective solution. As previously recounted, the F-5 was recommended, but the A-7 was ultimately chosen.

The procurement of the A-7 did not end the discussion of a high-low mix, and in fact it contributed to its continuation. Once it had been accepted as a viable option, and given the rising costs of the F-111 as its development continued through the latter part of the 1960s, those who wanted a simpler FX contended that it could provide the low side of an expanded high-low mix. When the FX turned out to be an expensive advanced technology aircraft, the opportunity again existed for a follow-on aircraft to be a lower cost, lower technology airplane that could complement the F-15 and effectively build up the force structure.

Acquisition Reform

When David Packard became the Deputy Secretary of Defense, beginning in 1969, he was faced with numerous residual problems in the F-111 and C-5 programs. In order to prevent such programmatic problems form reoccurring he implemented some changes to the acquisition process. In his view, the Total Package Procurement (TPP) approach used by McNamara, removed options by making long term decisions based only on paper designs and analysis. Later, if problems were encountered when the actual hardware was being built, contractors had to submit time consuming and costly engineering change proposals and get approval before making the change. In Packard's view, this could be avoided by testing the feasibility of technologies and designs through prototyping. Prototyping also encouraged creativity. Under the TPP approach, if a better solution was discovered, the cost and time penalties associated with submitting an engineering change proposal and gaining approval to incorporate the innovation often discouraged contractors from pursuing the improvement, thus stifling creativity.[9]

One way Packard chose to remedy this problem, as well as to increase the level of technology, which he saw as becoming stagnant, was to push for programs to prototype new technologies. As he testified to the Senate Arms Services Committee, "We want to find out… if things work – not just if they look good on paper."[10] Packard procured funds from Congress, as well as encouraging the services to begin identifying technologies that could be developed through prototype programs.

Packard also hoped to reduce the cost and duration of acquisition programs by streamlining the administrative requirements. This so-called "war on paperwork" was especially to be applied to prototyping programs.[11] The encouraging technology development environment established by Packard, and the relaxing of bureaucratic restrictions played a role in the period leading up to, and during, the LWF program.

Allied Air Force Modernization and Foreign Military Sales

At the end of World War II the economies of America's European allies were weak, and during this period of rebuilding they relied heavily on U.S. military aid to counter the Soviet threat. Many other nations throughout the world also offered the ability, if provided weapons, to help maintain political stability in the postwar environment. Therefore, it was in the interest of the United States, both from a security standpoint as well as economically, to provide weapons to these friendly nations. This aid came first through the Military Assistance Program, in which the U.S. provided the nations with equipment and training. Later, as the economies of nations improved, American weapons were sold to them through the Foreign Military Sales (FMS) program. Often those purchasing U.S. weapons had less exacting military requirements than those of a superpower. Also, many could only afford less expensive, and therefore less capable weapons. As the equipment of these foreign nations became outdated, and as allied economies grew, those countries became interested in purchasing, and even participating in the production of, more advanced and modern weapons through the FMS program.

As the Vietnam War was coming to a close President Nixon issued what came to be known as the Nixon Doctrine. In his words, "We will continue to provide elements of military strength and economic resources appropriate to our size and our interests. … The U.S. will participate, where our interests dictate, but as <u>a</u> weight -- not <u>the</u> weight -- in the scale."[12] In his speech to the nation introducing his Vietnamization plan he explained that "…we shall furnish military and economic assistance when requested in accordance with our treaty commitments. But we shall look to the nation directly threatened to assume the primary responsibility of providing the manpower for its defense."[13] This policy led to the development of aircraft that could be exported to allies, most of which could not afford the expensive advanced technology aircraft favored by the U.S. Air Force. An upgraded version of the F-5, the F-5E, was developed for this purpose, but many countries were reluctant to buy an aircraft that the U.S. chose not to have in its own inventory. Furthermore, decision makers in foreign countries were reassured that future logistics support would continue to be available if the aircraft they purchased was in the U.S. inventory.[14]

Unlike the lesser developed countries for whom the F-5E was targeted, NATO countries in Europe needed to modernize their F-104 aircraft. The F-104, which flew briefly with the U.S. Air Force, was adopted by many of the European nations beginning in the early 1960s. The Air Force and Lockheed arranged for an improved all weather version of the aircraft to be produced in Europe, under Lockheed licensing, as the frontline fighter bomber of all NATO countries except Britain and France. In the early 1970s some NATO countries began efforts to identify a replacement for their aging F-104s.

Brought together by geographical proximity and similar military requirements, NATO responsibilities, technical abilities, and weapons procurement processes, Belgium, Denmark, the Netherlands, and Norway united in an effort to identify a common aircraft to replace the F-104s and some even older F-100s in their inventories. None of the countries had the industrial capacity to design or manufacture a suitable replacement aircraft, so they were compelled to consider foreign options, although they were interested in participation in the program at some level. Based on a 1973 study conducted by the NATO Conference Armaments Directors, which recommended that those replacing their F-104s adopt a common fighter, the four countries formed a European Consortium to select candidate aircraft for evaluation. By this time, the LWF technology demonstration program was underway in the U.S. and the Consortium narrowed their list of candidates to the Dassault Mirage F-1E, the Northrop YF-17, the General Dynamics YF-16 (both of which were entries in the U.S. LWF program), and the Saab Viggen.[15]

Setting the Stage for the LWF Program

The LWF program was very different from any other aircraft procurement program because when it was conceived procurement was not its purpose. It was funded as a way to demonstrate the feasibility of integrating new technologies into an aircraft. The Air Force was developing the F-15 at the time, and most people were very enthusiastic about it. Almost no one in the Air Force besides the Fighter Mafia was interested in procuring another aircraft that would be in competition for funding with the F-15. Because of this the Air Force made it very clear as the LWF program was being considered, that it was not a procurement program, but simply a technology demonstration program.

Genesis of the Concept

The idea of a lightweight fighter had been around for a long time. In 1952, over a decade before the Bohn Study, and as large jet fighters began to be the norm, the Requirements Directorate on the Air Staff proposed a program for a lightweight day fighter that would be operational at the end of the decade. The proposal recognized that in the 1957-1959 time period the Air Force would be replacing its first line fighter, the F-100, with newer and more sophisticated aircraft, but that the cost of those aircraft would prevent their being procured in numbers sufficient to fill the requirements for day fighters in a worldwide conflict. Furthermore, even if enough could be procured, it would be wasteful because that level of capability would not be necessary in all fighters, since many of the enemy fighters at that time would be older, less capable aircraft. While not using the term, this plan proposed a high-low mix of fighters to address the future threat in the most cost effective manner. Furthermore, the plan suggested that the aircraft was a possible candidate for supply to allies as part of the Military Assistance Program.[16]

The LWF program, which came about nearly two decades later, would end up producing almost the exact results as those proposed by the 1952 plan, even though it was not conceived and started with that in mind. Another similarity was the way in which TAC initially responded to the two programs. In 1952 the lightweight fighter program was submitted to TAC for comments, a prerequisite for establishing a formal requirement. TAC's Official History recounts, "While there was some variation on reactions, they were generally rather critical of the proposed program."[17] The general consensus was summed up by the comments of the Director of Doctrine. The TAC History reports:

> The Director of Doctrine considered the entire program unrealistic and premised on faulty assumptions. This director contended that the U.S. must try to produce aircraft possessing the absolute maximum performance that is available with current "know how." In order to realize this, industry must be pushed to produce the best plane possible. … Doctrine contended that any day fighter designed must be built to defeat the best aircraft that could be pitted against it.[18]

TAC's response praised the idea of saving money by decreasing size and complexity in a future fighter, but it was not optimistic that it could be done without decreasing capability, to which they were very adverse. In one response to the proposal, addressed to the commander of ARDC, TAC Commander, General John K. Cannon, quoted a statement made by General Hoyt S. Vandenberg, the Chief of Staff at that time:

> But let us not delude ourselves that fleets of cheap "hot rod" airplanes will bring the economy we all desire. The right solution, we are convinced, lies not in masses of relatively cheap and simple aircraft, but rather in the careful choice of one aircraft most effective for the jobs that must be done.[19]

These ideas are important because they mirror the reaction to the same decision, with which the Air Force would again be faced in the mid 1970s. Not only was the idea of large quantities of less expensive, less capable aircraft a longstanding one, the strong opposition to that idea was equally longstanding. Nevertheless, when the realities of the rising cost of fighters that was predicted was actually felt, during the TFX program, the idea was resurrected in the Bohn Study.

The opposition to a lower performance aircraft, as the Bohn study recommended, was tempered by three factors. First, the resulting low performance aircraft was mainly to fulfill the CAS mission, a mission the Air Force cared little about.[20] Second, the acceptance of the lower performance aircraft was seen as a necessary evil to gain approval for the FX program, and was therefore palatable. Third, the recommended low performance aircraft was the F-5, which was still a reasonably capable air superiority fighter. When the low performance aircraft ended up being the A-7, a Navy bomber with no air-to-air capability, there was almost unanimous opposition, except for the senior leaders who actually made the decision.[21]

When Sprey and those aligned with him began proposing the lightweight fighter concept during the FX deliberations there were two results. The first was that the Air Force summarily rejected his ideas, with the exception of those like Boyd and Riccioni. Rhodarmer, who was tasked by McConnell to build consensus on the 40,000 pound all weather air-to-air version of the FX stated, “Pierre Sprey was the opponent.”[22] Despite reaction within most of the Air Force, Sprey’s ideas did gain traction in OSD. Sprey’s arguments were very well substantiated with analysis, and he was very convincing, which put considerable pressure on the Air Force to consider a lightweight FX, although Sprey admits they never did seriously.[23]

Sprey began pushing for a lightweight fighter based on the recommendations of the Thyng Study. The fighter aces that participated in the Thyng Study wanted a “high performance fighter,” but Sprey had a lack of confidence in, and near contempt for, the Air Force’s ability to rationally define high performance. Sprey described his thoughts on the state of the Air Force concept definition capability.

> Now, mind you, these people, and it's true today [1973] in TAC headquarters, are none too technically competent and they couldn’t even really define what high performance meant. Lots of them thought high performance was high speed which, of course, we now know is nonsense. Some of them were interested in maneuverability. Others were just interested in acceleration. They really had no concept to put these things

> together. … At that point [around 1966], Vietnam was dominated by F-105 pilots. There were a few F-100 pilots, but mostly F-105 pilots. Of course, F-105 pilots knew nothing at all about air-to-air because their airplane is incapable of fighting air-to-air, and they were being shot down by Mig-17's.[24]

Sprey's opinion that the Air Force could not be trusted to adequately define its own high performance fighter fueled his efforts to push for the lightweight fighter, which he viewed as the best solution.

The decision to procure a larger, more expensive FX, as opposed to a lightweight design, was accompanied by a realization by those who pushed for it that they would not be able to buy enough of them to fill the allotted force structure. Air Force leaders wanted the F-15, which they saw as the solution to their fighter needs, but also wanted to maintain their force structure, which they also saw as vital for national security, as well as for keeping the Air Force competitive with the other services for budget share and relevance. This dilemma allowed the idea of a high-low mix to resurface.

Initial Lightweight Fighter Study

When Riccioni arrived at the Pentagon in September 1969 he was assigned to the Air Force Requirements office, which was same office as Boyd, who had been transferred there from Kent's Air Force Studies and Analysis office. Through Boyd, Riccioni soon met Sprey and Myers, and became aware of their views, which corresponded closely to his, as put forth in his Air War College Thesis. As shown, Riccioni was already concerned by the unfavorable imbalance of force strength, and upon his arrival he further learned about the Air Force's dilemma of the inability to fill their allotted force structure with expensive FX aircraft. As he thought about this, he saw an opportunity to introduce a lightweight fighter into the inventory.

Sprey, Meyers, and those who agreed with them would have liked to see the FX program cancelled in favor of a lightweight fighter, and since FX development was barely getting underway, Sprey and his ideas were not popular in the Air Force.[25] Riccioni realized that approach would not get very far, so he attacked the problem from a different direction. He found out that groups within the Navy who, like the Fighter Mafia, had ideas outside of the mainstream, were considering the possibility of a lightweight fighter. Given the fierce competition between the services for funding, and given that if the Navy developed a lightweight fighter before the Air Force there was a good chance the Air Force would be pressured to adopt it, this approach succeeded in gaining the attention of some of the leadership.

In March 1970 Riccioni presented a memo to Lieutenant General Otto J. Glasser, who was the Deputy Chief of Staff for Research and Development, which detailed Navy lightweight fighter efforts, and made the case that if the F-14 were to be cancelled, a Navy lightweight fighter could surface and pose a serious threat to the F-15 program. He also implied that it could jeopardize FMS efforts by threatening the F-5E program. After considering this and conferring with Riccioni's immediate boss, Major General Donovan F. Smith, the Director of Operational Requirements and Development Plans, Glasser gave approval to quietly conduct official studies of the concept.[26][*]

[*] According to Riccioni, when he completed the memo Smith was out of town. Believing that the information was time critical, he bypassed Smith and took the memo directly to Glasser. The attached memo from Smith to Glasser (dated a month later) suggests that Glasser sent it back to Smith for action. Smith added a memo to Glasser stating that "there is some substance" to Riccioni's memo and asked if Glasser thought some official studies on the subject should be conducted quietly. Glasser replied in the affirmative with a handwritten note on the memo.

Riccioni was able to procure a small amount of funding (roughly $250,000) for a study. Even though he had approval for the study, knowing the strong resistance to the idea, he named it "Study to Validate the Integration of Advanced Energy-Maneuverability Theory with Trade-off Analysis," which avoided any mention of a lightweight fighter that might be in competition with the F-15. The study put General Dynamics and Northrop under contract for 6 weeks. Those contractors were selected by Boyd and Sprey who had worked with them during the FX^2 Study.[27]

The Riccioni Study was actually an effort to develop usable conceptual designs for very small maneuverable lightweight fighters. Riccioni planned to use existing engines, and asked each contractor to produce three designs. One was a twin engine aircraft using two 13,000 pound thrust class GE15 engines (a small turbojet that developed into the YJ101 and eventually the F404 engine used on the F-18), the second was a single engine aircraft based on the same engine, and the third was a single engine aircraft based on the 23,000 pound thrust class F100 engine, which was being developed for the F-15.[28] With Boyd's and Sprey's help, Riccioni wrote a set of requirements for the study statement of work. The requirements did not include the typical point performance specifications, such as top speed, ceiling, and so on. Instead, they gave a required maneuver profile. Thrust to weight was controlled by dictating the engine to be used along with a maximum weight. The requirements were designed to give the contractors substantial leeway to be creative:

- Weight: No more than 20,000 pounds, 17,000 pounds desired
- Payload: 20 millimeter cannon with 500 rounds of ammunition (no missiles)
- Avionics: Only those needed for a day visual fighter (no radar)
- Speed: No requirement for maneuvering above Mach 1.6

> - Profile: Fly a distance (radius) of 250 nautical miles and complete the following six maneuvers at 30,000 feet altitude: accelerate from Mach .9 to Mach 1.5, make three complete turns at Mach .8, and make two complete turns at Mach 1.2 (then be able to fly back).[29]

While the requirements may seem like the work of one person, or a small group of people, in quick response to the study opportunity, in actuality they were well thought out and studied. They were an adaptation of Boyd's and Sprey's work with EM theory, over the course of at least two years, to improve the lightweight fighter concept. Boyd initiated the work as one of the options for the FX, and Sprey had adapted that work to his FX^2 design. Besides the contractual work GD and Northrop had performed, Sprey, and especially Boyd, had met several times with Harry Hillaker, the chief engineer on the project from GD, who had become friends with Boyd before he was stationed at the Pentagon, and who was interested in pushing the limits of performance in a small fighter. Similar meeting took place with John Paterno from Northrop. Both companies were investing their own money in hopes of winning a future development contract. Interestingly, this work culminated in a very sparse set of requirements instead of a more specific list of detailed requirements.[30]

GD and Northrop both used more than six weeks, but since Riccioni, Boyd, and Sprey were the only ones monitoring the small scale study, and the contractors were really answerable only to Riccioni, who was working with them, that was satisfactory. Neither contractor was able to produce a workable design around the single small turbojet engine, which disappointed Riccioni. Northrop delivered a concept for a single engine aircraft based on the F100 engine, but they did not consider it a capable aircraft. They favored, and emphasized, their twin engine design based on their existing P530 design, which they had developed earlier as a possible export fighter. GD produced two designs as well, but they favored their original single engine design using the F100 engine, which they later developed into the YF-16.[31]

Technology

Technology was an important part of the LWF development, since much of the high performance of the small fighters could be attributed to such new technologies as high thrust-to-weight engines. After all, the prototype program that would eventually produce hardware was a technology demonstration program. Hillaker attributes the design of the YF-16 to a technology integration effort.

Much of Hillaker's work in the mid 1960s was to identify new technologies that could improve aircraft design. To evaluate them he needed an aircraft to which he could apply the new technologies, and the plane that eventually became the YF-16 was what he used. He admits that, although he liked small aircraft he was heavily influenced by Boyd, who he had met in 1962. Through the work previously discussed, the design was refined until it was in the form recognizable as a prototype.[32]

Some of the new technologies that had become available, and that were used on the two designs were the blended wing-body and use of aerodynamic strakes to increase lift and control, fly-by-wire controls, improved computer control (in conjunction with fly-by-wire) which allowed for relaxed static stability which added to maneuverability, computer controlled continuous fore and aft wing flaps which constantly self adjusted to provide constant optimized lift conditions, and a 30 degree tilt in the pilot's seat to allow for greater G tolerance. Numerous other innovations were also included in each design, but were less of a factor in the revolutionary aircraft performance that would result.

Some other important technologies that were developed around the time of the LWF program, or soon after, also played an important part in the way the aircraft would eventually be employed, and the perception of its success. One of these is the E-3 AWACS (Airborne Warning and Control System) aircraft. This system's airborne radar compensated for the lack of a long range search radar on fighters by providing radar information to them. Another is the development of improved weaponry. Precision guided munitions allowed for greater accuracy which provided increased combat effectiveness even with a small bomb load. The development of smaller and more effective radar guided air-to-air missiles, such as the AMRAAM, as well as very effective heat seeking missiles, such as the AIM-9L drastically improved the air-to-air capability of an otherwise simple fighter. Finally, the miniaturization of digital electronics allowed a substantial increase in avionics capability without the weight and cost penalties previously associated with such improvements.

Unsolicited Proposals

In early January 1971 Kelly Johnson approached the Secretary of the Air Force with an unsolicited proposal to build two prototype fighters. Lockheed had been conferring with the Dutch Air Force in the effort to replace the Dutch F-104s and the Dutch had offered to allow Lockheed to use some engines to develop a prototype of their proposal. Johnson, who had been involved with various specialized development programs in the past with minimal paperwork, was accustomed to working with the Air

Force on a very informal basis. He also had a very commanding personality and a strong reputation, and he fully expected the Air Force to provide the $30 million he was asking for. Secretary Seamans, who had an impressive reputation of his own resulting from his work on the Apollo program, informed Johnson that any proposal would have to be in writing. Johnson returned with a four page proposal, and submitted it to Packard as well.[33]

When other contractors learned that the Air Force was considering Lockheed's unsolicited proposal, they submitted their own proposals. In the first six months of 1971 proposals were submitted by Boeing, Northrop who submitted two different proposals, and LTV, besides the Lockheed proposal. The DDR&E, who at this time was John S. Foster, Jr., expressed interest to Packard, who advocated his prototyping plan as a means for considering the proposals.[34]

Prototype Program

In 1971 Packard began to implement his goal to prototype promising technologies. Accordingly, in May of that year he directed the Air Force to formulate a prototype development program and plan to begin some programs in FY1972. Air Force Secretary Seamans requested proposals from the Air Force for possible prototype programs and suggested a fighter program as a likely candidate. In response, the Air Force set up a USAF Protoype Study Group in June and formulated a strategy. Prototype programs would last 24-36 months, would be for the demonstration of design concepts related to some future military application, and would be for the sole purpose of technical feasibility without consideration for production. Furthermore, the programs would have minimal administrative requirements, and managerial constraints.[35]

220 different programs were proposed, and of those six programs, including the Lightweight Fighter Program, were forwarded to Packard for approval. The first one to be approved was the LWF. Packard was able to procure funding from Congress with the stipulation that the LWF was strictly a technology demonstrator and nothing more. On 25 Aug 1971 Secretary of Defense Melvin Laird directed the Air Force to fund the development of two competitive lightweight fighters. In keeping with the goal to give contractors the freedom to explore technological possibilities, no ROC document was prepared. Some program goals were provided in a Program Memorandum, prepared by the Prototype Study Group, and approved by Foster, the DDR&E. These goals were very similar to Riccioni's instructions for his study.

> - Weight: 20,000 pounds maximum (internal fuel, ammunition, and two AIM-9 missiles)
> - Capable of unequaled performance as a day visual fighter
> - Speed: Designed to conduct operations in the Mach .8 to Mach 1.6 range
> - Profile (with internal fuel): 500 nautical mile radius with four complete turns at Mach .9, three complete turns at Mach 1.2, and level acceleration from Mach .9 to Mach 1.6 at 30,000 feet.[36]

In January 1972 the LWF RFP was sent to nine contractors.* Five of those submitted proposals by the 18 February deadline. The following table is a summary of the proposals.

* The nine contractors who received the RFP were: LTV, Grumman, Boeing, Lockheed, Fairchild, Northrop, General Dynamics, McDonnell Douglas, and Rockwell International. Of those, Grumman was developing the F-14, Fairchild the A-10, McDonnell Douglas the F-15, and Rockwell International the B-1, and therefore did not submit proposals.

Contractor	Prototype Designation	Weight (pounds)	Engine	Features
Boeing	908	16,940	F100	2x20 mm guns, sidestick controller, fly-by-wire, 45 degree swept wings
General Dynamics	401	16,902	F100	Blended body, sidestick controller, fly-by-wire, forebody strakes, auto maneuvering flaps, blended wing body
LTV	V-1100	15,546	F100	forebody strakes, extendable canards, high positioned wing, maneuvering slats
Lockheed	CL-1600	19,544	F100	semi-automatic maneuvering flaps, high positioned 26 degree swept wings
Northrop	P-600	18,800	YJ101	2x20 mm guns, twin tails, automatic maneuvering flaps

Table 5.1. LWF Proposals Received [37]

From those two were selected. On 1 April 1972 the announcement was made that General Dynamics and Northrop would be put on contract to produce two prototypes each of a lightweight fighter in accordance with the program goals. The GD version was designated the YF-16 and the Northrop version, the YF-17. Each company signed a $45 million contract with the Air Force on 13 April 1972, and official development began.[38]

With the approval to put the two companies on contract, Laird also requested that the Air Force prepare a Development Concept Paper, in case consideration was later given to developing the aircraft further. He endorsed as a proposed cost ceiling $3 million per production aircraft, based on a buy of 300 aircraft. On 19 January 1973 the document was approved with the $3 million cost goal included. The only change to the requirements as stated in the RFP statement of work was the addition of a twenty minute loiter at the end of the mission profile. Kenneth Rush, who had replaced Packard as the Deputy Secretary of Defense, and who was acting in the position of Secretary by this time, approved the DCP, and raised the topic of a production program by warning contractors to keep costs under control in case production was pursued. He further warned that his office would not support a development program with costs above $3 million per airplane. The Air Force still maintained that it was not interested in the aircraft and the Secretary of the Air Force, who was now John L. McLucas, reminded the DDR&E (now Malcolm Currie) that the program was strictly for technology demonstration.[39]

While discussion continued, with OSD leaning toward Full Scale Development (FSD) of a version of the LWF and the Air Force maintaining that it was simply a technology demonstration program, the YF-16 completed its first official flight on 2 February 1974 and began flight testing.* The YF-17 first flew 4 months later on 9 June. Both prototypes were completed with ample time to finish testing within the allotted time.[40] The following table shows the planning estimates of the two prototypes as they began development, compared with estimates of actual values after 5 months of flight testing the YF-16 and 1 month of testing the YF-17.

* The actual first flight occurred on 20 Jan 1974 during what was to be a high speed taxi test. Due to overly sensitive feedback in the controls a pilot induced pitch oscillation developed. The pilot corrected it by fixing the pitch attitude, but this resulted in the horizontal tail contacting the runway. The pilot decided the safest course of action was to take off and move away from the ground. After an uneventful six minute flight to bring the airplane around for a landing, the pilot landed the airplane safely. The problem was easily fixed by reducing the control feedback gain when the airplane was on the ground, and having it change to the normal setting once airborne.

	Planning Estimates			After Flight Estimates	
Contractor	**YF-16**	**YF-17**		**YF-16**	**YF-17**
Level Acceleration Time Mach .9 to 1.6 at 30,000 ft (sec)	50	57		56.4	78.1
Combat Radius under LWF Mission Rules (nautical miles)	500	500		800	610
Design Mission Takeoff Gross Weight (pounds)	17,518	19,600		19,700	23,500
Thrust-to-weight Ratio	1.35	1.47		1.2	1.27
Wing Loading (lb/sq-ft)	62.5	56		70.4	67.1

Table 5.2. LWF Prototype Performance Comparison. Predevelopment planning estimate versus estimate after 5 months of test flight for the YF-16 and 1 month of test flight for the YF-17.[41]

TAC Modernization Study

As pressure was building in OSD for the Air Force to consider the potential adoption of a production version of the LWF, and with the continuing question of how the Air Force would be able to fill its force structure, on 25 March 1974 General George S. Brown, the Air Force Chief of Staff, asked for a Tactical Modernization Study Group to convene. The ad hoc group met at Wright-Patterson Air Force Base, and included representatives from the Air Staff, AFLC, AFSC, PACAF, USAFE, and TAC. Its purpose was to develop a tactical fighter force modernization strategy for the 1980s. Specifically, they were to determine what characteristics the fighters should have that would fill the force structure into the 1980s.[42]

An ulterior motive for the Study Group was to determine if there was a place for the LWF in the future force structure, and if so, what it was. Secretary McLucas was becoming convinced that given European interest, if there was a place for the LWF in the

U.S. Air Force the program could provide an economical way to procure the needed fighters. Based on that idea, in January 1974 McLucas and Brown, along with leaders from TAC and AFSC received briefings about the capabilities of the LWF and its potential to transition to an FSD program. Although the attendees expressed surprise at how capable the LWF was, the briefing was not received enthusiastically by most attendees because of implications for the F-15 program. Brown must have been interested, as evidenced by his request for the study, although he did make the comment that the interest should be based on the needs of the Air Force, and not the potential foreign military sales. The needs of the Air Force were what the Study Group was commissioned to determine.[43]

The study concluded that: "An operational derivative of the lightweight fighter should be developed and procured in sufficient numbers to modernize the tactical fighter force in the 1980s." It further concluded that the LWF would be very effective as a replacement for the F-4. Finally it formalized the high-low mix idea with the conclusion that: "Fiscal realities dictate procurement of an austere modernization aircraft with sufficient capability to retain a force mix that provides qualitative superiority to mitigate quantitative deficiencies." It went on to say that such a mix of F-15s and LWFs would be an "attractive option." The study then offered some recommendations for requirements for the missionized version of the LWF, most of which described equipment to be included, and not performance criteria for the actual aircraft:

- It should be optimized for close-in air-to-air combat with a gun and close-in IR missiles
- It does not need to be equipped with Sparrow (radar guided) missile capability
- It should be equipped with a "15-20 nautical mile coherent radar" for search/track function

- The inherent ground attack capability will be greater than the F-4 (This is a conclusion more than a requirement.)
- It will have Radar Homing and Warning (RHAW), Electronic Countermeasures (ECM), and a chaff dispenser
- It will have the following equipment: a heads up display, a data link compatible with the AWACS, capability to deliver guided munitions and nuclear weapons, and components for using anti-radiation missiles[44]

The Tactical Fighter Modernization Study Group is significant because it is the first time someone in the Air Force had officially supported adopting the LWF. As indicated, the F-15 was very well supported in the Air Force. Given the serious concern that another fighter development program could jeopardize funding for the F-15 program, support for development of the LWF was inversely proportional to that of the F-15. This study was the beginning of a reversal of this attitude.

European Consortium Influence

As the Tactical Modernization Study Group was being set up, the European Consortium of Belgium, Denmark, the Netherlands, and Norway officially organized and began considering possible fighters with which to replace their F-104s. As the Consortium expressed interest in the LWF Secretary McLucas had the Air Force formulate a development and production plan, which he submitted to Secretary James R. Schlesinger, who was now Secretary of Defense, in April 1974 At the end of that month Schlesinger announced that the lightweight fighter program had been redirected from a technology demonstration to a competitive flyoff, the winner of which would be developed as the “Air Combat Fighter” and supplement the F-15 as the “low” end of a high-low mix.[45]

In June 1974 the European Consortium sent a team of 54 representatives to America to formally investigate the YF-16 and the YF-17. Besides touring the GD and Northrop facilities, receiving briefings on the two programs, and even visiting the Flight Test Center at Edwards Air Force Base, CA, where the prototypes were flying, the representatives held its first official meetings with U.S. officials at the Pentagon. By the end of the visit U.S. officials had agreed to move source selection up from April 1975 to 1 January 1975, that the Air Force would include the aircraft in its inventory, that it would station the aircraft in Europe, that the U.S. would pay for FSD, and that it would share production with European countries. These were all concessions required by the European Consortium. The Air Force immediately began to accelerate the test program and to prepare for the source selection process.[46]

Selling the Program

The LWF program had many supporters, including the Fighter Mafia, the contractors, Packard, and Schlesinger, but none of them were Air Force leaders. The program was resisted by Air Force leaders because they believed another aircraft program would threaten funding for the F-15. Despite complying with instructions from OSD, they continued to maintain that the program was strictly a technology demonstration, and that there was no operational requirement at that time for such an aircraft. If those who wanted the program were to succeed they would have to convince the Air Force leadership that it was in their interest.

Riccioni's disclosure of Navy LWF efforts, and the associated threat of another Navy aircraft being pushed on the Air Force, convinced his superiors to fund a study. In order to move from a study to a hardware program, however, much more commitment was required. Proponents of the program would have to convince the Air Force that their needs could be meet by, or in spite of, the LWF program.

Knowing that they would have little success trying to supplant the F-15 program with the LWF, the Fighter Mafia decided to sell the program as a complement to the F-15. Riccioni prepared a presentation which he called the "Falcon Brief" and began presenting it around the Pentagon. He briefed many of the decision makers, including General J.C. Myers, Vice Chief of Staff. The briefing started out with an overview of the Soviet threat, establishing that NATO forces were outnumbered. Next he presented what he termed the "internal threat," and showed extractions from Navy work on a LWF program. Finally he presented the LWF option as a solution to both threats. Without using the term high-low mix, he basically presented the concept, emphasizing that the LWF would be a complement to the F-15, and not in competition with it. While Riccioni's briefing raised the issue and began a debate, no evidence was found that he convinced any decision makers. This was due in part to the approach taken by the Fighter Mafia, which was somewhat condescending.[47]

Kent's analysis group, which was very familiar with the work of the Fighter Mafia having had Boyd in their group, understood the dilemma the Air Force was in. Welch later described this way:

> The Air Force was really facing two real challenges that were driving people in different directions. One was the challenge of the F-14, and therefore the need to have tremendous support for the F-15, and the other one was the challenge of the affordability of the F-15 to fill all the Air Force needs, which would drive you to a high-low mix. And those two conflicting issues were very painful for the Air Force.[48]

The group did some preliminary analysis as early as 1969, while the FX program was taking shape, which showed how a high-low mix using the LWF could solve the force structure problem created by the high cost of the F-15. The presentation of their findings received mixed levels of acceptance. Some in the Pentagon, such as Deputy Chief of Staff for Research and Development Lieutenant General Marvin L. McNickle, were adamantly opposed to it. McNickle actually collected the names of those promoting the idea and told them to stop or he would cause problems for them. Others, such as Glasser, who later took McNickle's position, General Myers, and the Chief of Staff at the time, General John D. Ryan, seemed to accept the idea of the high-low mix, even if they weren't ready to commit to it openly at that time. The need to fully support the F-15 and questions about what should constitute the low part of the mix were still factors.[49]

It is difficult to know when various decision makers began to accept a certain position. It is clear from public statements that as late as the YF-16's first flight in early 1974, in which the Air Force emphasized that the LWF was solely for the purpose of technology demonstration, and that FSD was not planned, that they were not ready to slacken their support for the F-15. Several events, however, support the idea that Kent, Welch, and Riccioni had been able to convince decision makers that eventually the LWF could be integrated into the force structure. The decision to submit the LWF as a prototype program, despite the disclaimers; the Chief's request for the January 1974 briefings regarding the LWF and the implications of developing it fully; and the commissioning of the Tactical Fighter Modernization Study Group all point to the conclusion that many realized that the LWF would eventually go to FSD.

Another important factor in selling the LWF was the actual performance realized when the airplanes started flying. Sprey, Boyd, and later Riccioni, along with contractors, had done considerable analysis developing their concepts of lightweight fighters, but many were unconvinced, or at least did not appreciate the level of performance such an aircraft would have.[50] When the airplanes began to fly, and people could actually see and appreciate the capabilities they offered, that helped convince people that it could be an acceptable Air Force airplane.[51]

Another important factor in selling the LWF to the Air Force was the efforts of Schlesinger. Schlesinger had become sold on the idea as a replacement for the Europeans' F-104s, and partly for that reason he was pushing to have the aircraft in the U.S. inventory as well. Schlesinger was very aware of the problems that would arise if he tried to force the aircraft on the Air Force, and was committed to working with them to get Air Force support for the decision. When discussing the issue with General David C. Jones, who had very recently became the Air Force Chief of Staff in July 1974, Schlesinger came to realize that the Air Force was not so much opposed to the LWF as an airplane, but they were worried that it would result in a reduction of F-15s. Schlesinger made a compromise and committed to allowing the Air Force to procure all of their planned F-15s, as well as increasing the force structure by four more fighter wings if the Air Force agreed to fill those wings with the winner of the LWF fly-off. This compromise solved the Air Force problem of being able to fill its force structure without losing capability, and in such a manner as to not threaten the F-15 program.[52]

With Schlesinger's assurances Jones chose to support FSD for the LWF and integrate it into the force. He recognized, however, that he would need to convince the other leaders of the Air Force. Just as McConnell had spent considerable effort to build consensus around the single mission FX, Jones had to do the same for the high-low mix including the LWF. By this time, his task was made easier, since most people in the Air Force were willing to accept one of the LWF aircraft, having seen their capabilities and potential, as long as they would still receive the full complement of 729 F-15s, and as long as force structure would not suffer under the plan. Jones was able to present the agreement he had made with Schlesinger, and gain the necessary support.[53]

The Air Combat Fighter Development Program*

The actual Full Scale Development program of the newly renamed Air Combat Fighter, or ACF, was somewhat anticlimactic after all the events leading up to it. Work had been done by the Air Force before the decision to develop the ACF which allowed for a fast-paced start up. The overall program rivaled the F-15 in the perception of its success.

Program Origins

The beginning of the program was very rushed because there was pressure to move the program along to make it competitive when the European Consortium made their selection, however previous efforts had been accomplished to be prepared for this eventuality. As early as October 1973, when McLucas and General Brown asked for briefings about the implications of fully developing the LWF, the Prototype Program Office had come up with the beginnings of a program schedule and related cost. They

* The program name changed to "Air Combat Fighter" (ACF) once the decision was made to develop it fully.

envisioned a program start in April 1975, since they projected the prototype flight testing would be complete by then.[54]

When the decision was made that the Air Force would develop the LWF into an operational aircraft, and that it would select the winning prototype by January 1975 to align with the schedule of the European Consortium, program preparation efforts increased in tempo. The preliminary version of the schedule had to be compressed, and preparations for source selection and contract award were begun. No requirements were generated, but the description of a missionized LWF, as provided by the Tactical Fighter Modernization Study, were used as a guide for what would need to be done to the winner of the competition. The study called for all technology to be off-the-shelf except the radar. With that decided, an RFP was sent out for a coherent, medium repetition frequency, pulse doppler radar system. Six contractors submitted proposals, and of those Westinghouse and Hughes were put on contract to develop radars in a competitive strategy.[55]

On 24 December 1974 the Air Force submitted a Program Management Directive, which provided the direction and guidance for the FSD program. Instead of any detailed specifications, in the "Requirements" section it gave a general description of the need for a modernized, low cost, multi-mission, tactical fighter for the U.S. and its allies, based on either the YF-16 or the YF-17. It gave a buy of 650 aircraft as a planning number for the Air Force, with 350 more if the European Consortium chose the aircraft as well. It called for a very fast program start, with contracts being signed the following month. The PMD also stressed the low cost nature of the program, and emphasized the need to avoid cost growth.[56]

Source Selection

The source selection evaluation began in November 1974 after GD and Northrop submitted some requested information about program management and the life cycle cost of their respective programs. With completion of the flight testing in January of 1975, the board had all the necessary information, and on 13 January 1975 Secretary McLucas announced his selection of the General Dynamics F-16 as the winner of the ACF competition. A contract was signed the same day.[57]

Both of the aircraft performed very well in flight testing, and either aircraft would have been adequate as the low end fighter of the high-low mix. The YF-17 had an edge in payload capacity for the air-to-ground mission due to its larger size, while the YF-16 performed slightly better in almost every other category. Furthermore, the YF-16 projected substantial lifecycle cost savings due to lower fuel consumption with its single engine. Finally, the board determined that the development efforts required to turn the YF-17 into an operational fighter were higher risk than those of the YF-16. These factors made the YF-16 the clear winner.[58]

Requirements

It is significant that by the time a contract was signed for the Full Scale Development of the F-16 there was still no formal requirements document. The two prototype aircraft from which the basic configuration of the ACF was selected came only from the guidelines given to the contractors in the prototype program memorandum. Those guidelines were conceived with the intent that they would not limit the contractors to detailed specifications, but allowed them to explore options. In Packard's memorandum approving the prototype program he stated:

> I am not sure we have to establish a specific requirement – there will always be a need for a better aircraft, especially if less costly. … Only the price shall be firm. All specifications shall be open.[59]

Based on this direction, the weight, which in large part determines cost, was capped at 20,000 pounds, and a mission profile was given. The source of the weight limit and mission profile can be traced back to the work of Boyd and Sprey during their early work during the FX program. They were given more as targets than as set requirements. Hillaker stated that he never felt like he had any requirements, and was free to have "fun" evaluating different technologies to try to improve aircraft performance.[60]

After the decision was made to procure the ACF a Configuration Steering Group was convened to determine what changes should be made to the prototypes to transform them into an operational fighter. The group worked closely with the contractors, and inputs were made after the YF-16 had been selected as the ACF. The inputs were in the form of actual design changes to incorporate the operational equipment specified by the Tactical Fighter Modernization Study. Major changes included an expanded wing area, recommended by Boyd when he determined the wing loading would increase as a result of the added weight of the operational equipment; a ten inch fuselage extension to increase commonality with the F-16B two seat version; and a larger vertical horizontal tail, to improve the stability of the slightly larger aircraft.[61]

Programmatics

The actual F-16 program encountered even fewer problems than the F-15 program. This can be attributed to the fact that the aircraft had already been designed with a prototype having flown, and the fact that all of the required technology besides the radar was existing, or had already been proven on the prototype. Another very important factor in program success was a conscious decision that the airplane was not a full solution, and that the primary constraint was cost. If a proposed design change threatened to increase cost or cause a schedule slip it was not approved, since the aircraft was not conceived as the optimum technological solution to any specified requirements. A conscious decision was made to use technology that was available, but with the flexibility to upgrade the aircraft as new technology became available. Finally, the program enjoyed the benefits resulting from the reform efforts put in place by Packard. The requirements for documentation, reporting, and approval had been significantly streamlined. The results were that much of the decision making was retained in the program office, as it had been for the F-15, and that much less time and effort were expended on administrative work.[62]

Similar to the F-15 program, the F-16 program was described with superlatives, such as “a program to brag about.”[63] Although it experienced the minor problems of any development program, problems were fixed in a timely and efficient manner. The program received a boost in June 1975 when the European Consortium announced their selection of the F-16 as the replacement for their aging fighters. Ongoing testing demonstrated that all performance goals were achieved or exceeded. The FSD program and the testing were completed on schedule. The Defense Systems Acquisition Review

Council met on schedule in October 1977 and approved production of the aircraft. The Air Force achieved Initial Operational Capability in October 1980 with the 4th Tactical Fighter Squadron, 388th Tactical Fighter Wing, Hill AFB, Utah.[64]

The F-16 was accepted by the public as another success. Events such as the arrival of the first F-16 to Hill AFB were attended by throngs of enthusiastic citizens, and it is difficult to find any articles that do not praise the new aircraft.* The selection of the F-16 to represent the Air Force and the nation as the Thunderbirds, the Air Force official demonstration team, in 1983 further attests to the public appeal of the aircraft.[65] The flexibility designed into the F-16, which has allowed its longevity while still providing a state of the art capability, is a major contributor to its perceived success.

Alternatives to the Program

Although there was no operational requirement established prior to the development of the LWF, there were alternatives presented during the genesis of the program. While each decision was not necessarily made with the end result in mind, each one did contribute to that final outcome. At each juncture alternatives were considered and not chosen, which had they been would have resulted in a different solution.

The obvious alternative to the LWF program was to decide not to have a program. Given the fact that there was no documented operational need, the Air Force could have concentrated on the F-15 and other aircraft programs. The decision was forced with the introduction of the unsolicited lightweight fighter proposals. Instead of dismissing the

* The author was present at the gala event of the arrival of the first F-16 to Hill Air Force Base. The plane arrived, and put on a spectacular flight demonstration before landing.

proposals because of the lack of a requirement, the decision was made to develop two lightweight fighter aircraft as prototypes.

The next set of alternatives consisted of the lightweight fighter concepts proposed for the prototype program. Although the proposals had many characteristics in common, the differences were substantial enough that choosing one of the other proposals would have changed the options available later when the Air Force studied the possibility of missionizing the aircraft. That in turn would have had an impact on the result.

The Tactical Fighter Modernization Study Group had a range of alternatives for a missionized LWF, bounded of course by the limitations imposed by the two prototype aircraft. Ultimately they considered in depth four different configurations, as well as a modified F-15. The options ranged from a day visual fighter similar to the FX^2 to a sophisticated air-to-air and air-to-ground aircraft with fully autonomous capability. Based on cost, and the inherent maneuverability that already existed in the prototypes, as well as the capabilities of inventory aircraft, they chose a medium level of sophistication for both the air-to-air and air-to-ground missions. The adoption of this recommendation determined the range of options for future decisions.

When the announcement was made in July 1974 that the Air Force planned to procure 650 lightweight fighters, McDonnell Douglas provided another alternative by offering to continue production of 600 additional F-15s for $5.6 million each (flyaway cost in FY1975 dollars). While the price was not excessive and the F-15 was considered more capable than a LWF option, other factors also had to be taken into account, such as the needs of U.S. allies, and the option was not chosen.[66]

A final set of alternatives was presented at the ACF source selection, with the choice being limited to the YF-16 and the YF-17. The selection was based on information gathered during flight test, as well as program data supplied by the contractors. Previous decisions reached leading up to the source selection had resulted in simplified circumstances where the Air Force had to make a choice between only two alternative airplanes.

Predetermined LWF Decisions and Origins

In the cases of the TFX and the FX it was possible to trace the requirements of the programs in an attempt to determine the source of those requirements. The LWF case is somewhat different because there were no documented requirements to trace. It is still possible to identify some important decisions that had a defining effect on the outcome of the program. Because there was no formal requirements process involved, all of these decisions were influenced by inputs not accounted for in such a process. Eight major decisions have been identified for analysis, and can provide insight into the decision making process.

Lightweight

The reversal of the trend toward bigger and bigger fighter aircraft was a result of the change in emphasis to the close-in air-to-air combat mission. This change began in the early 1960s, and was in reaction to those factors previously discussed. The correlation between the ability to accomplish the close-in air-to-air mission, and the size of the aircraft can be traced primarily to Boyd's EM theory. Previous to the availability of EM data, “high performance” was measured by characteristics that detracted from maneuverability, such as top speed which in turn increased size. With EM theory Boyd could substantiate the assertion that smaller was better.

Greater maneuverability, and therefore smaller size, is only synonymous with better performance when that performance is defined by the close-in visual combat mission. If other tasks are included in the aircraft’s mission, such as the ability to shoot down an enemy in bad weather, capabilities such as the ability to detect, locate, and track targets is a determinant of performance. The outcome of the FX program was heavily influenced by the EM work of Boyd, which accounted for its reduction in size compared to previous aircraft. That the F-15 was designed around a large high performance radar reveals that other missions were still important to the Air Force.

Boyd, Sprey, and those with similar beliefs, such as Myers and Riccioni, thought the F-15 had missed the mark and was too big. Therefore they continued to advocate an even smaller fighter in order to solve problems they considered to be left unsolved by the F-15. For Boyd, that meant improving the close-in air-to-air combat capability even further with a smaller more maneuverable airplane. Sprey and Riccioni were not satisfied with the F-15’s large size because they felt it was too expensive, which would lead to the inability to afford a sufficient number of them within a reasonable budget to meet the threat. As believers in the need for only close-in aerial combat, they pushed for a smaller fighter to save money by eliminating what they considered the unnecessary capability of radar and missiles. The best outcome for the Fighter Mafia would have been the cancellation of the F-15 program in favor of the LWF program. The end result, a mixture of missionized (larger) F-16s with the F-15s was seen as a weak compromise by the Fighter Mafia and those who thought like they did.[67]

Another group who advocated a small fighter was made up of the contractors that submitted proposals. Many of those had been working on designs for small aircraft to market to foreign countries. If they could interest the U.S. Air Force in their designs they could generate more business. The contractors also felt that if the U.S. Air Force bought their airplane, foreign air forces would be more inclined to procure it as well. The contractors emphasized the lower cost of their small fighter designs, their enhanced ability to build force structure, their potential commonality with allies, and their applicability to limited conventional wars.[68]

OSD was one of the early groups to begin pushing for a lightweight fighter. This began with the desire to build the conventional forces in the most cost effective way, as advocated by Sprey and those who thought like him. When the opportunity arose to sell aircraft to allies, especially European allies, OSD, led by the secretaries, saw that as being very beneficial to the U.S. Not only would it strengthen the U.S. defense industry, it would also allow the U.S. and its allies to share cost, since the price per airplane decreases as the number produced increases. This would save money for the Air Force, and it would allow allies to procure weaponry of higher quality at a more affordable price. Given the shortfalls in funding goals of NATO allies during the conventional build-up during the 1970s, the availability of affordable advanced aircraft for the NATO countries was seen as a way to assure the defense of Europe against the Soviet Union. Commonality with allies was another motivation, since using the same type of equipment offered advantages, such as easier coordination and planning, and less complicated logistics requirements.[69]

Allies made it clear that they were more likely to buy an American aircraft if it was flown by the U.S. Air Force. In fact the European Consortium established as a requirement that whatever aircraft they selected would have to be part of the operational inventory of the country that developed it. For these reasons, OSD, and especially Secretary Schlesinger, pushed for the Air Force's acceptance of a lightweight fighter suitable for export.[70]

The final group who decided that a lightweight fighter should be developed was made up of Air Force officers that saw it as the low end of a high-low mix to fill up the Air Force force structure. Among those were Kent and some in his group, including Welch. Ferguson was also an early advocate for the high-low mix and favored a lightweight fighter to accomplish that. Glasser, J. P. Myers, and others, culminating with General Jones became convinced that this was a viable way to maintain and even build force structure, although most were reluctant to openly support the idea. The main reasons for rejecting a lightweight fighter, at least as an official position, was to protect the F-15 program. Most of those people saw the LWF as a compromise, and although it was acceptable as a low end fighter, they were not willing to give up the much more advanced capability of the F-15 to boost their numbers. The second reason was the belief that, given a fixed force level (number of wings), they needed to push for all the highest quality aircraft possible. Accepting a less capable aircraft without increasing quantity was unacceptable. By squelching the development of a lightweight fighter these people believed they were enhancing national security by ensuring continuation of the F-15 program, and maintaining the quality of the Air Force's limited force structure. Once they felt that the solutions to those problems were assured many of them were more willing to agree to a lightweight fighter.[71]

Emphasis on the Close-in Air-to-Air Mission

Despite the fact that the F-16 was eventually missionized as a multi-role fighter and has been employed mainly as an air-to-ground aircraft, and despite the fact that the Air Force was in the middle of producing the world's premier air-to-air fighter, the F-15, the F-16 was designed with a close-in air-to-air mission emphasis. The primary reason for this was the acceptance of a change in the criteria of high performance. As previously established, the Air Force has always pushed for the highest performance possible in its new fighters. Boyd succeeded in convincing the development community that his EM criteria, based on maneuverability, were better measures of performance than those previously used. Just as a new fighter previous to the introduction of EM theory had to be faster than its predecessor to be accepted, the measure of a new fighter's performance was its maneuverability. If it compared favorably using EM criteria, it was considered high performance and was acceptable.

While this mentality was used in the design of the F-15, the F-16 further helped to establish it. The F-15 was accepted and sold under the premise that if it was capable of the close-in air-to-air mission, a substantial air-to-ground mission capability would fall out. The F-16 was conceived by Boyd, Sprey, and Riccioni strictly as an air-to-air fighter. The airplane prototypes were designed and built based on criteria established by Riccioni, which was based on the air-to-air mission. It was later accepted by the Air

Force with other missions in mind, but there is no evidence that any mission other than the close-in air-to-air mission should be the emphasis for the design.

This is illustrated by the Tactical Fighter Modernization Study. The study gave as its primary recommendation that the missionized LWF should be procured, and should replace the F-4, which was being employed primarily in an air-to-ground role with the addition of F-15s to the inventory. Despite this, it further concluded that "the aircraft should be optimized for close-in air-to-air combat." It implied that an aircraft optimized for air-to-air would be capable of doing the other missions.[72]

Further evidence that overall mission emphasis had changed to close-in air-to-air combat for all fighters is the selection of the YF-16 over the YF-17. The YF-16 was reported as outstanding in close-in aerial combat with no deficiencies noted. The YF-17 was found to be excellent at the mission, though with some deficiencies in the higher speed ranges. Even though the YF-17 was graded better in the air-to-ground mission, it was not chosen, and the air-to-air deficiencies were among the reasons cited. Even though it was known that the LWF would assume an air-to-ground role, close-in air-to-air capability was emphasized over the air-to-ground mission.[73]

Finally, the increase in wing size, at Boyd's insistence, to lower the wing loading of the missionized version demonstrates the emphasis placed on agility and maneuverability. He asserted that the failure to increase wing size would be placing themselves "in the position of supporting the idea that the selection of wing area is independent of gross weight." In other words, the new Air Force position was that wing loading was now a defining design characteristic. Boyd urged a larger wing size to keep the F-16 optimized for the air superiority mission. The design change was approved and implemented even though the airplane was destined to replace the primarily air-to-ground F-4.[74] As one article expressed it after interviewing Lieutenant General James T. Stewart, ASD Commander:

> The inherently good air-to-ground capability of the Lightweight Fighter – the result of low wing-loading, high thrust-to-weight ratio, and great structural strength – is to be emphasized in its transformation to the Air Combat Fighter. "We want to squeeze as much air-to-ground capability into the aircraft as possible without unduly compromising its primary air-superiority mission," [Stewart said].[75]

Lower Top Speed

The de-emphasis on top speed was a natural outcome of the replacement of point comparison analysis by EM theory, which corresponds to the change in mindset from fighters that support the bombing mission to that of fighters optimized for the air-to-air mission with other mission capability falling out. The source of the lower speed mission profile was Riccioni, based on Work by Boyd, Sprey, Hillaker, Paterno, and others. In the statement of work for his initial LWF study, Riccioni stipulated that there was no need for the ability to maneuver above Mach 1.6.

When the original mission profile was written by Riccioni, he was interested only in the close-in dogfight capability. Studies had shown that Mach 1.6 was sufficient for dogfighting, since close-in combat rarely if ever occurred at higher speeds. Furthermore, Riccioni knew that higher Mach number could only be attained in maximum afterburner, which would rapidly decrease range. Therefore it was a conscious decision to favor maneuverability and range over top speed.[76]

The Mach 1.6 parameter was kept in the statement of work for the LWF prototype program RFP. Once the aircraft were designed and built it would have been difficult to impose a drastic top speed increase, although it could have been required of the missionized version. There is no evidence, however, that any such concern existed. The absence of debate over top speed could be the result of a number of factors.

One possible explanation is that at the beginning when the mission profile was established and the prototype program was begun, there was virtually no interest in fully developing a lightweight fighter, except by those who had established the Mach 1.6 parameter. When interest in an operational version began to emerge, the design was established, and the opportunity to debate requirements was past. Debate centered around whether or not to use the existing design, and if so how, not whether the design should be changed.[77]

As explained in chapter four, analysis conducted during the FX program had established that top speed was not the determinant of high performance. The efforts to convince people of that fact in order to sell the F-15 had made it unnecessary to establish the idea again. Almost universal acceptance of EM theory, and its accompanying redefinition of high performance allowed the LWF to be accepted with a lower top speed.

Another factor in the acceptance of a fighter that was not specifically designed to achieve high speeds was the demonstrated capabilities of the prototypes. Most people who were not part of the Fighter Mafia were opposed to an FSD program for the LWF for reasons other than top speed, such as the threat it posed to the F-15 program. When they did seriously consider acquiring a version of the LWF, which for most people was during or after the Tactical Fighter Modernization Study, or even after the Schlesinger force structure deal, the prototypes were already completed and flying. Both aircraft proved to be high performance aircraft, and both achieved speeds near Mach 2. This may have helped to eliminate concerns in this area.

Low Cost

The decision to make the LWF a low cost aircraft was essential to the whole concept. This aspect was accepted almost unanimously, and support for the program by virtually everyone was contingent on the fact that the LWF was conceived as a low cost airplane. The ability to keep the cost low as the program moved into FSD and production was a fundamental reason for its long production run, and its procurement by so many different countries (twenty-four of them).

The Fighter Mafia was interested in low cost as a means of procuring enough aircraft to offset the force imbalance with the Soviet Union. OSD wanted a low cost fighter to be able to build an affordable conventional force, as well as being able to provide an affordable fighter to U.S. allies who could not afford a more expensive aircraft. When people in the Air Force accepted the idea of the LWF it was as the low end of the high-low mix. A low cost airplane was the only way the Air Force could have built up its force structure, especially without threatening the F-15.

Multi-Mission Capability

Although the Fighter Mafia saw the YF-16 as the realization of their ideal air-to-air fighter, there was very little consideration by anyone else in the Air Force of acquiring the aircraft in the day visual combat configuration. Much of the disinterest in the LWF prototype program was a result of the fact that people saw it as the unsophisticated fighter that had been pushed by Sprey since during the FX program, and which the Air Force had rejected in favor of the more sophisticated F-15. While Fighter Mafia members felt like the F-15 had grown too big, most of the rest of the Air Force had to be convinced to procure an FX aircraft without a stated air-to-ground capability. After McConnell and other leaders had testified to Congress that the Air Force was pursuing a single mission aircraft for the FX and funds were procured, the actual program, as set forth in the documentation, included provisions for an air-to-ground capability, which it was understood could be further expanded later.[78]

This reflects the mindset that has existed since the Air Force was established that fighters should be able to accomplish more than one mission. While there have been exceptions, most aircraft have been designed to perform both air-to-air and air-to-ground missions. The main debate has been about which mission should take precedence. Up until the mid 1960s the emphasis had been on the bombing mission, so the air-to-ground mission took precedence. As explained in chapter four, several factors changed the emphasis to the air-to-air mission at that time, but most people still believed a fighter should have some capability to perform both missions to some extent.[79]

This idea of designing for the air-to-air mission and adding the air-to-ground mission afterward, which had been done with the F-15, was also done with the F-16 as described above. The F-105, F-111, and other aircraft had been designed just the opposite, with the emphasis on air-to-ground, with air-to-air as a fallout. The transition was not completely smooth. The emphasis on single mission with the FX, while temporary, represented somewhat of an anomaly from the accepted multi-mission mindset held by the Air Force, but in reality much of that was a reaction to the negative experience of the F-111, from which people believed too much had been expected in the peripheral missions.[80]

The missionization of the LWF was never questioned, other than by the Fighter Mafia. As General Stewart summed up the Air Force position in September 1974, "There is no way we can live with the barebone avionics of the prototype vehicles." He went on to explain that a significant air-to-ground capability would be added in the missionized version.[81] Contrary to the opinion of the Fighter Mafia, Hillaker, who had worked closely with them on the design of the YF-16, felt like adding the air-to-ground mission was "the smartest thing the Air Force ever did." He felt like there was no mission for a strictly air-to-air aircraft, and that its survival as a program depended on its assumption of the air-to-ground mission.[82]

The inclusion of an air-to-ground capability was especially important on the new aircraft since the Air Force was catering to the Europeans with the ACF program in hopes that they would choose to buy it. The F-104s they were replacing were G-models and were used in the air-to-air and air-to-ground roles. The fighter they chose to replace it would also have to be capable of performing both roles.

The decision to change the YF-16 from a day visual single mission air-to-air fighter to a dual role air-to-air fighter with a significant air-to-ground capability was formalized in the Tactical Fighter Modernization Study. It was adopted as the Air Force position so the new aircraft could be used to replace its F-4s, as well as providing flexibility in future combat. Because the Air Force already had a very capable air-to-air fighter in the F-15, the need for an air-to-ground capability was more pressing. There was virtually no argument with this position other than from the Fighter Mafia, which was unable build enough support for their position. It was also supported by Schlesinger, who was committed to selling U.S. aircraft to the European Consortium.

Use of Proven Technologies

The decision to rely on proven technologies was directly related to the need to reduce cost. No one was interested in increasing the program risk, or raising the cost by incorporating unproven technologies that would need to be developed. The premise on which the LWF program was based, was to maximize performance using low cost available technology, and to sacrifice performance in favor of low cost. The goals of each participant could not be met if the cost increased, but they could be met with existing proven technologies.

Flexibility for Future Upgrades

One of the things that contributed to the success of the F-16 was the flexibility that was envisioned in the design. As indicated, a driving factor in the program was the low cost of the fighter, and which led to decisions to accept lower technology. The purpose of this was to allow increased force structure as well as keeping the aircraft competitive in the FMS market. Along with these decisions, however, was the decision to allow for higher technology to be added later. The F-16A was designed deliberately with technology that was available at the time, but with the knowledge that it was not the end product.

Hillaker and those who worked with him on the F-16 also planned for greater flexibility. Even though the aircraft was designed as a technology demonstrator, a priority in the design was to make it easily adaptable to a production program. Knowing that potential customers would represent different countries with different needs, flexibility was a key part of the design. Hillaker decided to use a modular architecture that would allow components such as avionics and the engine to be substituted based on the needs of the customer. This included the future needs as well. The Configuration Control Board ratified this approach when they made the decisions of what equipment would be included on the initial version of the aircraft.[83]

The decision to design for flexibility had a big impact on the outcome of the program. The ability to readily replace avionics, coupled with rapid advancements in the miniaturization of electronics, allowed the aircraft to become increasingly capable while avoiding the risk of accepting the technology at the beginning of the program. It also allowed the multirole fighter to adapt to those missions most needed without adding external pods, which would increase weight and drag, thus decreasing the maneuverable air-to-air capability. The approach was so successful that it later became adopted as the preferred method of acquisition.[84]

YF-16

The decision to develop the YF-16 instead of the YF-17 is another one that seems to have been nearly unanimous. That the YF-16 was the clear winner was determined by the criteria by which the selection board chose to judge them. The most important criterion was the ability to perform close-in air-to-air combat. Secretary McLucas, who held decision authority, explained that the main characteristics that won him over to the YF-16 were the smaller turn radius, the better agility, the better visibility, and in general those things that made it a better dogfighter. He added, however, that the fly-off was not all that determined the winner. Lower production per unit costs, a smaller effort required to missionize the YF-16 and lower costs associated with that, and lower lifecycle costs were also important factors. Schlesinger noted that the smaller, single engine F-16 would have a thirty-six percent fuel savings per hour, which would equate to a $300 million savings over a 15 year period. He highlighted the importance of such a savings to the potential European customers.[85] Factors such as this were significant enough even to overcome the bias for two engines.

The FSD Decision

With all of the decisions that were made, the most important one was whether or not to proceed with Full Scale Development, and transform the prototype into an operational fighter, for which no requirement had been written. The decision came down to the Air Force, since Schlesinger was committed to making sure they agreed with the procurement.

Schlesinger, who had decided early on that he wanted to develop the fighter, made his decision based on the ability to sell an airplane to the European Consortium. This was a desirable outcome because it would support President Nixon's policy of allowing allies to provide more support, and improve the conventional capability in Europe by strengthening the European allies. There is evidence that he also wanted the U.S. to maintain its preeminence in the world arms market, especially in light of the challenge being put forth by French weapons.[86]

Those in the Air Force became sold on the LWF over a period of time. As stated, the main reason this happened was that Schlesinger assured the Air Force that it would get all of its F-15s, and that it would be granted an additional four fighter wings to its force structure. Once the concerns of losing some or all of the F-15s and the weakening of the force structure were resolved, there were few in the Air Force who were not in support of acquiring the aircraft, once suitably missionized.

Missionization and performance were the final reasons that there was enough support within the Air Force to fully develop the LWF. When Air Force acquisition decision makers, as well as pilots across the Air Force, found out they would have a very capable airplane, and it would add significant capability to the force, and when that was reinforced by seeing the airplane's actual performance, they were willing to support it.

Summary of Predetermined LWF Decisions and Origins

Following is a summary of major decisions that defined the LWF program, along with information about their origins.

"Predetermined" LWF Decisions and Origins

Decision	Who	Why
Lightweight	Consensus of all participants	Boyd: More maneuverable close-in air-to-air combat fighter; Sprey and Riccioni: Lighter equals lower cost which allows greater numbers to be bought; OSD: Like Sprey, less cost allows more cost effective conventional force; Contractors: Pushed small fighter with Air Force, knowing acceptance would open both domestic and foreign markets; Secretary of Defense: lightweight equals lower cost, which makes it marketable to allies; Air Force Leaders: Smaller allowed for the low end fighter of a high-low mix which would allow force structure even with F-15.
Emphasis on close-in air-to-air mission	Fighter Mafia Air Force mindset	Boyd: Quest to improve close-in combat capability; Sprey and Riccioni: Believed air superiority would be won in the air, with strictly visual combat; Air Force: With acceptance of EM theory the measurement of "high performance" had transformed from bigger-higher-faster-farther to maneuverability which placed emphasis on close-in air-to-air combat as primary mission

Lower top speed	Fighter Mafia Air Force mindset	Fighter Mafia: Supported goals of close-in air-to-air combat; Air Force: Accepted maneuverability as new measure of merit, as shown in FX development, also actual top speed was higher than statement of work profile speed
Low cost	Consensus of all participants	Fighter Mafia: Necessary to procure large numbers and to reverse threat imbalance; OSD: Allowed more cost effective conventional force for U.S. and allies; Air Force: necessary to build force structure with high-low mix
Multi-mission capability	Air Force OSD Contractors NOT Fighter Mafia	Air Force: Longstanding use of multi-mission aircraft for flexibility, and fighting to and from a target, also F-15 provided good air-to-air capability and with air-to-air emphasis, air-to-ground mission provided by multi-mission aircraft; OSD: needed a multi-mission aircraft for cost-effectiveness, and also to offer allies who needed to replace multi-mission aircraft; Contractor recognized multi-mission aircraft more marketable in U.S. and with allies
Use of proven technologies	Consensus of all participants	Proven technologies reduced program risk and chance of escalating costs. Low cost was essential for all program goals, while performance could be traded off for low cost.
Flexibility for future upgrades	Jones General Dynamics Configuration Control Board	Jones: Add to force structure by keeping low cost using existing technology for initial design with option to improve later; General Dynamics: Decision to use modular approach (airframe, avionics, engine, etc.) so design could allow for various configuration desires of allies, or future needs of the Air Force; Configuration Control Board: Implemented Jones' approach with selected missionized configuration
YF-16	Consensus of all participants	Better capability in emphasized mission of close-in air-to-air combat due to greater agility; lower development, production, and lifecycle costs.
The FSD decision	Consensus of all participants	OSD: Provided marketable replacement aircraft for allies, supported President's policy to give allies more active defense role; Air Force: allowed modernization and force structure build up with high-low mix without threatening F-15 program (with Schlesinger deal), provided significant capability once developed

Table 5.3. Summary of predetermined LWF decisions and their origins.

Preliminary Conclusions from the LWF Case

Like the F-15, the F-16 is almost unanimously considered to be extremely successful by almost any set of criteria. To date, during a production run of over thirty years more than 4300 F-16s have been produced for 24 different countries (2230 of them for the U.S. Air Force).[87] The F-16 costs significantly less than its predecessors, and yet its combat record is unsurpassed. It has flown the bulk of combat missions in all conflicts since it became operational, with widely acknowledged success.

The F-16 grew out of a combination of ideas that represented the needs of various groups. The fact that there were no formal requirements illustrates the importance of inputs other than those documented in a formal requirements generation process. General Welch later described this nonstandard sequence of events as compared with the development of the F-15.

> The F-15 was enormously successful because we had a long period of defining what we wanted it to be. We had a lot of the very best thinking in it with competition from the best fighter companies in the world, and we approached it with enormous discipline. The F-16 was almost an afterthought. It didn't have any of those advantages, but it turned out to be an enormously successful airplane. And a good part of that was just good luck.[88]

While there may have been some luck involved in the airplane's success, Welch overlooks the fact that years of the very best thinking also went into the F-16. The early work of Sprey and Boyd, along with the collaboration with contractors, especially Hillaker and Paterno, led up to the LWF prototype program. While the design work and analysis were not done by Welch and the others in Kent's group, it was done nonetheless. During the prototype program Hillaker's and Paterno's teams, working closely with Boyd, Sprey, and Riccioni to produce aircraft at the pinnacle of close-in air-to-air combat performance, and used the latest engineering techniques, which can hardly be considered luck.

What Welch may have been referring to is the fact that once the close-in air-to-air prototype fighter was complete, it fortuitously provided ample capability for other missions. It could easily be turned into a true multirole fighter, despite the fact that it was designed primarily for a single role. It took on the roles of bombing, CAS, and

Suppression of Enemy Air Defenses (SEAD), as well as that of an all weather air-to-air fighter.

This, however, should not have surprised Welch, because the F-16 fit exactly the mission the Air Force had chosen to emphasize. After the F-111, the Air Force realized a fighter with bomber emphasis could not adequately fulfill all of the other fighter missions as they had come to be defined. It was especially deficient in close-in air-to-air combat capability. The new mindset still emphasized multirole fighters, but with the primary mission being close-in air-to-air combat instead of bombing.

The F-111 was consistently maligned for "trying to do too much." It was designed for so many missions, the detractors complained, that it could not do any of them well. The fact is that it was a very capable bomber, which was its primary mission. The F-16 had inadequacies in its peripheral missions just as the F-111 did. Just as technologies, such as air-to-air missiles, were developed to compensate for the F-111's weaknesses in the air superiority mission, technologies such as precision guided munitions made up for the F-16's weaknesses in the air-to-ground missions. Although its small size limited its payload capability, accuracy of munitions enhanced its effectiveness. Similarly the AWACS and AMRAAM missiles compensated for its limited radar capability, and improved signals intelligence and anti-radiation missiles have helped to improve survivability against SAMs. Even though the F-16 was asked to do many missions, and used technological advancements to compensate for its weaknesses in the peripheral missions, it has been very capable at the mission it was primarily designed for as well as its secondary missions.

The U.S. Air Force procured the F-16 as a relatively inexpensive air superiority fighter that would be able to contribute to the secondary missions of CAS and bombing. Thanks to the existence of the F-15, the F-16 has not performed the air-to-air mission as often as it otherwise might have, but it has been successful in the air-to-air engagements it has encountered, with a kill ratio of approximately 70 to 0.* This combination of a high-low mix of air superiority aircraft, together with the absence of a formidable air-to-air challenge during the service life of the two aircraft, has led to undisputed air superiority for the Air Force. Furthermore, thanks to the supporting technology, it has performed its secondary missions satisfactorily as well. Finally, the F-16 was procured for relatively low cost.

The F-16 is the end result of a deliberate decision to design fighter aircraft that emphasize the close-in air-to-air mission, while still maintaining a multirole capability. The F-16 is an excellent fighter and has performed well in every mission it was asked to do. Significantly, the expectations have remained the same, as mission emphasis has not changed since the aircraft's acquisition, which has primarily led to the great success of the aircraft.

* Different sources give different numbers of air-to-air kills achieved by the F-16, most likely because of the difficulty in gaining access to, and verifying reports of such events from the numerous countries that fly F-16s. Sources give a range of 69 to 72 kills. All sources referenced were in agreement that no F-16 has been shot down in air-to-air combat. When comparing the F-16 kill ratio with that of the F-15, the fact that nearly five times more F-16s were produced than F-15s must be taken into account.[89]

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Chapter 6
Undocumented Inputs and "Dominant Mission Emphasis"

The preceding three chapters explored the sources of predetermined requirements for systems, and decisions that were made which affected the resulting artifact. It has been shown that there is no set process or even set of documented inputs that determine the need for a system, and what the requirements of that system will be. The case studies also explored the relationship between the mission that is being emphasized at the time of system conception, the system that is conceived, and the perception of the success of the resulting system. This chapter will present a model for describing that relationship.

Undocumented Inputs to Weapon System Requirements

From the analysis of the sources of predetermined requirements and decisions that shaped the systems studied, several inputs were identified. These inputs are often considered to be external to the process. Even though they are not documented in a formalized requirements generation process, the cases studied show that they are in reality an important part of determining weapons needs, and formulating ideas to meet those needs. Several important undocumented inputs are listed and explained.

Strategy and Doctrine

Military strategy and doctrine are very important in determining the needs of new weapons, since the purpose of the weapons is to carry out the strategy in accordance with established doctrine. Although requirements processes have always directed that strategy be an input, it is not clearly specified how that should be done. As long as a program can be shown to support strategy it can be considered justifiable, but there is obviously no one-to-one correlation between a given strategy and a given weapon system to carry it out. For this reason strategy and doctrine have been listed as undocumented inputs.

The cases show that strategy and doctrine were influential, but were general enough to allow debate regarding how a weapon would fulfill them. In the cases there was room for the interpretation of strategy and doctrine. In some cases there was also a lag between the issuance of strategy guidance and its acceptance by the Air Force, or individuals in the Air Force, if it was accepted at all.

The TFX program was heavily influenced by the strategy of nuclear deterrence by massive retaliation carried out by manned bombers. Air superiority doctrine at that time also called for a bombing capability, preferably with nuclear weapons. This strategy was widely accepted, and the resulting F-111 airplane fit well into it. The TFX concept anticipated the need for conventional bombing, as well, that would support the new strategy of flexible response that was put in place by the Kennedy administration. For this reason advanced avionics were included giving the airplane a more accurate delivery capability for conventional weapons.

By the time the FX was being conceived the flexible response strategy had been in place for a few years. Many of those involved in the beginnings of the FX did not base their concept on the new strategy, but saw the lack of an air superiority fighter as a weakness even under the old strategy. People like Myers and Agan believed that air-to-air combat would be a feature of any type of war the U.S. fought. The introduction of the new strategy, which increased the probability that future wars would be conventional, was very useful, however, in convincing others of the need for such a fighter. Myers titled his advocacy briefing “Air Superiority in Limited Wars,” basing his pitch on the new strategy as a way to persuade others to support development of a close-in dogfighter.[1] As the strategy was put into action in Vietnam the points being made verbally by people like Myers became more apparent, and support for the FX increased.

The flexible response strategy not only increased the chances that the Air Force would engage in conventional combat in limited wars, it also increased the likelihood that a war in Europe would be conventional, at least at the beginning. Planning for a conventional war in Europe highlighted the imbalance of forces, and the need to build force structure. Riccioni’s motivation when he began his LWF study was to ultimately develop a fighter that would support that strategy by being affordable enough to allow for large numbers of them to be produced. He was another example of someone who held the idea before the strategy was changed, but the need to mitigate the conventional imbalance that was highlighted by the adoption of the flexible response strategy was an important motivation for most people in the Air Force to accept the high-low mix, which resulted in the F-16.

Published doctrine during this period did not keep up with how weapons were actually being employed. For example, the doctrine manual published in 1966 still focused primarily on nuclear war and stated, “The counter-air mission can best be accomplished by multiple attacks against enemy air bases.”[2] Combat experience in Vietnam largely contradicted this, and the practical employment of air superiority fighters in Vietnam influenced the FX and LWF programs more than the published doctrine.

Upbringing

Upbringing is more than just the sum of the experience of a person. In the context used it goes beyond merely observing or experiencing certain events as one matures, but is the immersion of a person in a certain way of approaching a problem. The result is that the approach under which a person was brought up becomes the default method for addressing new problems. There are many examples of people allowing other inputs to override upbringing, but in the absence of a convincing reason to change, often the upbringing of a person will dictate his or her decisions.

General Everest, for example, was commander of TAC, which was a fighter command, but there is little doubt that his upbringing in bombers contributed to his concept of the TFX. Although Everest's first assignment was in fighters, and he had other fighter assignments during his career, his upbringing was heavily influenced by the bomber approach to warfare. While still a captain he graduated from the ACTS, the source and strongest advocate of bomber doctrine. During World War II he had significant formative combat experiences flying bombers. He commanded the 11th Heavy Bombardment Group in the New Hebrides Islands and Guadalcanal, earning the Silver Star on a key mission against the Japanese in February 1943. As the war ended Everest led efforts at the Air Corps Headquarters to develop post World War II war plans, which were heavily oriented toward strategic bombardment. He later assumed the additional duty as the senior Air Force member on the Military Liaison Committee to the Atomic Energy Commission, which was responsible for developing nuclear weapons. Even during Everest's assignment as commander of the Fifth Air Force, Far East Forces, during the Korean War, which was a fighter command tasked with securing air superiority, he focused on the bombardment role. He later recounted his air superiority efforts in bomber terms: "We kept all of the usable airfields in North Korea, even the rudimentary ones, pretty well useless with bomb craters, and only rarely did they make the effort to replace them."[3] This upbringing is evident in the fighter Everest conceived to meet the challenges of the next decade, which emphasized bombardment, even for the air superiority role.

The same influence can be seen in the FX program, and a detailed look at the upbringing of key participants verifies that. Agan spent his career in fighters including 45 combat missions in World War II, on one of which he was shot down. Burns also flew fighters, including over a hundred combat missions in World War II and over a hundred more in Korea. Myers was a fighter pilot in the Korean War and then a test pilot of high performance fighters. Boyd flew F-86 fighters in Korea and taught on the faculty of the Fighter Weapons school before his participation in the FX program. Welch was also a fighter pilot, completing a combat tour in the F-4C in Vietnam prior to reporting to Kent's Studies and Analysis team. Disosway also spent his career in fighters, including combat experience in World War II.[4] This is not to imply that the decision makers had to have a fighter upbringing in order to accept an air superiority fighter, or that all fighter pilots viewed the problem the same way. It does show, however, that many of those who gave input into the determination of the need for an air superiority fighter, and who helped formulate proposed solutions were influenced by their upbringing, and therefore it affected the outcome.

The actual start of the LWF program can be attributed to Riccioni, and his upbringing as a fighter pilot in Cold War Europe has been cited. Civilians can be influenced by their upbringing as well, and Packard's was influential in the LWF program. He was co-founder of the Hewlett-Packard company, which was known for a management philosophy that encouraged creativity and tried to avoid traditional business hierarchy and formality. The numerous innovative electronics products created by the HP company attest to his desire to advance technology without the impediments of administrative barriers.[5] This no doubt influenced the open-ended approach to his prototyping program, which affected the outcome of the LWF.

Personalities

The personalities of those involved in the development of new weapons affect the outcome. A creative personality can lead to innovative solutions. A controlling personality can lead to a management style that stifles creativity. An energetic personality can lead to more effective advocacy. These are just a few examples.

The cases studied demonstrate this. Upon entering office as the Secretary of Defense McNamara reflected that he could follow one of two philosophies of management. He could play a passive role, reviewing decisions made by the services, or he could take an active role of aggressive leadership. In this role he saw himself questioning decisions, suggesting alternatives, proposing objectives, and stimulating progress. He decided, "The active role represents my own philosophy of management."[6] McNamara's aggressive decisive overturning of the TFX source selection and his insistence on commonality in the program affected the F-111, which most likely would not have happened under a secretary with a different personality.

Boyd was notorious for his tenacious personality, without which he may have given up on the pursuit of his EM theory. It took him years of wrestling with the problem before he finally arrived at a useful method of comparing fighters. The rebellious and confrontational side of his personality was also essential in motivating him to work on a lightweight fighter design with Sprey, Hillaker, and Paterno, and in encouraging Riccioni's efforts despite the unpopularity of the project throughout the Air Force. Playing the role of underdog was part of Boyd's motivation, without which he may not have pushed the idea nearly as hard.[7]

Seamans explained that when Kelly Johnson brought his unsolicited lightweight fighter proposal to his office prior to the LWF prototype program, his insistent personality, coupled with his reputation as a successful aircraft designer, put a lot of pressure on him to approve the project. Seamans was prepared to respond objectively to the pressure since he had a very confident and assertive personality, along with a similarly strong reputation from his work on the Apollo program. He is convinced that there are many people who would not have stood up to Johnson had they been in his position. The decisive and assertive personality of Seamans allowed the LWF competitive prototype program to occur.[8]

Competition

Competition has long been used as a method to improve the outcome of programs. Competitive source selection, and in one case a competitive flyoff, helped determine which design would be developed for each program. Competition among the services, interservice rivalry, also played a major role in the decisions of what systems the Air Force needed, and how to fulfill them.

The requirements coordination process of the TFX was viewed as protecting Air Force interests, and any compromise in favor of Navy-specific requirements was seen as a defeat. The program delay caused by the inclusion of the Navy was partially to blame for the need to procure the F-4, a Navy fighter. The insistence by the Army that the TFX would not be able to adequately fulfill its CAS needs, and the desire not to lose the mission to the Army, led the Air Force procurement of the A-7, another Navy airplane. These Navy acquisitions, the A-7 and the F-4, would influence the FX program as well.

An important factor in the decision to start the FX program was the desire of the Air Force to develop its own fighter instead of being forced to use another one developed by the Navy. Many of the early decisions were influenced by the desire to control the design of the next fighter, and the budget associated with it. The air-to-ground mission was completely de-emphasized in the FX, and one of the primary motivations was to make the program competitive compared to the Navy F-14. Also, emphasis on close-in air-to-air combat provided a capability which no Navy airplane could provide, which was a selling point for the program.

The LWF program was similarly influenced by competition with the Navy. Riccioni was unsuccessful in generating interest for anything related to a lightweight fighter until he provided evidence that the Navy was committing resources to the concept. Riccioni was convinced that many in the Air Force considered the Navy to be more threatening than the Soviets.[9]

Technology

Technology in this context refers to new technological developments. These can influence a system in different ways. The first one is generally in accordance with the formal process, which stipulates that once a required capability or specification is defined, an exploration of available technology is conducted to determine the best way to meet the requirement. Another way is for a required capability to be brought to light by a technology. This second situation can include the case where an engaging technology is developed, and a need is sought or created to enable its use.

The variable geometry wing is at least partially described by the second type of technology integration. Although the mission Everest envisioned would have been difficult, if not impossible, without the technology, the absence of debate or exploration of alternatives suggests that it was accepted as a requirement. The opinion that the variable geometry wing was considered a requirement for the sake of using the technology is expressed by people who were involved with the program.[10]

The LWF program was defined by predetermined technology decisions because the system began as a technology demonstrator. It was the sum of all available technologies which the contractors had determined would be useful on a new fighter. Technologies such as the afterburning turbofan engine, fly-by-wire, and others were the starting point in a sense, and they helped define what the airplane turned out to be. When the Tactical Fighter Modernization Study Group convened they had a new technology (or set of technologies) and simply determined if there was a need for the airplane.

The LWF introduces another way technology can affect a program. Technologies being developed around the time of the LWF program, but for other programs, influenced it. Supporting technologies such as the AWACS enabled the use of a fighter with a smaller shorter-range radar. Precision guided munitions allowed a fighter with a small payload to be an effective bomber. Technologies such as these influenced the airplane toward lighter weight, but also made such an airplane viable. Without these emerging supporting technologies development of the LWF may not have been accepted

Budget

Even when budget limitations are not explicitly included in various steps of the requirements generation process, it is recognized that they must be taken into account. Budget considerations can sometimes become more important than operational considerations. When that occurs budget inputs can be considered as one of the undocumented inputs.

The TFX provides an example, where the drive for commonality, motivated by the need to decrease costs, pushed the Air Force and the Navy to develop an airplane together. Despite the fact that the Air Force and Navy consistently maintained that their operational requirements could not be met adequately by a common airframe, they were overridden for the sake of budget-driven commonality. The list of resulting degradations, presented in chapter three, represent some defining characteristics as a result of budget constraints.

The FX and LWF both had cost caps imposed, which affected the product. The FX was fairly well defined by the time the cap was set, but the cost limit of the LWF was one of the main requirements. The contractors were given a sum of money and were basically asked to maximize performance within the cost limit. As the F-16 was missionized the $3 million unit cost dictated the level of performance it would have. A conscious decision was made to give priority to budget over operational capability. Much of the reluctance to support the concept of an LWF resulted from doubt that the low cost ceiling was enough to produce a useful operational capability. When the prototypes began flying, and people became convinced that with missionization such an airplane could contribute significantly to a combat effort, those concerns lessened.

Politics

It is common knowledge that political factors influence weapon systems, but they are among the least accepted as part of the process. Neufeld, an Air Force historian tasked to officially chronicle the F-15 program concluded that "the Air Force overcame opponents, critics, and bureaucracy to produce the … fighter."[11] Similar statements in an official TFX chronology refer to the program being plagued with "political interference."[12] This view assumes that there is some correct military solution that can only be worsened by political factors. It fails to recognize that the political influences such as critics and the bureaucracy were a part of the defining process, and were not simply overcome.

Commonality in the TFX program was seen as a political battle over control of military acquisition. Beyond simply maximizing the budget, if commonality prevailed the Secretary of Defense, and not the individual services, would determine what equipment would be available with which to fight wars. The battle over requirements was fought to assure that the operational requirements of each service were met, but it was also fought in an attempt to establish the right of the services to make their own determination of what was required operationally. This is illustrated by the fact that the Navy pulled out of the TFX program because it claimed the F-111B was too heavy resulting in too high of a wind over deck requirement. They later went on to produce their own fighter, the F-14, that closely resembled the F-111B, and performed similarly. This struggle over commonality continued with the FX program.

	F-111B	**F-14**
Empty weight (pounds)	46,000	41,353
Maximum takeoff weight - catapult (pounds)	77,724	74,349
Maximum landing weight - arrested (pounds)	62,000	54,000
Typical landing weight (pounds)	50,000 - 57,000	45,000 - 54,000
Stall speed w/ approach power (knots)	95 - 100	102 - 112
Length	61' 9" (nose folded)	61' 11"
Width - wings swept	33' 11"	38' 2"
Height	16' 7"	16'

Table 6.1. Navy fighter performance comparison. Weight affects deck strength requirements. Wind over deck requirements are determined primarily by approach speed, which is dependent on stall speed. Physical dimensions determine deck parking space requirements.[13]

There were some in TAC who, despite their personal preference for more of an air superiority fighter, supported a TFX concept based on the bombing mission, for political reasons. It has been established that TAC worried about losing budget share and relevance, which would threaten its existence. Those who chose to support Everest's TFX concept just to get a new airplane, regardless of what it looked like, in order to maintain relevance, were acting for political reasons.

The LWF program had other accusations of political meddling. According to the accusers, the Air Force had no need for a fighter, but was forced to buy it in order to boost FMS opportunities.[14] Another is that the aircraft was only accepted in its low performance state as a means for the Air Force to build force structure, based on the political agreement between Schlesinger and Jones. While the decision to develop the LWF into an operational fighter was based on implications for FMS opportunities and increased force structure, those political factors also influenced the ability of the LWF to meet Air Force operational needs, which cannot be discounted.

Political influence over source selection has been raised, especially in the TFX case. Though the allegations were never proven, it is difficult to imagine that there was not some consideration given to factors such as the impending closure of the aircraft plant in Fort Worth. Similarly, the willingness of Congress to allow the cancellation of the F-111B and the reduction in Air Force F-111s procured was almost certainly influenced to some degree by the conflict between McNamara and those in the Senate, such as McClellan, who mistrusted him and disapproved of his handling of the program.

Biases

Bias is another input that is not accounted for in the documented requirements process, but which is a factor. The bias toward a bigger aircraft was shown in the TFX case, and the position was represented again in the FX case. Bias was also shown to be a factor in the selection of a twin engine and a single seat FX.

Bias for advanced technology certainly affected the three cases studied. The FX was constantly being pushed toward a higher technology solution, and may have included more advanced technology than it did, had it not been for the weight and cost restrictions imposed. The LWF was constantly threatened by the fact that it went against the bias for advanced technology. The Fighter Mafia constantly ran up against this bias, and they claim it drove the size and cost of the F-15 to excessiveness. They also feel like it ruined the F-16 by leading to its becoming too complex and costly when it was missionized.

Bias tends to have a negative connotation. Often, however, bias is based on one's interpretation of analysis results or experience. Brigadier General Richard A. Yudkin, who worked on the Air Staff in Plans, noted in a letter discussing acquisition issues to Lieutenant General Momyer, who in 1966 was commanding the Seventh Air Force in Vietnam:

> To state it bluntly, if you have prejudices – like the rest of us – I respect them too because they are the product of particularly pertinent experience, understanding of the Pentagon problem, plus what I know to be a deep and abiding interest in giving rational consideration to issues like these.[15]

Thus biases, though unaccounted for, can be a valuable input to weapon system decisions. At the very least their influence must be recognized and accounted for.

Analysis

It is a commonly held opinion that decisions about military needs are, or should be, the result of objective analysis. This is reflected in documented requirements processes. The JCIDS process, for example, calls for several sets of analysis.* The

* The following analyses, included in the JCIDS process, are typical of those found in earlier requirements processes. Functional Area Analysis (FAA) identifies the operational tasks, conditions, and standards needed to achieve military objectives. Functional Needs Analysis (FNA) assesses the ability of the current and programmed warfighting systems to deliver the capabilities the FAA identified. Functional Solutions Analysis (FSA) is an operationally based assessment of all approaches to solving or mitigating capability

reason analysis is included in the list of undocumented inputs to needs and systems, is because the varied amounts, types, and uses of analysis cannot adequately be captured in the documented process.

Besides the studies called for in the documented process, numerous other studies were completed in the three cases. There were technology feasibility studies done by NASA, ASD, contractors, and other agencies; there were studies to determine whether Air Force requirements were compatible with those of the Army and the Navy; there were studies to answer questions about specific characteristics, such as single seat versus two seat. Tradeoff studies using EM theory and TAC Avenger were done for over two years during the FX program. Boyd and Sprey conducted an ongoing study, working with contractors, to improve their lightweight fighter concepts.

The analysis that was used to define the need and solutions in the cases studied was done for a variety of purposes. A major purpose was typical engineering analysis, used to quantify the different characteristics of a proposal, such as forces that would be experienced. Other purposes for analysis were more social in nature. Some was done to support a position, such as the Air Force and Navy analysis that showed their requirements were incompatible, and the OSD analysis of the same timeframe that showed they could all be fulfilled by a single airframe. Some analysis was done for advocacy, such as the Thyng Study that Agan commissioned to build interest for an air superiority fighter. Some was to prove a concept being advocated, such as Sprey's FX^2 study. Riccioni used his LWF study as a vehicle to produce workable aircraft designs in hopes that their production would later be funded.

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gaps identified in the FNA. Post Independent Analysis (PIA) is a second look by a separate group from the one that did the FSA.[16]

Feedback

The determination of needs and possible solutions depends on the performance of preceding and existing systems. The F-111 was Everest's response to the vulnerabilities resulting from the F-105's dependence on long runways and its inability to bomb with sufficient accuracy. The idea for the FX came in part as an answer to poor aerial combat results of the F-105 and F-4 in Vietnam, and EM study results showing that the F-111 would not improve the situation. Furthermore, its emphasis on the air superiority mission was a reaction to the perceived problems experienced during the TFX's attempt to fulfill what were considered too many missions. The perceived intrusions of Navy airplanes with the A-7 and F-4, and Navy requirements in the F-111, caused the Air Force to redouble their efforts to avoid a joint FX program. This same feedback prompted Glasser and Smith to give Riccioni permission to proceed with his LWF study. The LWF was conceived, and support was also built, based on the high cost of the F-15.

Dominant Mission Emphasis

The influence of undocumented inputs on the determination of needs, and the systems conceived to fulfill those needs, can be applied at a higher level as well. The preliminary conclusions of the case studies showed that the ensuing systems were a product of the mission which received the dominant emphasis. As shown, each of the airplanes was expected to fulfill more than one mission, even the so-called single-mission

F-15. The predetermined requirements and decisions that were made resulted from the choice of this "dominant mission emphasis" or DME as it will be referred to.

As stated, the DME is simply the mission which receives the most emphasis, or about which the majority of the decision makers, and those who influence decision makers, care about. In a large and varied organization like the Air Force there are obviously many different missions that receive emphasis at any given time, but the DME is the one receiving the most emphasis – the one all of the other ones ultimately support.

As an example, an emerging mission in the Air Force today is that of cyber warfare, or protecting computers from intrusions while finding vulnerabilities in enemy computer systems. While this is an important emerging mission, ultimately the Air Force currently flies airplanes, and computer security is subordinate to air operations. To continue the example, with a DME of tactical fighter combat, future computer system upgrades might be influenced by the need to securely transfer aerial target data more than some other requirement. As the actual DMEs that existed during the TFX, FX, and LWF programs are discussed, the concept will be clarified further.

The TFX was conceived as a multirole fighter that would perform all of TAC's basic missions: interdiction, air superiority, and CAS. Of these, however, it was designed primarily for the interdiction bombardment mission, which aligned with the strategic nuclear bombardment mission being emphasized at the time. Similarly the FX emerged as an airplane that was primarily an air-to-air fighter, although it was accepted that it would assume an air-to-ground role at some point. This reflected a sharp change in emphasis to air superiority, especially close-in air-to-air combat. This was partly a reaction to the neglect of this mission, and partly a reaction to the perceived failure of the

F-111 to achieve a multi-mission capability as effectively as was envisioned. The missionized version of the LWF moved back toward an emphasis of a true multirole fighter, but with emphasis given to close-in air-to-air combat.

Considering the case studies using a *systems*-level approach to the questions of needs determination and fulfillment, it can be shown that the DME which influences the systems developed, is itself a product of the undocumented inputs identified. Appendix A provides a summary of cross case analysis of the case studies, establishing this relationship between undocumented inputs and the DME. The rest of this chapter will develop the DME concept.

The Dynamics of a DME

A bell-curve can be used to model the lifecycle of a DME. Based on existing conditions the mission must react to, such as the threat, the political environment, the economic climate, the current strategy, the available technology, and so forth, a particular mission emerges as being dominant. This is depicted graphically as follows:

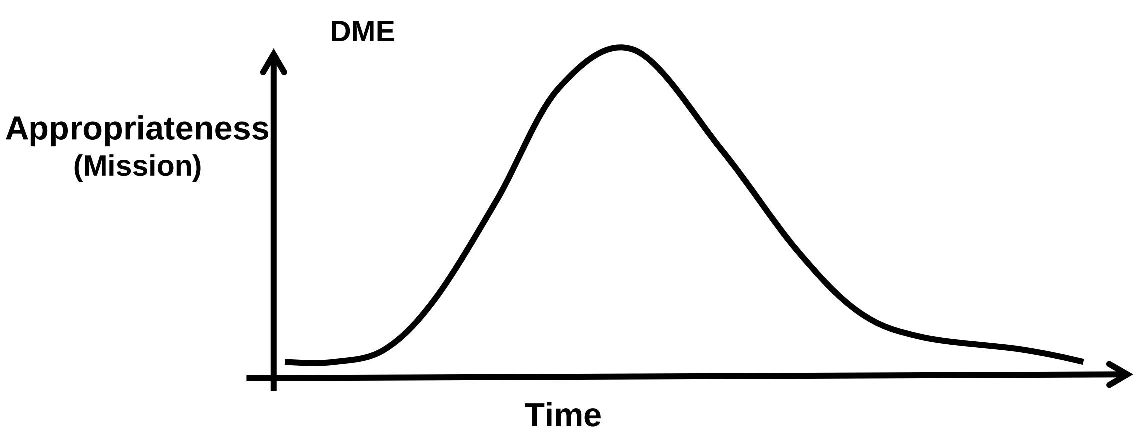


Figure 6.1. The dynamics of a DME.

A DME is accepted because it is deemed appropriate by a majority of decision makers for the national security conditions, including all of the undocumented inputs to it, under which it will be carried out (depicted by the left vertical axis). Over time the threat will adapt, and other conditions will change which invalidate the existing DME. The tail on the right side of the graph corresponds to the ability of the Air Force to adapt equipment that was not purpose-built for the new conditions. The horizontal axis represents time, but no scale is provided since there is no set time period during which conditions change enough to invalidate a DME. Similarly, although the bell curve is depicted as a smoothly rounded curve, the period of time during which it remains valid can also vary. Thus, the curve could include a plateau of varying lengths, depending on how long the DME remains appropriate for the conditions that exist. When a DME no longer meets the needs imposed by the conditions, a new DME will emerge which responds to the new conditions.

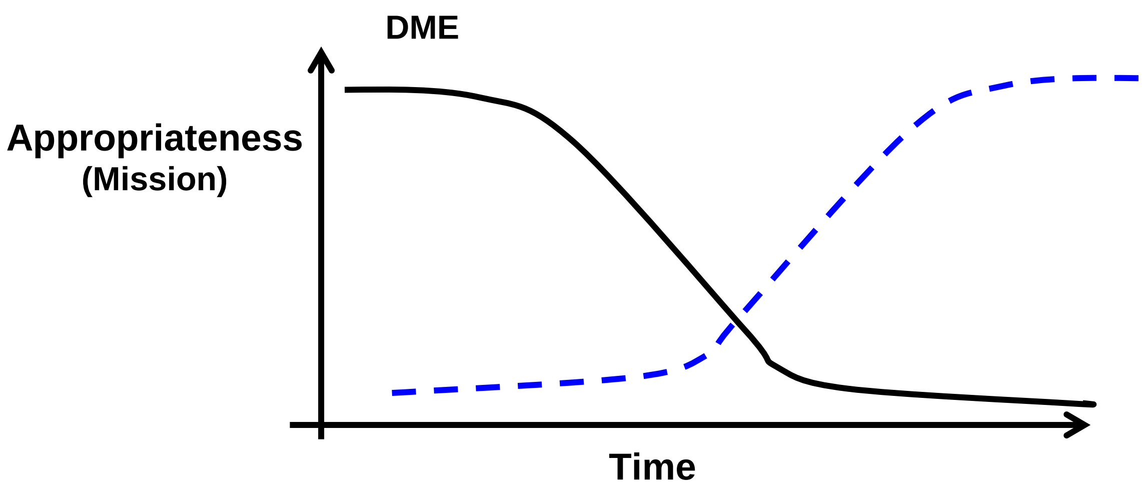


Figure 6.2. The emergence of a new DME.

The Establishment of the DME

One way to better understand the idea of a DME is to trace its development. The events leading to its establishment can aid in defining the mission being emphasized and the reasons for the emphasis. The earliest use of aircraft in combat was simply as a way for Army officers to see over the horizon. This was useful for gathering intelligence about what enemy forces would soon be confronted, as well as functioning as an artillery spotter. There was no mission-specific equipment for this, except maybe a pair of binoculars, other than the airplane itself. Airplane technology evolved quickly, but conditions changed equally quickly during this period characterized by the DME of observation. These changes were a result of innovative thought applied to the rapid change of war brought on by industrialization.

World War I led many to believe that traditional land warfare was impractical due to the destructive power of new technologies such as machine guns and poison gas. Furthermore, the airplane made it unnecessary to fight such wars in an attempt to reach the heart of an enemy nation. Ideas of airpower theorists, such as Douhet and Trenchard, led to a new DME; one that emphasized strategic bombardment of an enemy's vital centers.

The DME was not as quick to catch on in the U.S., as Army officers returning from Europe committed few resources to airplanes. One officer who took an early interest in strategic bombardment was Billy Mitchell. Besides being a flamboyant advocate for the strategic bombardment mission and a separate Air Force, and providing the theory for the ACTS curriculum, he also converted a core group of devoted followers who became the leaders of the Air Corps and later the Air Force. These included Arnold, Eaker, and Spaatz.

Mitchell's ideas became widely dispersed and implemented as the Air Corps expanded for combat in World War II. As a the force grew from approximately 8500 people in 1920 to over two and a quarter million by 1945, those future leaders who had been educated in the strategic bombardment doctrine at the ACTS during the 1920s and 1930 became more influential as they filled the numerous leadership positions that became necessary. The ACTS was also influential as the organization that produced the strategic bombardment plans the Air Corps used during World War II.

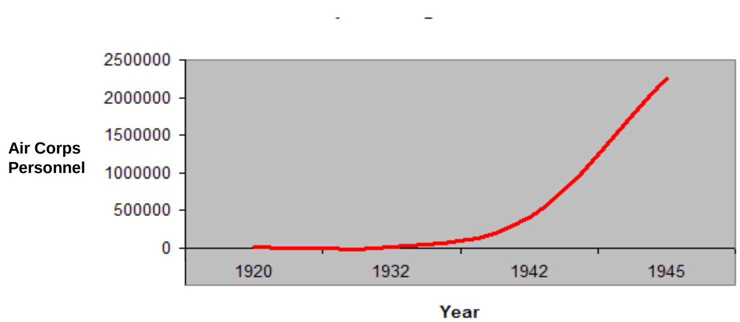
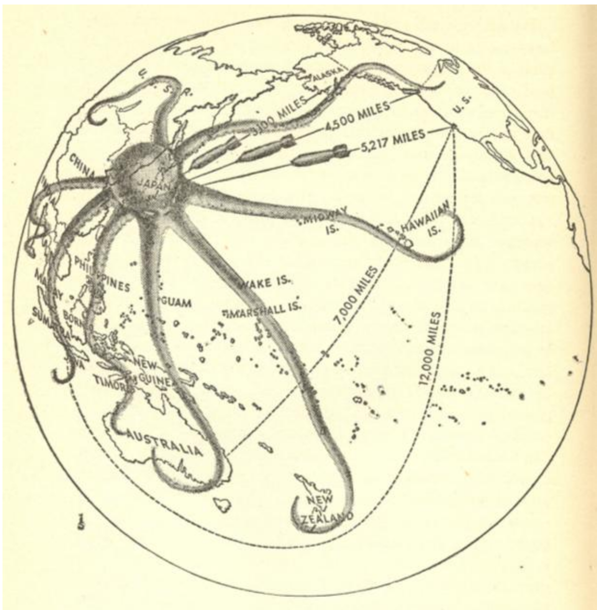


Figure 6.3. Air Corps strength over time.[17]

The strategic bombardment DME also had the support of the public. Airpower received much attention with the air attack on Pearl Harbor, and soon afterward Alexander de Seversky published his influential book, *Victory Through Air Power*, which was a very widely read Book of the Month Club selection, and a huge bestseller. The ideas in de Seversky's book come straight out of the writings of Billy Mitchell but are presented with an urgency bordering on fear-mongering. The book opens with a reprint of a signed photograph of Billy Mitchell, and the facing page has a full-page dedication by the author to “my superior, my colleague, my friend -- General William Mitchell.”[18]



AIR POWER IGNORES THE TENTACLES

Figure 6.4. A cartoon advocating strategic bombardment in de Seversky’s best selling book, *Victory Through Air Power*.

The public acceptance of strategic bombardment was strengthened with the surrender of Japan immediately after U.S. bombers dropped the two atomic bombs in Japan. Not only was the public convinced of its efficacy, but government officials were as well. The national security strategy in the post World War II period was based on the mission of strategic bombardment, the capability for which was increased dramatically, even as other elements of the military were being severely reduced.

Besides advocating strategic bombardment, Mitchell ineffectively campaigned for the Air Force to become a separate service, led by airmen who understood airpower. He believed that the strategic advantages of airpower would be squandered by ground oriented leadership that lacked “air-mindedness.” As long as airpower was seen as a support for ground troops, either through interdiction, CAS, or transport, there was justification to keep control under Army commanders. If the most effective characteristic of airpower was considered to be its strategic contributions, Mitchell's contention that it should not be limited by being controlled by the Army could be justified.[19] Army Air Corps leaders toward the end of World War II, who were just as committed to an independent Air Force as was Mitchell, though less aggressive in their advocacy, successfully made the case. Soon after the war, the nuclear bombardment mission was entrusted to the Air Force, which became an equal and independent service.

The very existence of the Air Force was based predominantly its ability to carry out the strategic nuclear bombardment mission. The Navy had also campaigned vigorously to control this mission. It advocated the development of super aircraft carriers that would deploy near enemy countries and launch bombers with nuclear weapons. In the infamous Revolt of the Admirals, in which the Secretary of the Navy, John L. Sullivan, resigned over the cancellation of the supercarrier program in favor of the Air Force's B-36 intercontinental bomber, the Navy launched scathing attacks on the B-36 program. The attacks went as far as the fabrication of evidence that Secretary of Defense Louis A. Johnson, Air Force Secretary Stuart Symington, and other Air Force officials had been involved in corruption in the selection of Convair as the contractor for the B-36 program. Congressional investigations later cleared all who were allegedly involved and identified the perpetrator of the false documents.[20] A loss of the strategic nuclear mission to the Navy would have meant the loss of justification for the existence of the Air Force, making the successful outcome of political contests such as this extremely important. These contests, therefore, reinforced the strategic bombardment DME.

The acceptance of the nuclear bombardment DME persisted through the 1950s, and even remained intact during the Korean War, which provided evidence that there were flaws in the strategy it supported. The influence of the DME permeated the Air Force which became dominated by SAC, the owner of the strategic bombardment mission. As shown, all those who hoped to receive funding, and have relevance in the Air Force needed to contribute to the DME of strategic nuclear bombardment.

As the Air Force increased in importance, as well as in budget share, during the strategic buildup of the 1950s, the Army struggled for a sense of purpose. Wars would be won simply by sending bombers across the world to enemy nations. Those troops deployed along the front lines were seen merely as a tripwire to activate the strategic nuclear forces. In one attempt to establish some relevance by taking on some small role in nuclear war the Army developed and fielded artillery armed with nuclear warheads.[21] It was against this backdrop that General Taylor began developing a strategy that focused more on conventional forces, with a more prominent role for the Army. While Taylor's ideas had much validity from strictly a national security standpoint, the implications for service relevance cannot be overlooked.

The change from the strategic nuclear bombardment DME to the close-in air-to-air multirole fighter DME has been traced through study of the three aircraft development cases. Taylor's prominent role in working with the Kennedy administration to implement the Flexible Response strategy, McNamara's efforts to build a conventional force; air superiority advocates becoming more vocal and influential; feedback from the Vietnam War and the Arab-Israeli Wars; the use of new analysis techniques such as EM theory and TAC Avenger; changing budget priorities, and the development of new technologies such as the AWACS, precision guided munitions, improved air-to-air missiles, and improved avionics all played a part in the transition. The result was a conventional force that was dominated by fighter aircraft capable of providing all types of air power functions, but optimized for close-in air-to-air combat.

The shift from the strategic nuclear bombardment DME to one of multirole fighters that emphasize close-in air-to-air combat, occurred over a period of a little more than a decade. This period, beginning in the early 1960s and stretching into the mid 1970s, is also the period covered by the three case studies presented. This allows for an analysis of not only the origin of the weapon system, but its relationship with the DME.

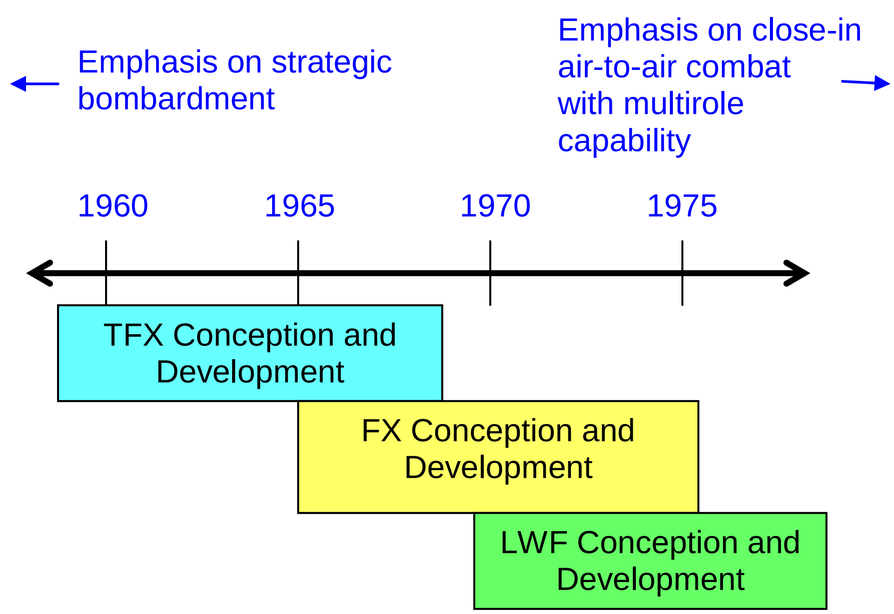


Figure 6.5. Timeline of the DME shift as it relates to the case studies.

Perpetuation of the DME

Much is invested in and committed to the DME. The main commitment is that the nation's security depends on the ability of the emphasized mission to meet the military needs in case of war, and proponents of the DME believe it can do that. Money is also committed to the DME. As shown in the case studies, systems are designed and produced based on it, which is an investment of billions of dollars. More than just money is invested in the DME, however. Organizations are built to support it, and people within those organizations, build their careers around it. Because a career is such a large part of one's life, identities and egos can become tied to a particular DME. It was said of General Thomas S. Power, LeMay's successor as commander of SAC, that it "broke his heart" to watch the bomber mission slowly lose importance during the 1960s. It meant more than a security strategy to him, and many of those who devoted their careers to it.[22] The relevance and influence of organizations, and the people within them also relies on a DME supported by them. The Air Force based its existence, at least initially, on the strategic nuclear bombardment DME, and TAC almost withered during the same period, and may have had it not contributed to the DME with tactical nuclear weapons. Because so much is invested in the DME, those who have made the investment are compelled to protect and perpetuate it in order to protect that investment.

DME as a Way to Bound a Complex Problem

Decision makers are forced to make strategy and procurement decisions, choosing from a nearly infinite number of permutations of an unmanageable number of variables. This enormous amount of information is impossible to collect, much less assimilate. According to Simon, as a result they seek ways, either consciously or unconsciously, to bound the problem in order to reduce the complex decision to one that can be made in a more rational manner. In this context, the DME serves as a mechanism by which decision makers reduce the solution space. The rational and irrational inputs (Simon's terms) to the DME, which will be discussed later, are the heuristics which Simon argues are used to create the bounds. The resulting decision will not be an optimization, if such a solution exists, but will satisfice for the given conditions.[23]

DME as a Vehicle for Consensus

Strategy and procurement decisions will almost never be unanimous. They can only be made by consensus, reached when there is enough support to enable a decision. In the *system* under which the Air Force operates, and by the nature of its purpose, decisions about how to employ force and which equipment to use in the undertaking, require significant amounts of economic, technological, political, and military resources. As seen in the three cases, the ideas of decision makers regarding where and how to commit resources can be spread across many options. The DME provides a vehicle for marshalling enough support for one idea in order to amass sufficient resources to support actions, such as a procurement program, on it. An example of this was the establishment of a unified Air Force position that the FX should emphasize the close-in air-to-air combat mission, with the unofficial understanding that it would have a secondary air-to-ground capability.

Challenges to the DME

Because the DME has a limiting effect, and narrows the field of solutions to those based on accepted ideas, it necessarily excludes some ideas from being acted upon. Participants can either choose to adopt the DME and be included, or they can achieve inclusion by changing the DME to one based on their dissenting ideas. In the 1950s many fighter pilots adopted the strategic bombardment DME either because they believed in the bombardment mission, or because they believed that was the only way to obtain resources and maintain relevance. In the early 1960s those who believed fighters should not be an appendage to the bombing mission, but should emphasize a multirole fighter with the primary mission being close-in air-to-air combat, chose to try to change the DME, and were successful. Not all challenges are successful, such as that advocating low technology, day, visual fighters deployed in very large numbers, which was pushed by the Fighter Mafia. Because of the wide range of ideas that exist, and the ever changing environment in which they are conceived, there is constant questioning, challenging, and testing of the existing DME, at least to some degree.

Indicators of "Emphasis"

A concept such as emphasis is difficult to quantify since it is based on the prevailing thoughts and beliefs of those involved. It is, however, possible to establish a qualitative measurement to determine which mission is being emphasized, and how forcefully. To do this it is necessary to examine the indicators of the thoughts and beliefs of those involved.

Verbal Indications

Statements made can be indications of thoughts and beliefs affecting the DME. In procurement activities, where building consensus and support is vital to successfully procuring a new weapon, the dialogue and debate provide indicators for prevailing thought. Congressional testimony, public statements, briefings, and even private conversations, as well as any accompanying documentation of such verbal communications, serve this purpose. Of course the decisions of interest such as those dealing with the procurement of weapons are very political activities, and therefore not everything that is said can be taken at face value. Arguments can be used to gain support, but may not be indicative of the actual thought process. For this purpose actions must be observed and correlated with verbal statements.

Strategy, Doctrine, and Plans

Strategy, doctrine, war plans, and other official policies which are used to commit forces can reveal what decision makers' thoughts are regarding those forces. The strategy of Massive Retaliation and Flexible Response were the policies the DME was supposed to support. A study of Air Force Doctrine over the existence of the service indicates a pattern of thought that correlates to the existing DME as well.*

Initially each edition of the Air Force Basic Doctrine Manual placed a heavy emphasis on the strategic bombardment mission. It was not until the August 1964 edition that a small section was added addressing conventional warfare, even though it still exhibited a primary reliance on nuclear bombardment. For example it stated that the best way to defeat enemy air power was to bomb airfields, and the preferred method of protecting U.S airpower was through dispersion and shelters. In 1971 the approach was more balanced, but two chapters were dedicated to nuclear war, and only one to conventional. By 1975 the presentation was approximately even, but a clear emphasis on nuclear warfare was expressed in the tone of the document. Finally the 1979 edition

* The study referred to included a review of all Air Force Basic Doctrine Documents and Manuals published during the period from 1946 to the mid 1980s. See note 24 at the end of the chapter.

presented warfare as a spectrum of conflict across which the Air Force must be prepared to fight. It listed nine basic operational missions of which strategic aerospace offense was only one, and its deterrent role was listed as primary. Counter air and CAS were given equal representation, and defensive counter air (air-to-air combat) was given the same priority as offensive counter air (bombing of air assets).[24]

These indicators are useful, but only insofar as decision makers choose to follow established policies. Kennedy's mere statement of his new strategy did not mean that all Air Force leaders accepted it, and would make decisions based on it. Also, although established doctrine did correlate to the DME, there was lag after the time a DME appeared to be accepted, when the published doctrine caught up with it. War plans too, may or may not reflect current thinking. The plans for Vietnam were developed independently despite the existence of the Single Integrated Operating Plan for nuclear war. With these limitations, however, published policy can provide an indication of thoughts and beliefs related to the DME.

Intellectual and Academic Writings

The intellectual writings of those in the Air Force, while not policy, can give an indication of the prevalent thought in the service. The main vehicle for such writings in the Air Force was the *Air University Quarterly Review* (later the *Air University Review* and then *Air & Space Power Journal*). When General Muir S. Fairchild was the Commandant of Air University he established the journal in 1947 stating that it would be, in certain respects, "an extension of the concepts and doctrines developed at the Air University."[25] A comprehensive review of the articles that appeared over the course of publication reveals articles supporting the DME, along with some that focus on different missions and topics, including logistics, analysis, air transport, and toward the end of the 1950s space related topics, as well as some about tactical air power and fighters. While there is no consistent strand of topics over time, it is possible to gain an idea of prevalent thinking based on the general tone of the articles.

The articles in the first volumes, published in the late 1940s, were decidedly oriented toward the strategic nuclear bombing mission, including articles with titles such as, "Employment of Strategic Air Power,"[26] or "The Air Offensive in Overall Strategy."[27] There are even some articles submitted by de Seversky.[28] This continued well into the 1950s, with some volumes having more divergent ideas than others. These include, for example, an article titled, "Tactical Air Power,"[29] by Lieutenant General Elwood R. Quesada, the first commander of TAC; and "The Tactical Air Command School of Air-Ground Operations," a 1950 article positing that Korea showed the need for better air-to-air training in TAC.[30]

Beginning in the mid to later 1950s articles with titles such as, "Atomic Weapons and Theater Warfare" and "Nuclear Weapons and Limited War" began addressing the introduction of tactical nuclear weapons, and TAC's gravitation toward SAC's mission.[31] Issues at the end of the decade and into the 1960s were dominated by articles addressing space and missiles. Topics related to the Vietnam War, such as counterinsurgency and limited war began to appear in the early 1960s, with a corresponding decrease of attention on strategic nuclear bombardment, although articles addressing the subject continued to be published. By the mid to late 1960s, although the number of strategic bombardment oriented articles dropped, the space was not taken over by fighter oriented articles, although more were published than previously. Some of those were of the advocacy variety such as one by Vice Chief of Staff, General Holloway titled, "Air Superiority in Tactical Warfare."[32]

The journal articles do not show a distinct transformation, although over time there is a trend away from the strategic bombing mission as a topic, and a slight increase in interest in tactical fighters, especially the air-to-air mission. While the subjects of the journal articles provide insight into the thoughts of the Air Force, again there are limitations. Authors come from all career fields and are not necessarily decision makers. Often those involved most heavily in frontline operations are not as involved in the intellectual side of the Air Force and their views may be underrepresented. Furthermore, articles addressing possible DME options are mixed in with articles about law, management, logistics, training and education, and several other diverse topics, which make it difficult to determine if an idea is part of an emerging DME, or just a passing thought for an academic discussion.

Organization

The established organization of the Air Force can indicate the DME and how strong it is. In March 1946 the Strategic Air Command, the Tactical Air Command, and the Air Defense Command (ADC) were organized out of the diminished forces left after the postwar demobilization. It is significant that two of the three commands, SAC and ADC were in direct support of the nuclear bombardment mission. SAC had responsibility to deliver the weapons, and the interceptors assigned to ADC were to defend the nation against incoming enemy bombers. TAC was created at the insistence of Eisenhower, who was Army Chief of Staff, to ensure air assets would be available, trained, and ready to support ground troops.[33]

SAC, as custodian of the premier mission, quickly assumed a dominant role. All Air Force Chiefs of Staff until the 1980s were raised in SAC as were most of those who held key positions on the staff. There was a general recognition that SAC received priority, and all other commands were there to support it. Disosway claimed, "[SAC was] bigger than the Air Force."[34] As shown, TAC struggled to acquire new equipment, and to maintain relevancy. Ultimately it found ways to participate in the DME to solve these problems. As one fighter pilot and general put it, "[TAC] tried to 'out SAC' SAC."[35]

In the 1960s with the shift in DME, as a result of factors already presented, the importance of TAC began to grow. With the replacement of the Soviet bomber threat with that of nuclear missiles, the air defense mission grew less important, and in the early 1970s most of the interceptor units had been consolidated and moved to the Air Force Reserves or National Guard. By 1979 all ADC assets were put under TAC, and early the next year the command was deactivated altogether.[36]

SAC's dominance also began to diminish as a result of the DME shift to fighter missions. The secondary role played by strategic bombers in Vietnam, along with a realization that future wars would most likely exclude SAC as well, added to this. After a slow decline, in 1992 SAC was inactivated, with SAC assets being combined with TAC assets in the new Air Combat Command (ACC). The justification was the decreased likelihood of massive nuclear warfare and the disappearance of a meaningful distinction between strategic and tactical missions.[37] Perhaps tellingly, however, the new ACC insignia looked identical to the TAC insignia, with only the name having been changed.

Another perspective on organizations is the number of wings (formerly called groups) of each type of aircraft over the course of Air Force History. Figure 6.6. shows the general decline in forces as technology replaced numbers, but the number of bomber wings is a steady decrease, while the number of fighter wings builds slightly beginning in the 1960s. Figure 6.7. shows the same numbers, but as a percent of the total of both fighter and bomber wings. This view shows the increase or decrease in number of the two different variety of aircraft wings relative to each other. In this view a clear reversal of organizational dominance can be seen taking place beginning in the early 1960s.

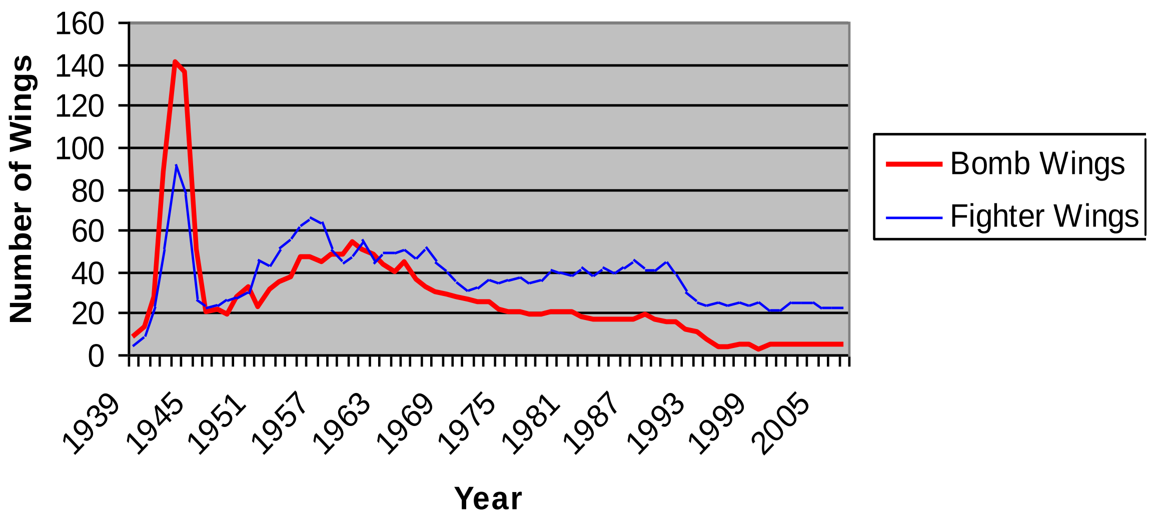


Figure 6.6. Bomber and fighter force strength over time.

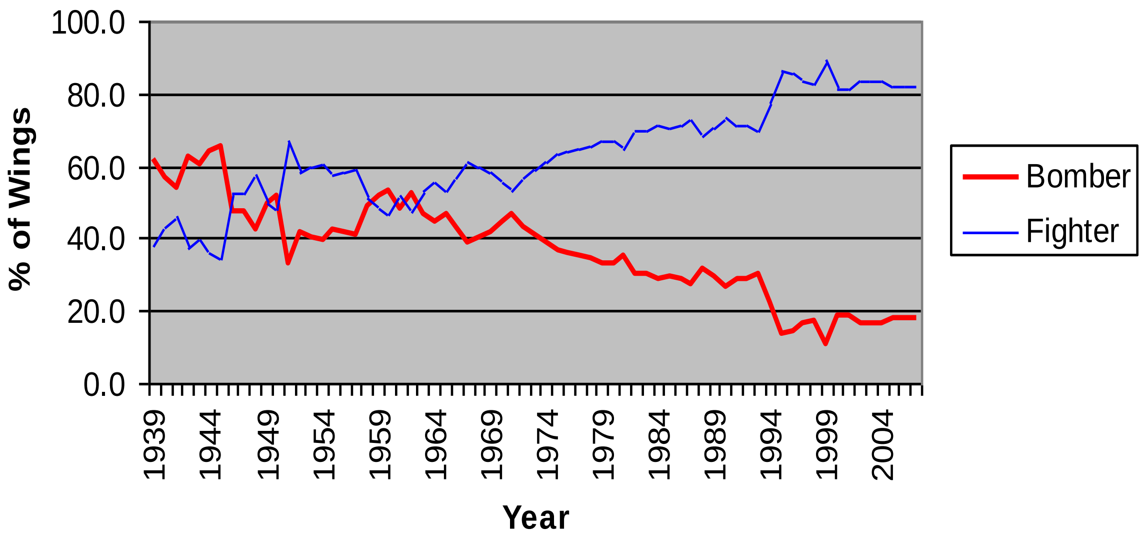


Figure 6.7. Number of bomber and fighter wings as a percent of total (bomber plus fighter wings) over time.[38]

Resources Committed

One of the most telling indications of what decision makers think and believe is the commitment of resources. The following charts consistently show a change in emphasis from the strategic nuclear bombardment mission to the fighter missions. This change is evident beginning near the early 1960s in each graph. The various graphs show SAC and TAC resources of different types. As with force structure, the raw numbers will be shown, followed by the resources of each command as a percent of the combined total, in order to show relative change.[39]

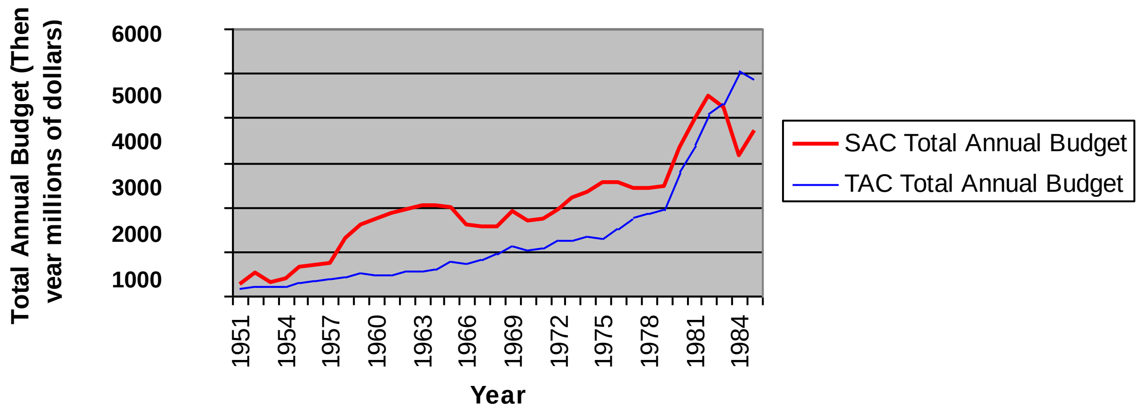


Figure 6.8. SAC and TAC annual budgets over time.

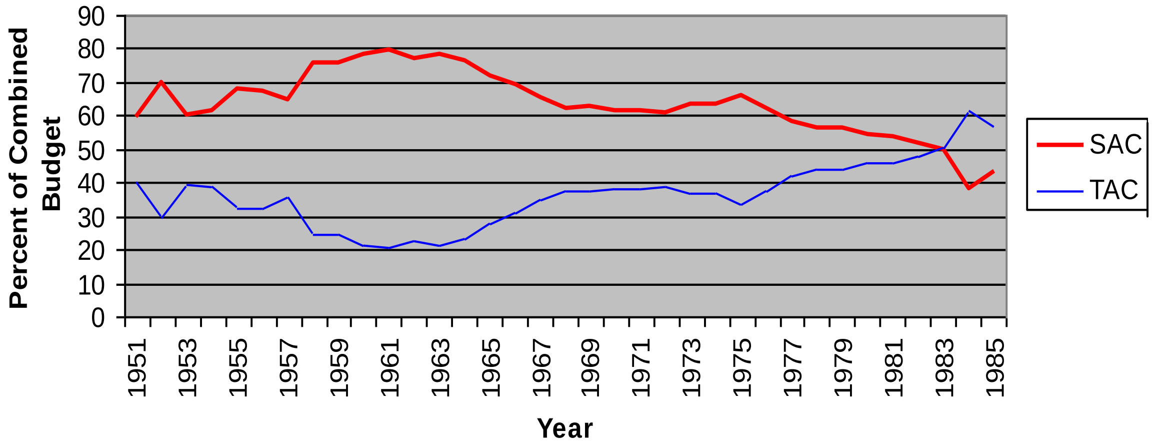


Figure 6.9. SAC and TAC annual budgets as a percent of total over time.

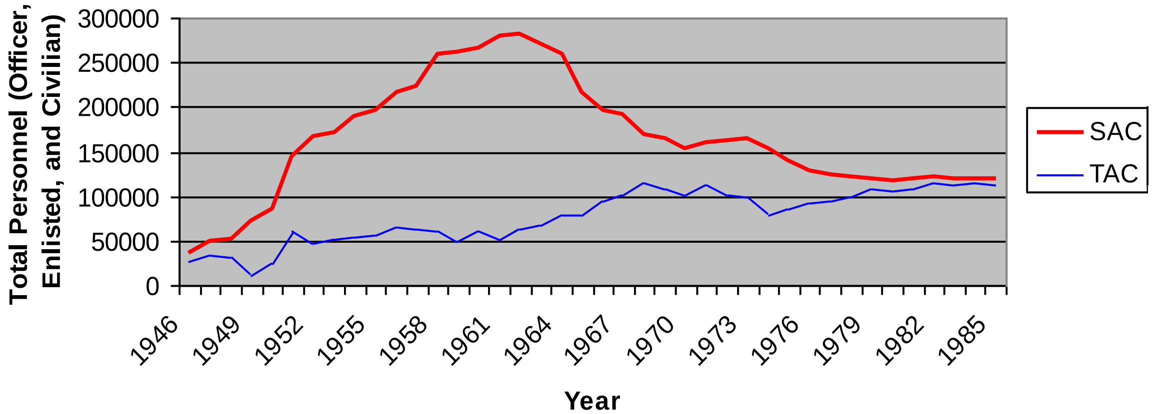


Figure 6.10. SAC and TAC total personnel assigned over time.

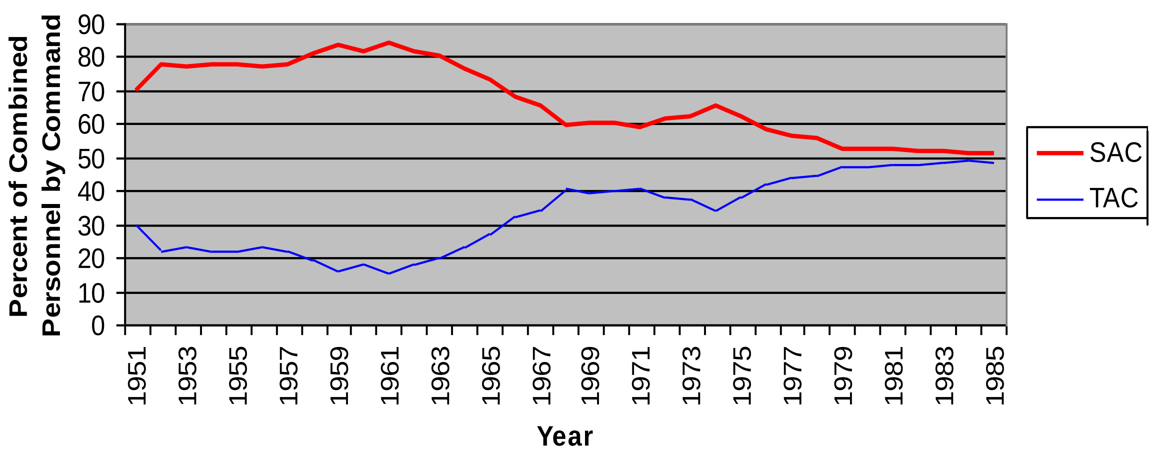


Figure 6.11. SAC and TAC total personnel assigned as a percent of total over time.

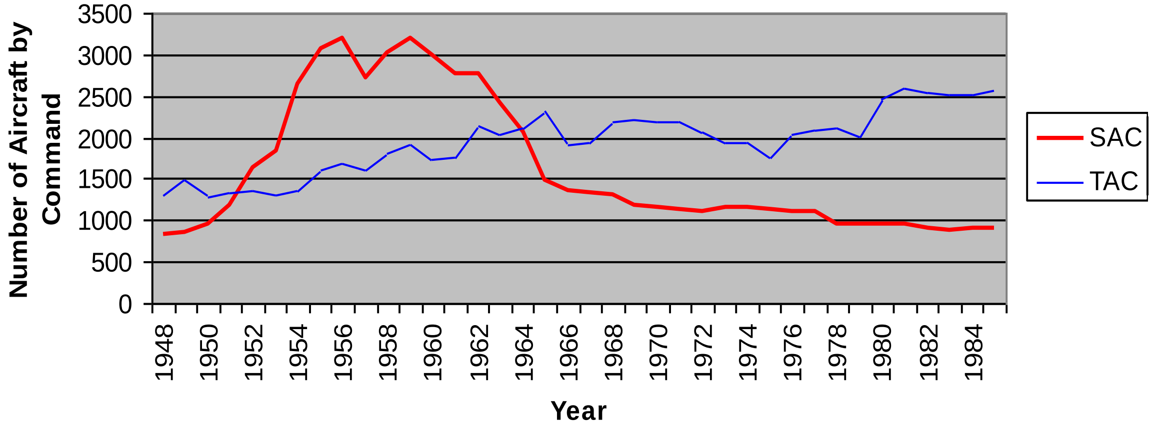


Figure 6.12. SAC and TAC total aircraft assigned over time.

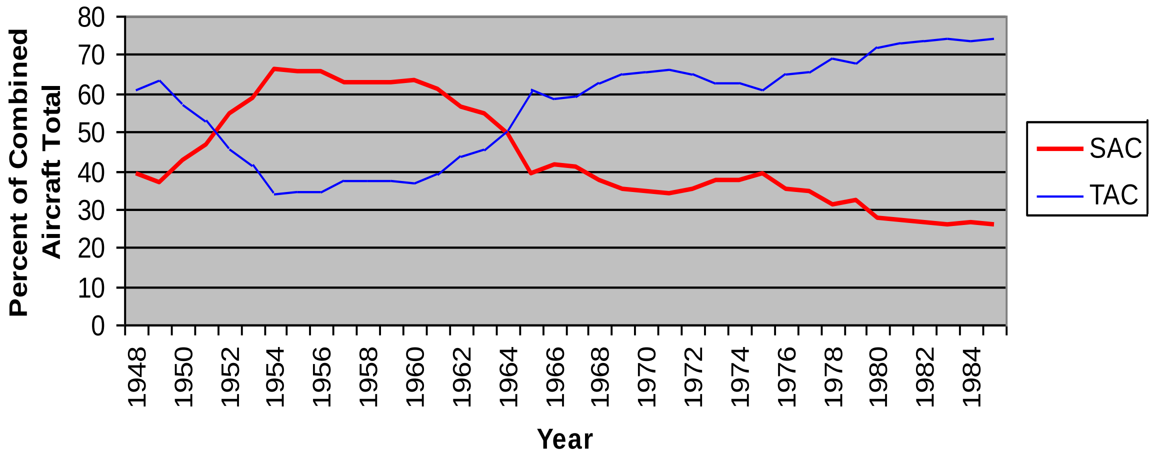


Figure 6.13. SAC and TAC total aircraft assigned as a percent of total over time.

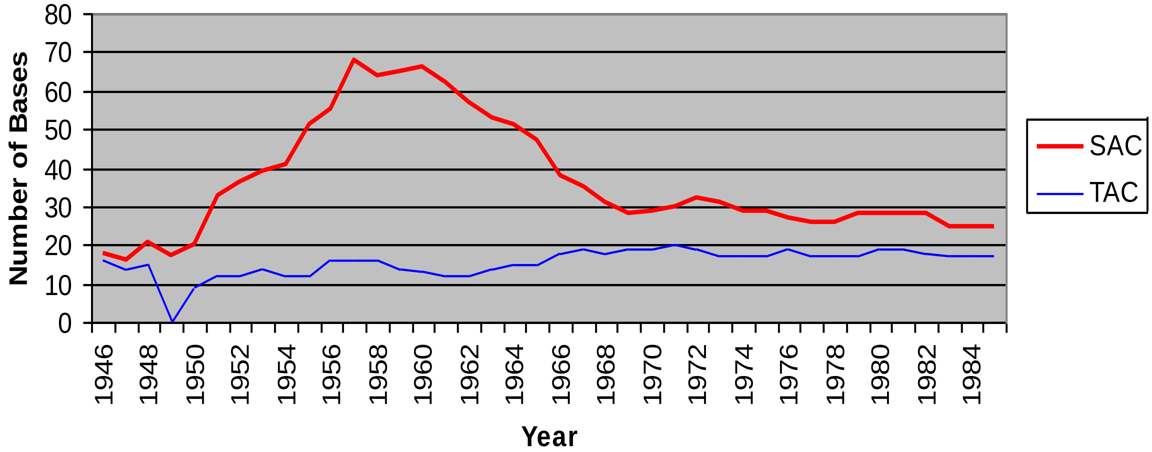


Figure 6.14. SAC and TAC total bases over time (including SAC intercontinental ballistic missile bases).

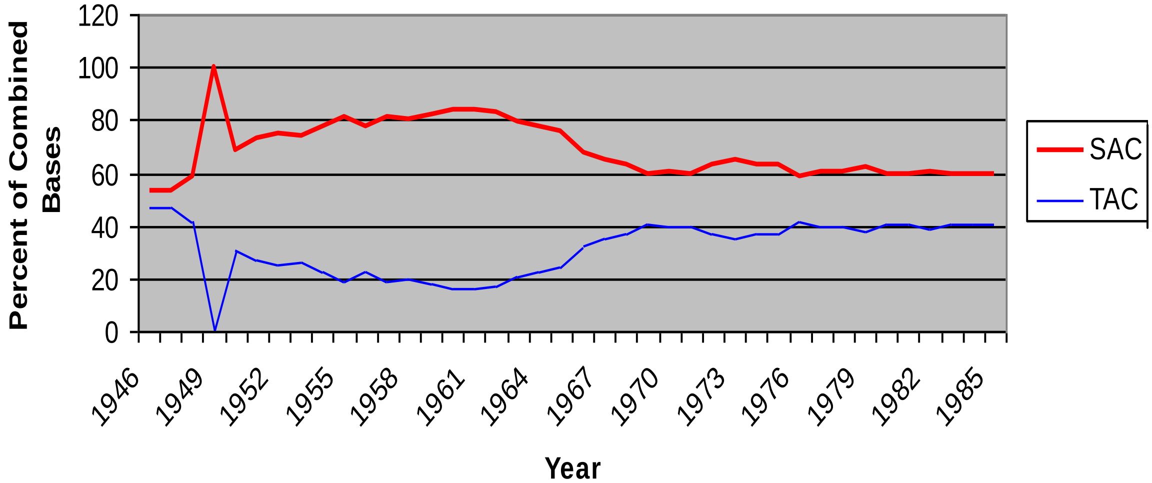


Figure 6.15. SAC and TAC total bases as a percent of total over time.

Training

One way to measure the emphasis placed on a mission is to observe the training that is done to improve the capability. During the 1950s SAC crews trained and were exercised regularly in the details of the nuclear bombardment mission. Alert procedure, command and control procedures, launch procedures and bombing were consistently practiced, with crews being scored on their performance. In 1957 crews began maintaining constant nuclear alert, which further heightened training levels. Fighter training during this time consisted predominantly of bombing and intercept operations. Close-in air-to-air combat training was not only neglected, but in most circumstances it was against regulations because the associated danger was considered to be unjustified since the skill was seen as unnecessary.[40]

Later, as emphasis shifted to the fighter mission close-in air-to-air combat training was resumed and improved, along with that of other fighter missions.* SAC, in the meantime, began lowering their alert commitment and increasing training in conventional warfare. In 1964 the number of nuclear missiles on alert surpassed the number of bombers, and continued to increase. This added to the decline in the emphasis on manned bomber missions, and by 1991 the alert force was stood down.[42]

Promotions and Positions

Who is promoted and who is put in key positions indicate what mission is being emphasized, and how much emphasis it is receiving. In the 1950s the emphasis on the strategic bombardment mission was evident from the way SAC dominated the Air Force. The Air Staff was largely made up of former SAC officers, and while he was commander of SAC, LeMay sent competent SAC officers to the Pentagon, and later recruited them

* In 1975 a comprehensive combat training program called Red Flag was established at Nellis Air Force Base, Nevada. The program was based on a study that determined that those pilots who survived ten combat missions increased their survivability rate from around 50% to approximately 90%. The exercise attempts to simulate combat as realistically as possible, including encounters with dissimilar fighters employing tactics used by potential enemies.[41]

once he was Vice Chief, and then Chief of Staff. This not only provided an indication of emphasis on SAC's mission, but also served to perpetuate the DME, since LeMay was a strong supporter of it. These actions were the result of a conscious decision by LeMay to further SAC's interests.[43] He also instituted a spot promotion program in SAC, in which those crews who achieved the highest bombing scores received promotions, along with the increased pay, emphasizing the importance of mastery of the mission. No other command in the Air Force had such a program.[44]

Worden conducted a study on career progression as a function of career field, and established that those raised in the strategic bombardment career field made rank faster, and at a higher rate than those in other career fields. By the early 1960s over half of the four star generals were bomber pilots, and with LeMay's appointment as Chief, that number increased. A SAC general (Sweeney) was even appointed to command TAC. In the later part of the 1960s, however, officers brought up in the fighter career field began to have more influence. They were promoted at an increased rate, until eventually there were more fighter pilot four star generals than those brought up in bombers. In 1982 for the first time a fighter pilot held the position of Chief of Staff. Over time, bomber generals were completely replaced by fighter generals in leadership positions.[45] While there was somewhat of a lag, the trend of promotions and appointments does correspond to the establishment of a DME, and can therefore be used as an indicator.

Undocumented Inputs to the DME

The same undocumented inputs that go toward shaping a weapon system also shape the DME for which the system is being developed. Figure 6.16. gives a visual summary of those inputs, and their relationship with the DME and the resulting weapon system. As shown in the figure, the documented requirements process is carried out with the DME as a backdrop. The undocumented inputs influence the determination of the DME, which becomes a starting point for the documented requirements process of a weapon system. This influence is manifest in predetermined decisions in the resulting weapon development programs. Therefore, this model for understanding undocumented inputs can be applied both at the weapon system level, as described above, but it can also be applied at the broader *system* level, in the establishment of a DME.

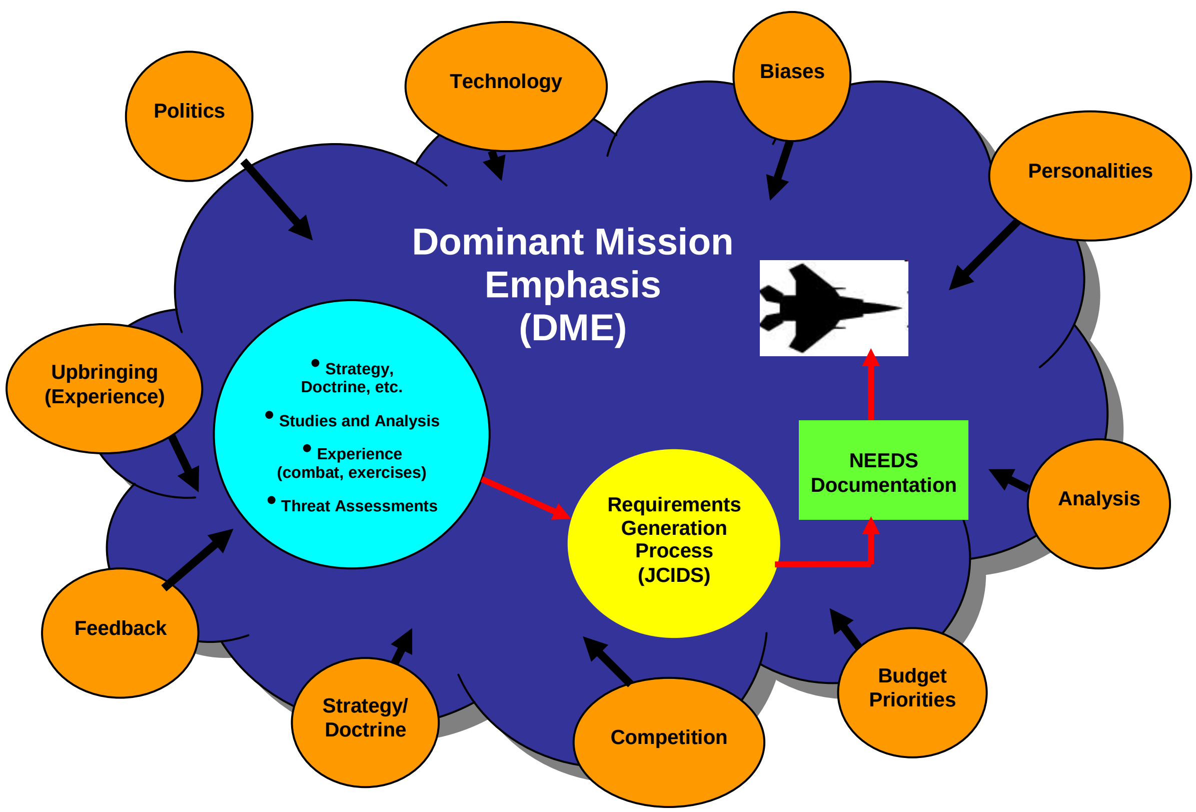


Figure 6.16. Undocumented inputs to the DME and weapon systems.

In this figure, the orange bubbles represent the undocumented inputs that influence the DME (the blue cloud). The cloud representation connotes the changing nature of the details of the DME and its indistinct boundaries resulting from the irregular magnitude and direction of the inputs. Within the DME, in the light blue bubble (the circle on the left), are the documented inputs to the requirements of new systems. These feed into the documented requirements generation process, which is currently the JCIDS, represented by the yellow bubble in the center. The green square represents the documented needs, which are in the form of formal documents, and from which the system is designed.

The physical and intangible resources invested into a DME (or a system), such as money, time, political capital, careers, personal reputation, and so forth, create momentum, in the Hughes usage of the word. This momentum will continue to push a DME in the direction it is going despite rapidly changing conditions, and despite constant challenges to the DME. One result is that the momentum acts as a damper, which keeps efforts focused on the emphasized mission through perturbations of conditions that would invalidate the DME if considered in the short term, but over time fail to warrant a change. Another result is to create inflexibility in the *system* because any DME change in response to new conditions which actually do warrant a change must first overcome the momentum of the established DME.

To complete the introduction of the DME model, Appendix A presents analysis explaining each of the inputs that create and perpetuate a DME. As pointed out, these inputs are the same as the undocumented inputs to a weapon system.

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Chapter 7
Conclusions about the DME and Its Inputs

Appropriateness of the DME

This study has referred to a DME as being decided upon, or selected. If one accepts the premise of a DME, as described, and based on the results of the case studies and the analysis of those results, it follows that some mechanism exists for a DME to come into existence. This "selection" is not a deliberate action of one person or organization, however. As stated, it requires the support of a majority of decision makers, and those who support them. When enough support builds behind an idea related to a mission, so that major decisions regarding the commitment of resources are made based on that idea, it becomes the DME. The definition of a "major decision" is a subjective evaluation based on the indicators presented in chapter six.

The emergence of a DME begins with ideas resulting from the undocumented inputs presented, and then is spread through a social process of convincing others to support the ideas. Because there is no one correct DME, there can be no fixed process for proving that a certain DME is the most appropriate. The best one can do is to amass evidence for the appropriateness of a DME, and then work to use that evidence to gain allies who will also support the DME. This effort has a technical side, as well as a political side, a financial side, a personal side, and so forth. The side or sides of this multi-faceted effort that is most convincing or influential depends on the person who is the object of the efforts. For example, an engineer may be more convinced by a quantitative based computer model, a member of Congress by a budget analysis, one officer by the alignment of the new DME with his or her upbringing or chosen career path, another officer by its perceived effectiveness against the threat, and to the public by the appeal of the advanced technology associated with it. Those attempting to sell a DME, whether it is already established or not, will necessarily make efforts at convincing others in a variety of ways. Rhodarmer described the process as “missionary work,” and Myers referred to his work as a “crusade” and a “campaign to alter the mindset at Washington,” and talked of getting people “on our team.”[1]

Because the DME has such an impact on the commitment of resources, it is useful to know if the DME is appropriate for the existing and future conditions. In other words, if the DME is on the bottom right tail of the bell curve presented in Figure 6.1., it would be useful for decision makers to know that before committing more resources. The dynamics for determining the appropriateness of the existing DME are the same as for determining the appropriateness for a new proposed DME.

When the evidence that the DME is no longer appropriate is enough to overcome the DME’s momentum being felt by a person or group they will work to sell the need for change. This is usually accompanied by the advocacy of a certain solution, or new proposed DME. The momentum can be in the form of a belief that the current DME is the best way to defeat the enemy, faith in current technological capabilities, a perception that the existing DME will enhance a career, or other factors based on the undocumented inputs. The threshold for overcoming momentum can be different for each participant. Whether or not the DME is at the bottom right side of the bell curve, and therefore needs to change, is a subjective evaluation of cues regarding DME appropriateness, which will be discussed below.

In this subjective evaluation, the term appropriate is defined as fulfilling the military, political, financial, and personal objectives expected by the person or organization conducting the evaluation. The mere presence or absence of a particular cue does not necessarily mean that the DME is inappropriate, only that it may be. All inputs must be evaluated as a complete *system* in order to make a determination.

The following list of cues indicating that a DME may be at the bottom right side of the bell curve is not exhaustive, but includes those primary cues that were evident in the case studies. A change in national strategy, such as Kennedy's change from massive retaliation to flexible response is a cue that the DME may no longer be adequate. When the implications of the new strategy become apparent, for example the inability to use nuclear weapons to bomb enemy airfields in Vietnam, the cue becomes stronger.

Another cue is the emergence of a new technology that either decreases validity of the existing DME, or that offers the capability to implement a new DME that was previously not feasible. An example of the first case is the capability of SAMs to reach strategic bombers. The B-70 was an attempt to adjust to this new technology, but its effectiveness was questionable, and its cost prohibitive. The technology innovations that allowed a low cost lightweight fighter to have a credible combat capability (afterburning turbofan engine, relaxed static stability, AWACS, improved weapons, etc.) fall into the second category.

Combat experience can be a cue. The loss of frontline U.S. fighters to older Soviet MiGs while performing their bombing missions in Vietnam prompted many people to begin to question the strategic bombardment DME. For some, the Cuban missile crisis indicated the need to rethink the DME, however for some it confirmed the existing one, demonstrating again the difficulty in drawing a consistent interpretation of results from combat scenarios.

New ideas being introduced by people, such as Billy Mitchell advocating strategic bombardment, or Agan and Myers advocating air superiority fighters, can lead to questioning, and thus be a cue. A change in the economic situation resulting in more available funding, such as the increase in funds associated with the conventional build up on the 1960s that allowed a single mission FX to be considered, or a decrease in funding, such as the associated de-emphasis on the nuclear mission which led to the cancellation of the B-70, is a cue. A change in the expected threat, such as the MiG-25 which called into question the ability of bombers to reach their targets and the ability of an FX^2 type fighter to succeed, can indicate the possibility of the need to change the DME.

The results of analysis can be a cue that a DME might be at the bottom right side of the bell curve. Analysis is related to previously-mentioned cues, since it is done in those areas, such as budget analysis, threat analysis, and technology analysis. As before, however, it is listed separately since a study or a method itself can be a cue. For example, EM analysis brought a new approach to threat analysis. While the known attributes of the threat aircraft did not change, the EM analysis that showed a previously unknown vulnerability to the threat caused people to rethink the DME.

These cues were those conditions present during the DME change that occurred during the case studies. They did not cause the change, however. Overcoming the momentum to change the DME is a result of the social process described below.

Changing the DME

The primary factor in overcoming the momentum of a DME, and convincing others to support a new DME is credibility. From the case studies those factors that established credibility and made a difference in building sufficient support for the new fighter oriented DME were identified. Different credibility factors influenced people in different ways. What provided a credible reason to change the DME for one decision maker may not convince another. Ultimately it required a varied mix of credible evidence to convince an individual that the DME needed to change, and that the new DME was more appropriate. To convince enough individuals for the new DME to be accepted required an even broader mix.

One of the most important factors in the establishment of the credibility of a person who is advocating the need to change the DME, or a possible new DME is that person's experience. Especially important is combat experience, as determined by such things as number of combat missions flown, decorations received, aircraft shot down, difficult targets bombed, pivotal missions participated in, hardships endured, and similar things. Other measures of experience are time in service and specific assignments or positions held. Experience other than that in combat is also valued. Longevity and accomplishments in other areas are also respected, such as academic, government, or corporate service.

Rank and position, while often based on experience, represent a separate factor of credibility. Regardless of an individual's experience, if a high ranking general, a commander, the CEO of a major defense contractor, a Senator, or a Service Secretary, for example, weighs in on a subject, people will be more inclined to be persuaded than by a person without the rank or position. Furthermore, rank and position can gain access to a wider audience of listeners, thus increasing their influence.

Also related to experience, but treated separately, is the association with prior successful programs or projects. Stack's work with the X-1 and Johnson's work on such successful aircraft as the P-38, the F-80, and the SR-71 gave them credibility enjoyed by few others. Seamans' work on Apollo, Bellis' work as SR-71 program manager, and Packard's corporate success are other examples.

Personal presentation in advocacy situations was shown to be an important factor in establishing credibility. Such situations include meetings with high profile decision makers, Congressional hearings, and public engagements such as press conferences. Impressive personal appearance, articulate speech, and decisive confident responses were cited as having a positive effect on one's credibility. Of course, also important was preparation so that the presenter was able to anticipate questions, give clear and accurate responses, and think on his or her feet.

Analysis, tests, and combat results were shown to be a major factor in the establishment of credibility. EM analysis and TAC Avenger provide example of credible analysis that heavily influenced decision makers. Such tests as the bombing and sinking of the captured German battleship *Ostrfriesland*, considered unsinkable by the Navy, by Billy Mitchell in early bombers provided credibility to his claims of bomber capabilities, and advanced the argument beyond verbal debate. The importance of the "combat proven" label, and the difficulty of arguing against actual combat results have been established as arguably the most powerful factor. This is the case whether results are positive or negative. The negative results of the F-111 in Operation Combat Lancer made it difficult for anyone pushing for a continuation of the DME that produced it to gain credibility. Ideas that can be supported with positive results of validated analysis, tests, and combat operations are very difficult to discount.

Simply because an idea is new does not make it better, yet innovation, especially as it relates to technology can add to credibility. The TFX program derived credibility from the innovative variable geometry wing. As insignificant a factor as it is, the side stick controller on the YF-16, which Hillaker said was simply a necessity because of the size of the aircraft, the cockpit layout, and the position of the pilot, was seen as very innovative and received an inordinate amount of attention and praise.[2]

The very fact that people begin to accept an idea accelerates its acceptance among others. Consensus for an existing DME can influence people to trust the collective wisdom of the majority. As support begins to form for a new DME that support increases the credibility of the new idea. Consensus can add to the momentum of an existing DME, but once that momentum begins to shift, support for the new DME will contribute to that shift. One form that support can take is a "corporate position," or an openly recognized position of leaders in an organization. Whether or not all of the generals agreed with an FX that was a single mission air superiority fighter, McConnell was able to get them to acknowledge that position publicly, which increased the credibility of the position, and thereby increased the credibility of a change in DME.

Many decision makers have a personal bias, even when they attempt to suppress its influence over decisions. When a new DME is proposed that is compatible with an existing bias, the bias has the effect of giving credibility to that DME. The bias toward advanced technology held by many in the Air Force made the arguments for a high technology F-15 more credible. The same was true for an F-16 that was missionized with, and supported by, advanced technology. Sprey, Riccioni, and others found difficulty convincing others to support a shift of DME to one of day, visual fighters employed in large numbers because they did not conform to the advanced technology bias that existed.[3]

Based on these conclusions, it follows that in order to establish a new DME, if it is determined that a new one would be more appropriate, a person should focus his or her efforts on building credibility. The factors identified that affect credibility provide a guide for doing so. Conversely, any action that could hurt credibility should be avoided.

As established, there is no official declaration of the adoption of a DME, but rather it can be determined by the indicators identified in chapter six. Therefore, when enough of the indicators point toward a certain DME, it can be considered as "established," which means future weapon system decisions will be influenced by it. If a person or group is trying to establish a new DME, therefore, the goal should be to increase the strength of the indicators.

The indicators are things that can be controlled. For example, verbal indications can be increased by speaking out about ideas, such as the efforts by Mitchell and Myers. While national strategy is beyond the control of the military, the Air Force writes its own doctrine and plans, and they can be oriented toward a new DME. People at all levels can submit articles and speak at conferences. Organizations can be manipulated to support a new DME. Depending on the level at which a DME is being introduced, training can be conducted in the mission for which emphasis is being advocated. People in favor of the new DME can be put in positions to have more of an impact. At the Air Force level those whose experience and expertise support the new DME can be rewarded with promotions. Finally, resources can be committed to the new DME.

Being able to control this last indicator; resources, is the goal of the advocacy efforts. The establishment of a DME influences the decisions regarding weapon system development, which is almost the equivalent of deciding where to invest resources. Committing resources at lower levels in support of a DME is a way to create a situation in which resources at the weapon system development level can be controlled, and be invested in support of the DME. For example, Riccioni's efforts at procuring funds for the LWF study led to more funding for the LWF prototype program. These initial investments led to a production aircraft that supported the new DME.

Efforts to control the indicators require credibility. Verbal efforts, articles submitted, proposed doctrine, organizational structures, training conducted, requests for resources, and promotion decisions all must be done with credibility. If efforts are not credible they will either be ignored, or they will create negative reactions, such as criticism, cynicism, or animosity, and ultimately undermine efforts to bring about a change of DME.

The Role of Leadership

In the mythology of institutional change, especially concerning the military, there is often a focus on the charismatic individual leadership of a single personality. Mitchell is seen as the driving personality behind strategic bombardment. Similarly, some people, such as Boyd's biographer, give him credit for the resurgence of the air-to-air mission. This study disputes the concept of the individual champion that single-handedly changes institutional thinking. Leadership is important in the change process, but it is only one factor. It must be used in conjunction with the change mechanisms described, and it must also have credibility.

Mitchell was a central figure in the establishment of strategic bombardment, and his leadership was essential. The flamboyance and outspokenness for which he is well-known, however, was in addition to several other efforts. Ultimately Mitchell's contribution was to provide credible evidence that his ideas were sound. When enough people accepted his ideas, change occurred. Mitchell's efforts included verbal efforts, as well as published writings, including his book, *Winged Defense; the Development and Possibilities of Modern Air Power - Economic and Military*. He further set up organizations, such as the First Provisional Air Brigade at Langley Field, Virginia, which in 1921 included all twenty of the bombers in the Air Service. He oversaw training in the bombers which supported his vision of strategic bombardment, and he facilitated the promotion of those who supported his ideas.[4]

The extent to which Mitchell succeeded was proportional to the credibility he achieved. To his advantage, Mitchell was the son of a senator who attained the rank of brigadier general. He held the position of commander of all U.S. air forces in France during World War I, and earned several impressive decorations. After the war Mitchell was given the position as Deputy Director of the Air Service. Along with these achievements Mitchell was educated, articulate, and debonair, which captured the attention of people in high decision making positions. He further established credibility with tests set up to prove the value of the new bombers. Besides the famous sinking of the *Ostrfriesland*, he also conducted successful tests on three other battleships, which demonstrated the innovativeness of his ideas and equipment.[5]

Besides all of the credibility-building factors, Mitchell also lacked credibility in his attacks on institutions and ideas that were more strongly accepted. The idea of fabric covered bombers sinking armored battleships was incredible to the powerful naval hierarchy of the time, for example. Debates over interpretation of the *Ostrfriesland* test, which centered mainly around the absence of personnel on the ship which could have conducted damage control while shooting down the attacking aircraft, left those in the Navy unconvinced. Because Mitchell's ideas were based on the future possibilities of aircraft technology, with which most people in the Army and Navy – and in the country – were unfamiliar, he was not able to overcome the momentum of traditional army and navy forces.[6]

Mitchell's main success came in convincing those who were predisposed to his ideas, and had an existing bias for airpower. Lieutenant General Harold L. George, who as a First Lieutenant participated in the *Ostfriesland* test, later expressed that Mitchell was extremely influential to those in the Air Service at the time. Most of these were young officers the sum of whose experience was flying in World War I. These are the officers who went on to lead squadrons, establish and teach air doctrine, eventually lead the Air Corps in World War II, and succeed in establishing an independent Air Force based on Mitchell's ideas of strategic bombardment.[7]

Similarly Boyd has been called the leader of the Fighter Mafia, and by all accounts played an important leadership role in changing the DME. For some, Boyd's credibility came from his reputation as a fighter pilot. This was somewhat self promoted, but was supported by his publication of a fighter tactics manual while serving on the faculty of the Fighter Weapons School, as well as by some combat missions flown in Korea. Boyd's personal presentation, which was unkempt by military standards, was characterized by an extremely confident and argumentative delivery of his views, punctuated by profanity and gesticulations. While some were drawn to these characteristics, the main source of Boyd's credibility was his unsurpassed analytical capability. Most people involved in the establishment of the air-to-air fighter DME assign a great amount of credit to Boyd's EM theory, and his ability to apply it, in the selling of those ideas.[8]

Boyd's efforts in changing the DME were essential, however it is important to note that the DME Boyd was advocating, one supported by numerous very small, day, visual fighters, was not accepted. His important contribution was his EM theory, which allowed the comparison of aircraft maneuverability, and even contributed to the acceptance of maneuverability parameters as the new measures of aircraft performance, instead of size, speed, range, and altitude. Despite his strong personality, Boyd was not able to control how the results of the analysis were used, nor was he able to single-handedly change the DME.

The role of leadership, then, is the same as any other advocate for a change of DME, which is to control the indicators of the DME, as detailed above. Because credibility is the primary factor in the ability to control the indicators, one of the main goals of leaders should be to build credibility for their ideas. Those in formal leadership positions have a distinct advantage due to a certain amount of credibility inherent in the position, which is a result of its authority. Such leaders have greater access to the indicators that influence the DME. Leaders have authority to manipulate organizations, commit resources, and control promotions and positions, for example.

Because every leader is subject to his or her superiors, there is a limit to the effectiveness a leader can have in changing the DME. Before someone can implement changes beyond the level of responsibility associated with the leadership position, he or she must convince the leader or leaders at the next level that the new DME is worth the investment. Leaders at the top of institutions, such as the Air Force or Defense Department, not only have to convince those above them, but also their peers, and even people who are below them. This is what precludes the possibility of a leader simply dictating a change.

McNamara attempted to dictate a position that would have all services using joint aircraft systems. Despite his authority, and his strong insistence on his position, the Navy was able to outlast him and cancel the F-111B. The F-15 and F-14 programs are examples of deliberate efforts to avoid jointness, in reaction to McNamara's policies. McConnell assembled the team led by Rhodarmer to convince the Air Force to accept his unified position of a single-mission air superiority FX, since he knew simply dictating it would be ineffective. Jones made the agreement with Schlesinger to accept the LWF in return for more fighter wings, but stipulated that he had to convince the other four star generals that the idea was a good one. He stated, "When you get to four star, you are a pretty well protected species. You gain independence at that level. A Chief is much more successful if he can build consensus."[9] Schlesinger also described the constraints that even top leaders have. Speaking of the office of the Secretary of Defense he stated:

> …Although the responsibilities are very imposing, they are not matched by the powers of the office. Those powers are not awe inspiring.

> To some extent it is like the office of the president. The office provides the secretary simply with a *license to persuade* outside parties. Even within the building [the Pentagon], quite frequently, it is only a license to persuade.[10]

While the control of resources and the influence associated with a leadership position provide access to the indicators which can lead to DME change, the ability to have changes become permanent relies on the acceptance of those changes by others who must implement them. Convincing those people requires credibility.

Informal leaders do not benefit from the advantage of position or authority, but they can play an important role. Charisma or other strong personality traits can enhance one's personal presentation, which is a source of credibility. A combative personality, or the propensity to fight against authority, which has often been touted as the key to changing an institution, was found in this study to be counterproductive.

Many believe Mitchell's attacks on Navy and Army leadership steeled those with competing ideas against him, and actually slowed the process of the acceptance of his ideas. They also credit his efforts with inducing bitter interservice rivalries that lasted for decades. One biographer claims that Mitchell's efforts provided encouragement for the Navy to develop an aircraft carrier fleet and to implement their own ideas of the employment of airpower in competition with those of Mitchell.[11]

Those who worked with Boyd recount similar effects of his abrasive personality. Boyd was prevented from briefing people about his ideas of an air superiority fighter because as soon as he began addressing them he angered them and they quit listening. In order to share Boyd's valuable research results, someone had to be a spokesman for him.[12]

Riccioni could be quite persuasive, but at times he allowed Boyd's influence to affect his briefing style. Like Boyd, his manner of addressing those in leadership positions often resulted in the abrupt termination of the meeting, preventing the communication of ideas. The main weakness in his approach was a propensity to focus his arguments on the judgment of those who disagreed with him, rather than on the ideas themselves.[13]

The reaction to people who are advocating new ideas has sometimes been to remove the person from the debate. In moves seen by many as a form of exile, Mitchell was transferred away from Washington to Texas, Riccioni was transferred to Korea, and Boyd received various new assignments, but due to a dependence on his analytical capability they were eventually cancelled. Even people who were not personally offensive could receive such treatment. One example was Arnold, who was removed to Fort Leavenworth, Kansas because of his association with Mitchell.

In each of these cases the influence of the people who were removed was only slightly decreased. The success or failure of the object of their advocacy hinged on the credibility of the ideas, not on the presence or absence of the advocate. The time, effort, and resources expended to relocate them were largely wasteful. Besides the danger of stifling ideas that could have value, attacking people instead of ideas can decrease the credibility of the attacker.

Worden builds a case that those with strong beliefs in a strategy or weapon system consolidate power to maintain emphasis in that area, as LeMay did. He traces how the ascendency to leadership positions of those brought up in fighters during the Korean War corresponded to the retirement period of World War II bomber generals. This view, which places an inordinate amount of emphasis on upbringing, would suggest that once the leadership of the Air Force is taken over by generals of a given upbringing, mission emphasis will be in the area of that upbringing. In other words, bomber generals from World War II established the strategic nuclear bombardment DME, and fighter generals from Korea established the air-to-air fighter DME.[14] This view, however, is not supported by the cases studied.

While Worden makes a strong case, and upbringing is an important part of the equation, the case studies show that it was only one of the factors. According to Worden, the fighter DME should not have been adopted until the 1970s, when most of the fighter generals were in place. The case studies show that the DME change began in the early to mid 1960s. By the mid 1970s there were already two fighter aircraft in production that resulted from the new DME. Most of the top decision makers, such as McConnell, Ryan, Brown, and Jones (the USAF Chiefs of Staff) during the DME change, and many of those advocating it, such as Rhodarmer and Catton, had bomber upbringing. Even Bellis, the F-15 program manager, had a bomber upbringing.

A change in mission emphasis does not require a change in the upbringing of leadership, as Worden suggests. Rather, the change in leadership followed the adoption of the new DME. It is logical that those people whose experience best allows them to lead, given the demands of an accepted DME, will be appointed to leadership positions. This is what the case studies showed to have happened. Leadership change was the result of DME change, and not the converse.

The Role of Flexibility

Flexibility was shown to be a very important factor in the cases studied. Design features of the F-111, such as the variable geometry wing, and the commitment to a large, high speed aircraft prevented the aircraft from adapting to later changes in mission emphasis. The miniaturization of electronics allowed the F-15 and F-16 to upgrade air-to-air capabilities, and in the case of the F-16 to expand its air-to-ground capabilities, without losing maneuverability. The F-16 was especially flexible due to the modular architectural design.

While flexibility in a weapon system contributes to its success by making possible greater capability over a long service life, it can either impede or facilitate a change in DME. If a system is very flexible it can adapt to the new mission emphasis, thus lessening the momentum of the old DME. For example, the B-52 was able to carry ECM pods and drop conventional bombs allowing it to support the new fighter-oriented DME by assuming peripheral missions, such as CAS, that became important in the new way of fighting wars. Flexibility can also allow mission emphasis to persist in the face of changing conditions. Flexibility allowed the F-16 to assume its air-to-ground role and to adapt to any changes in that mission, as well as assuming new missions such as SEAD, while maintaining its emphasis on close-in air-to-air combat. Flexibility in the B-52 facilitated the change in DME while flexibility in the F-16 helps to maintain the current DME.

The same dynamics apply to an inflexible design. If an airplane is unable to adapt to a new proposed DME because of an inflexible design, it creates momentum for the old DME which must be overcome. When people such as Myers and Agan were advocating a change in mission emphasis in the 1960s while the F-111 was under development and being produced, there was resistance to the change because adopting the new DME would threaten the F-111 program. The fact that it took over two years to sell the idea of the FX program, especially as an air superiority fighter, attest to the fact that the F-111 program created momentum that had to be overcome. It wasn't until events such as the McClellan hearings, the Vietnam War; the resignation of McNamara; the 1967 Arab-Israeli War; the crashes of F-111s during development, testing, and combat; the rising program costs; the negative public image; and all of the other factors occurred which helped overcome the momentum of the strategic nuclear bombardment DME, that the FX was allowed to go forward. Conversely, it was the inflexibility of the F-111 when confronted with all of those factors that eventually highlighted the need for a new DME. The desire not to have "another F-111" was a factor in convincing people to support the new DME. Thus inflexibility in a weapon system can also impede or facilitate a DME change, just as flexibility can.

The Role of Analysis

Analysis is a way of increasing credibility, and is considered essential in many situations. McNamara relied heavily on analysis, to the exclusion of almost all other inputs, at least according to his stated position. Debates erupted over the effectiveness of analysis as compared to factors such as military judgment and experience. In the end, the Air Force found it difficult to advocate a position without analysis to back it up, and therefore created its own analysis capability. The problem with analysis is that it is not definitive, especially for complex problems. Furthermore, it is difficult to establish objectivity in analysis, since analysis is subject to social processes.

There exists a well-supported view that many of the undocumented inputs, such as politics, intuition, bias, and others shown to exist, should not be used, and that decisions should be based on analysis. This position is documented in formal requirements processes, such as the JCIDS. The impossibility of relying solely on analysis becomes apparent when it is attempted. One finds that different studies can yield different results. Even something as straightforward as well-established engineering analysis to determine how thick to make a support beam is subject to social factors. The results of the engineering equations are inexact enough that a factor of safety, a convention based on experience, is applied. Safety is necessarily traded off with such factors as cost, weight, and size. These tradeoff decisions are social as much as they are technical, even if they are well understood in many systems.

When analysis is used to help solve more complex problems the subjectivity increases, increasing the influence of the social factors. This is especially true in questions of military missions and weapon systems. Much of the information on which decisions must be based is impossible to know, either because it is subject to incomplete intelligence gathering, or it is a parameter that will not actually exist until some future time. In order to make the analysis possible assumptions must be made. The assumptions that define the problem shape the answer, and those assumptions are subjective, at least to some extent. The methods used to model and analyze a problem, and the priority given to various factors and results are also subjective to varying degrees, and determine the outcome of analysis.

Combat experience can be seen as another form of analysis, since that is how it is used. The basis for its use is that if an idea or a system is being proposed for use in combat, actually trying it out in combat is the best test of its appropriateness. The problem with combat as a form of analysis, however, is that it is the form that is the least controlled and the least instrumented for detecting results. This deficiency of hard data leaves the results open to interpretation, which can be used to support a variety of positions. Any limitations of analysis as a way to provide answers for decision makers apply just as much, if not more, to combat results.

This study does not call into question the usefulness of analysis or combat results, but it does caution that they too must be taken as only one input, and must be corroborated with other inputs. This is done by understanding the limits of what information analysis can realistically provide, and not using the analysis for more than those limits allow. It must be understood that analysis cannot prove, but it adds credibility by providing evidence that a certain position is more appropriate than another.

Defining the limits of analysis is done by determining what information is available and applicable, and formulating questions, answers for which can be revealed by the results of the analysis. Attempting to answer questions based on the results of analysis that is not applicable (incorrect or weak assumptions, for example) can result in poor decisions. Similarly, when analysis is undertaken as a form of advocacy, that is when the decision has been made and the analysis is set up in order to prove the decision is right, the choice of methods and assumptions may mask results that might otherwise be obtained. The misuse of analysis calls into question the competency and the motives of the person using it, and the consequence is a loss of credibility.

The Question of "External" Factors

The need to maintain a standing military after World War II, and the increasing costs of the weapon systems needed to do so, expanded the interest in, and oversight of, military procurement activity. This oversight has ranged from a desire to eliminate duplication, unnecessary procurements, and waste, to a desire to control where defense dollars are spent. Included also is a concern that the money spent, regardless of where or how much, is meeting the security needs of the country.

Influence by those outside of a military organization on decisions that were formerly considered to be strictly military is often considered "external," which often has a negative connotation. Neufeld's notion of the Air Force overcoming bureaucracy to procure the F-15 has been presented. Even Schlesinger, at the Defense Secretary level, equated Congressional oversight to "meddling."[15] It was widely held that Johnson and McNamara overstepped proper authority, even if not legal authority, in procurement decisions, and even strategy decisions during the 1960s. Other factors outside the control of the Air Force, such as the economy, world events, and public opinion have similarly been labeled as external.

These so-called external factors have been blamed for decisions that led to poor results, because the military-view did not take those factors into account. The sentiments that nuclear bombardment would have provided victory in Korea had Truman allowed the Air Force the freedom to do so, or that fewer U.S. aircraft would have been lost to enemy fighters in Vietnam had Johnson not provided political sanctuaries for enemy airfields, or that the F-16 would have been unnecessary if Congress had funded more F-15s, are examples of labeling factors as external, and implying that the reasoning based on those factors was less valid. Similarly, implying that certain favorable outcomes were luck because they were not based on strictly military considerations, is just as mistaken.

When taking a *systems* view of the decision making process, no events should be viewed as external. Even when those factors are beyond the control of the military, they must be taken into account by the process. While they are not controllable variables, they are part of the undocumented inputs that influence decisions. Rather than assessing the reaction of the DME or the systems to these uncontrollable variables, the current DME and resulting systems should attempt to respond adequately to all influences that exist, whether information provided by credible analysis, inputs from civilian political leaders, or current events. If any factors, uncontrollable or controllable, prove too disruptive to the ability to provide security, that may be an indication that the DME needs to change in order to appropriately account for those factors.

The Role of Strategy

In some cases the influence can be reversed, that is the DME can influence strategy and doctrine. Recently in Afghanistan, for example, a very expensive and technologically advanced F-15E fighter-bomber dropped a GBU-39 precision guided bomb in response to a sniper firing at U.S. ground troops.[16] In another scenario F-16s were tasked to conduct combat air patrol over the stadium where the super bowl was being played.[17] The air superiority tactical fighter DME that influenced the conception of these weapons, is now influencing the strategy employed in the low intensity conflict of the War on Terror. Nor is this the first time this has happened. B-52s providing CAS in Vietnam provide an example of the strategic nuclear bombardment DME, which influenced the development of the B-52, influencing strategy in limited conventional wars. When combat situations arise, the Air Force can only offer its existing capabilities, and therefore the DME that influenced the existing weapons also influences the strategies employed. There is a trend of increased service life of weapon systems, and as this happens, the DME that exists during the conception and development of a new system will have an increased effect on future strategy and doctrine.

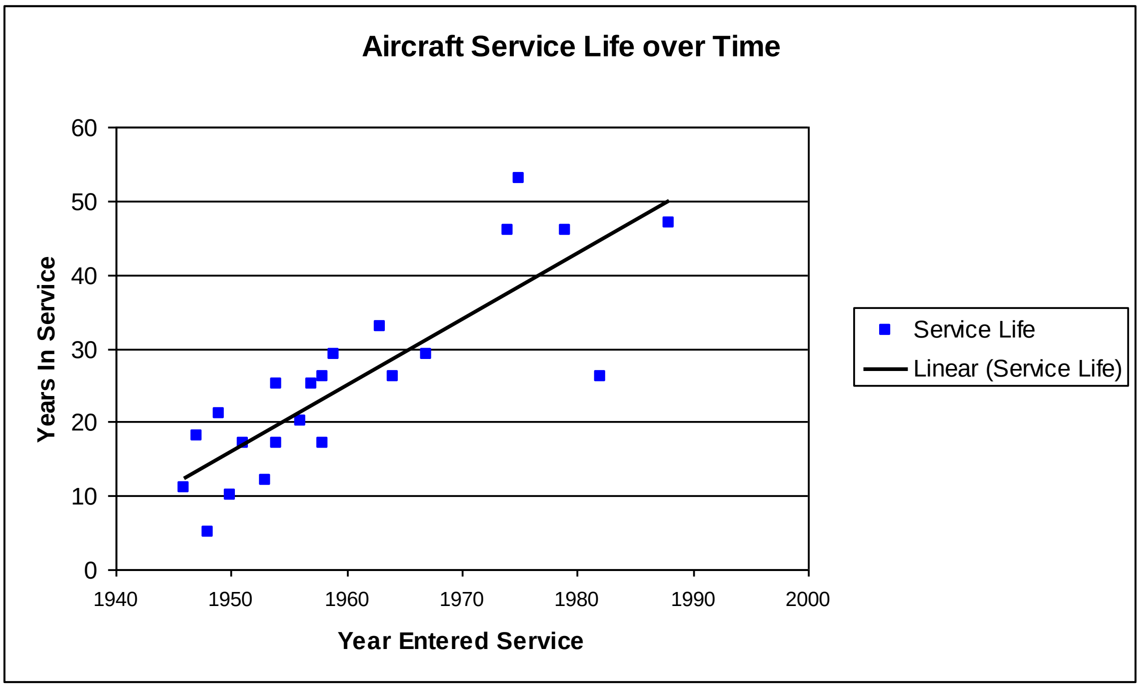

Figure 7.1. Service life of U.S. Air Force fighter aircraft as a function of the year of entry into service. While there are some outliers, such as the F-117, which entered service in 1984, there is a clear trend, as indicated by the black linear regression line. For aircraft still in service, service life is based on USAF projected retirement dates.[18]

Therefore, there exists a feedback loop between strategy and the DME. Ideally the DME is conceived to support the national security strategy that is in place, making strategy an input to the DME, as previously shown. (See Figure 6.16.) At the same time, the weapon systems available, which were developed based on the DME, dictate the missions that can be accomplished, and therefore influence the strategy that can be employed. Articulating a clear strategy can help establish and perpetuate a DME, and therefore influence weapons procurement, which strengthens the DME as well. That act, however, will limit the strategy options in the future.

Because DME and strategy are so interrelated, care should be taken to balance the influence allowed by each. For example establishing the nuclear bombardment DME resulted in a stop to the development of conventional munitions, which dictated the options when the situation changed and the nation needed to fight in Vietnam. As decisions are made to invest in such systems as the F-22 and a new strategic bomber, decision makers need to realize they are affecting future strategy options, and take care to allow for flexibility in case the appropriateness of the DME is diminished by changing conditions. On the other hand, strategy cannot be developed in a vacuum, but must take into account the inputs from all sources. Absent other inputs the only consideration in the formulation of strategy would be to defeat the enemy, but in considering the *systems* view, it must do so in a cost effective manner, in a manner that maintains Congressional support, in a way consistent with experience and bias, as well as satisfying as many other inputs as possible. If strategy does not sufficiently take the DME into account, it becomes irrelevant and ignored. In that case the momentum of the DME, and the undocumented inputs to the DME, become the driving force for the actual strategy employed.

The Role of the Documented Requirements Process

The focus of this study on undocumented inputs could lead the reader to conclude that the documented requirements process contributes nothing, or very little to the determination of needs for a new weapon system. That is not the case, however. Previous studies, as referenced in chapter two, have emphasized the documented process as the primary source of weapon system requirements. This study recognizes that the documented process plays an important role, but also asserts that many of the defining decisions are made independently from that process. Because of the substantial treatment of the documented requirements process in the existing literature, this study has not addressed it to a large degree, focusing instead on the less studied undocumented part of the process.

Some requirements do result from the documented requirements process. Considerable attention has been given to identify the primary "predetermined decisions." Some others, not identified in this study, may also exist. Those remaining requirements, which were used to develop and produce the resulting systems, resulted from the documented process, when it was used.

Another purpose the documented process serves is to validate or give credibility to requirements resulting from predetermined decisions. The decisions made by Burns, which contributed to definition of the FX, and which were made before any formal process began, were included in the resulting requirements documents which were staffed, and from which specifications were derived

Debates about the requirements of new aircraft are, in actuality, an extension of debates about what the DME should be. The documented requirements process is another tool to use in the establishment of credibility. The resulting documented requirements, and the weapon systems built from them, become a way of "banking," or establishing gains in the conflict of ideas.

Summary of Conclusions and Recommendations

Following is a summary of major conclusions and recommendations based on this study, as presented in the body of this chapter.

Conclusions	**Recommendations**
The determination of whether a new DME is warranted is a subjective evaluation of all conditions, and it is determined by majority opinion (not by any authority). When the support for a certain position is strong enough to change it, that indicates the appropriateness of a new DME.	
CUES that the DME may be at the bottom right side of the bell curve include: 1) Change in national strategy 2) Technology 3) War experience 4) New ideas 5) Budget inputs 6) Threat inputs 7) Analysis results (related to previous indicators)	To establish the need for a change of DME, use the CUES to demonstrate the inappropriateness of the existing DME.
Overcoming momentum to change a DME is a social process - not an analytical, technological, or authoritative one.	Utilize the INDICATORS of appropriateness (verbal statements, strategy and doctrine, published writings, organizations, resources, training, and promotions/positions) as "knobs" to change the DME.
CREDIBILITY is the key to changing momentum in the desired direction. Sources of credibility: 1) Experience (war record, time in service, assignments completed, academic experience, etc.) 2) Rank/position 3) Prior successful projects 4) Personal presentation (appearance, briefing/speaking ability, ability to think on feet, preparation and prior consideration of potential questions, etc.) 5) Analysis and combat results 6) Innovation 7) Consensus/corporate position 8) Compatibility with existing bias	Establishing credibility is the primary means to convince others to accept a new DME.
Leadership positions are important because of their inherent credibility, and the greater access to INDICATORS. Leadership cannot dictate change, but is a means of causing others to consider arguments for change - however, credibility is still required to convince others to support DME change.	Use credibility to convince, rather than dictating change, or the change will not be lasting and resources will be wasted.
"Strong" (combative) personality often hampers ability to achieve desired change.	Focus advocacy on building a credible case for change - address ideas, not the people who present them.

Flexibility or inflexibility of a weapon system are important for determining the success of the system, but they are not a decisive factor in causing DME change. They can be used either as a reason to change, or as momentum for the current DME.	
Analysis is subject to social processes. It cannot definitively prove that an idea is correct, or even that it is better, but it is one way to help establish credibility for an idea.	Focus analysis efforts on answering questions that will help make decisions.
When analysis is used inappropriately (to advocate, for example) loss of credibility and waste of resources results.	Clearly define the limits of analysis accomplished and do not exceed those limits (i.e., don't try to answer questions that the analysis doesn't cover, and don't try to justify decisions with analysis that does not apply). Do not initiate analysis to advocate.
Combat can be used as another form of analysis. It can provide answers to questions, but due to uncertainties: questions of details of the input conditions and results, repeatability, generalizability, etc., there are limitations to its usefulness as an input to decision-making. Determining the amount of influence assigned to combat results is a social process.	
No event should be labeled as "external" simply because it is beyond control of the person or organization (such as the Air Force, DoD, U.S. Government, etc.).	If the DME is inadequate to fulfill objectives as a result of the actions of others, world events, economic pressures, etc. consider it a cue to review the DME to determine if a change is needed.
There is a feedback loop between strategy and the DME - each is an input to the other.	Balance the influence of strategy on the DME, and that of the DME in the formulation of strategy. Consider the lasting effects on strategy by influencing the DME and by using the current DME as an input to strategy.

Table 7.1. Summary of major conclusions and recommendations.

Notes for Chapter Seven

1. Rhodarmer Interview, 12; Myers Interview, 2008.

2. Hillaker Interview, 2007.

3. Sprey Interview, 20, 39-44.

4. Harold L. George, "Origins of the Order of the Daedalians," *Air University Review* XXV (1984); William Mitchell, *Winged Defense; the Development and Possibilities of Modern Air Power - Economic and Military* (New York: G.P. Putnam's Sons, 1925).

5. Chun, 31-34; Meilinger, *Airmen and Air Theory*, 7-10.

6. Ibid.

7. Boyne, "The Tactical School"; George.

8. Coram; Boyd Interview, 1973; Boyd Interview, 1977; Hillaker Interview, 2007; Riccioni Interview, 2008; Titus Interview, 2008; Welch Interview, 2008.

9. Jones Interview, 1986, 151.

10. Hays, Vallance, and Van Tassel, 103.

11. Meilinger, *Airmen and Air Theory*, 9-10.

12. Kent, 173-174; Titus Interview, 2008; Welch Interview, 2008.

13. Kent, 173-174; Kent Interview, 1974, 15-17; Oral History Interview of Lieutenant General Glenn A. Kent, USAF (Ret.), by Capt. Mark Cleary, 9 February 1982. Typed transcript pp. 96-97, K239.0512-1305 Iris No. 01046654, in USAF Collection, AFHRA; Riccioni Interview, 2007; Titus Interview, 2008.

14. Worden.

15. Hays, Vallance, and Van Tassel, 103.

16. "Feb. 22 Airpower: F-15s Stop Sniper Fire." Air Force Link. 22 Feb 2007. United States Air Force. 28 Feb 2009 <http://www.af.mil/pressreleases/release.asp?id=123041967>.

17. Gabe Johnson, "Arizona Air Guard to Watch over Super Bowl," *Air Force Link*, 29 Jan 2008. United States Air Force. 28 Feb 2009 <http://www.af.mil/news/story.asp?storyID=123084064>.

18. Sources: Knaack, *Post-World War II Fighters*; Knaack, *Post-World War II Bombers*; Various volumes of *Jane's*; and various Fact Sheets and news articles from the Air Force Link.

Chapter 8
Applications and Future Research

Part of the rationale for the use of historical cases in the development of this model for understanding mission emphasis and the determination of needs was the limitations on access to data. For the same reason, it is not possible to fully apply this model to a current program. Some application of the model can be demonstrated, however, even with publicly available information regarding current programs. This can be done at the weapon system level as well as at the DME (*system*) level.

The KC-X Tanker

In February 2008 the U.S. Air Force announced its source selection decision for a $35 billion contract for development of a new aerial tanker aircraft, choosing the Northrop Grumman/EADS version of the Airbus A330.[1] A formal protest to the tanker decision was filed and parts of it were upheld by a Government Accountability Office (GAO) ruling.[2] While the protest targeted the source selection process, and the fairness with which the proposals were judged, issues related to undocumented inputs to the decision were voiced by many people.

According to Air Force statements,

> The KC-X source selection used a "best value" determination to select a winner based on five factors: mission capability, proposal risk, past performance, cost/price, and an integrated fleet air refueling assessment -- performance in a simulated war scenario. These five factors were developed after consulting with industry and were finalized prior to starting the competition.[3]

The Air Force continued to reiterate its selection of the EADS tanker based on analysis that showed that it would provide the best air refueling capability for the cost.

If weapon system selection could be based solely on the documented inputs, it should be possible, through analysis, to determine the air refueling capability needed by the Air Force, as well as an optimized solution to provide that capability. Differences of opinion existed, however, on the capability required. As with all complex systems, tradeoffs of different capabilities exist, and the priority given to a specific characteristic or capability depends on the undocumented inputs presented in the study.

In the case of the tanker, the main measures of performance include total fuel capacity which would favor a large tanker, number of receivers serviced in a given amount of time which would favor a smaller tanker that could be procured in greater numbers, cargo capacity which would favor a larger tanker, and parking and weight bearing requirements which would favor a smaller tanker. Cost is not straightforward either. There are tradeoffs between procurement costs, maintenance costs, and operating costs, to name the main ones. Many of these tradeoffs must be based on incomplete knowledge. For example, if in future combat scenarios the availability of forward basing is assumed, more, smaller tankers would be advantageous. If, however, the assumption is that combat operations will be conducted from U.S. soil, larger tankers with greater offload capability would be favored. Similarly, future fuel prices and durability of equipment, possibly beyond three or four decades, are currently unknowns, but must be taken into account.

Clearly analysis (FAA, FNA, FSA, etc.) alone cannot provide these answers. A 2006 RAND study of tanker alternatives concluded:

> The most cost-effective tanker replacement alternative is a fleet consisting of new commercial derivative tankers in the medium to large size range (300,000 to 1,000,000 pounds maximum gross takeoff weight). The candidates in this range include tankers based on the Airbus 330, the Airbus 340, the Boeing 767, the Boeing 787, the Boeing 777, and the Boeing 747. The AoA's [Analysis of Alternatives] estimates of the cost-effectiveness of these alternatives are close enough to each other that none of them should be excluded as competitive candidates, given the information developed for and analyzed in this AoA. A mixed fleet consisting of more than one of these alternative candidates also has comparable cost-effectiveness, so there is no reason to exclude *a priori* an Airbus-Boeing mixed buy on cost-effectiveness grounds.[4]

In other words, any of the aircraft listed would provide a suitable alternative to provide adequate tanker capability. Once the field was narrowed to the A330 and the 767, which were considered in the recent source selection, the differences between options became even less distinguishable. Military utility could no longer be used as the deciding criterion since, depending on the subjective tradeoff priorities, either option could be shown to provide more utility. Inputs which fall into the category of "undocumented," in fact, formed the basis of the protest by Boeing, who claimed that the Air Force analysis of future costs of the EADS tanker were too optimistic, and that the Air Force gave priority to different factors during the selection process than they had specified in the RFP.[5]

The protest process addressed factors that are stipulated in the documented process, but the consideration of undocumented inputs, such as competition, bias, politics, combat and operational feedback, and upbringing, were articulated as well. Many in the country, including decision makers, have voiced issues relating to these undocumented inputs in their discussions relating to the determination of tanker needs. One of the most prevalent undocumented inputs was the need to preserve American jobs.

Another was the need to maintain a proficient weapons development capability. Much of the debate centered on the loss of these assets to a foreign country, and especially to France. Especially vocal were members of Congress who were concerned about job loss among their constituency.[6]

Air Force decision makers can sometimes attempt to oversimplify the problem by addressing only documented inputs by advocating a position that does not respond to the undocumented ones. General Norton Schwartz, the Air Force Chief of Staff, exhibited this attitude in a press conference about the possibility of buying more F-22s when he told reporters that jobs are not a criterion for him and his colleagues to consider when they make decisions about which weapons to buy, but that other government agencies make that decision.[7] That may be true from a strict military utility view, but when the military utility of the choices are virtually the same, considering the undocumented inputs when establishing a position could be useful. After all, the same position could be taken with respect to the budget, which Congress controls. Air Force decision makers obviously factor that into their decisions about which weapons to buy.

Within the Air Force there were those who pointed to the fact that, with the exception of a small number of KC-10s, Boeing has produced all of the Air Force's tankers, and therefore has more experience. As a result of Boeing's dominance of tanker production, as well as the long service life of the KC-135, generations of officers, especially tanker and receiver aircraft crewmembers, have come to trust Boeing tankers. They consider the aircraft to have proven themselves in peacetime and combat operations.

At least one major newspaper highlighted the Air Force's need to repair credibility after a thwarted plan to lease tankers in 2004. The plan called for the lease, without competition, of 100 Boeing 767s. The article suggested that the desire to deflect remaining accusations of favoritism toward Boeing might have been a factor in the selection of the EADS tanker.[8]

After the GAO ruling, the DoD took over the tanker program, hoping to restore credibility to the process. It released a revised RFP, only to later suspend the entire program, preferring to allow the incoming presidential administration to carry out the process from start to finish. Currently the program is on hold while decisions are made on how to proceed.[9]

Secretary Gates is advocating that the release of an RFP followed by a competitive source selection be re-entered as quickly as possible to procure a new tanker. Despite the political challenges that would certainly be faced in another competition, Gates has emphasized the urgency for new tankers, and the cost savings that would result from a competitive procurement. He adamantly opposes the suggestion to simply award a contract to each of the competitors, Boeing and EADS. Of this course of action he stated, "It will incredibly complicate the Air Force's life because they will have two new tankers and the old tankers and the maintenance, the training, and the logistics just becomes a nightmare."[10]

Representative John Murtha, Chairman of the U.S. House of Representatives Appropriations Defense Subcommittee, who is pushing for a non-competitive split development effort, sees that as the only feasible way to procure a tanker.[11] Others have offered support for the idea as well. One example is retired Lieutenant General

Michael Dunn, president of the Air Force Association, who thinks a dual-source approach will cost less over a long service life, and reduce the chances of further protests. In reference to Gates' approach Dunn stated, "I'm afraid that you'll already start an appeal by the way you write the request for proposal."[12] General Mike Loh, former commander of Air Combat Command, echoed this opinion, "There's no way that the Air Force or anyone else can write an operational requirement for existing aircraft with known capabilities that results in a level playing field. Whatever you write will tilt the decision and end up in another protest."[13]

Based on publicly available information it appears that Gates' approach does not take into account many of the undocumented inputs to needs determination for a new tanker. Either proposed design, and therefore either approach, would satisfy the air refueling requirements of the Air Force, but a single contract given to EADS would not satisfy the requirement to have more domestic jobs, and maintain the tanker development capability in America (or at least the perception of those two things).[*] Nor would it satisfy the requirements of members of Congress from Kansas and Washington, where the Boeing jobs would be lost. Finally, it would not satisfy the requirement of many citizens who demand that the nation be able to provide weapons without relying on foreign countries. A Boeing contract would not satisfy the Alabama and California Congressional delegations' requirements for local business, nor would it fully satisfy the requirements to maintain good relations with NATO allies, who had the contract originally. It might also neglect the requirement to maintain open trade of U.S. arms to

[*] There is debate over how many U.S. production and development jobs would be provided by Boeing, who develops and produces their aircraft with a global strategy, and how many would be provided by EADS, who is teamed with Northrop/Grumman and would build a final assembly plant in Mobile, AL which would also be used for commercial Airbus production.

European countries. The approach of procuring a tanker from a single contractor is also contingent on the ability to overcome the fairness challenges that would almost certainly arise during the source selection.

As with the single contract approach, a split buy strategy would satisfy the operational requirements. It would also satisfy most of the undocumented requirements just listed. It would, however, impede the ability to meet the requirement to stay within budget, due to the cost of two development efforts, as well as the added costs of increased maintenance, logistics, and training requirements.

Even with limited information it is obvious that no solution will satisfy all requirements resulting from documented and undocumented inputs. According to the model, the solution must come as a result of the ability to convince enough decision makers that their requirements will be met adequately, even if not completely. The key to this will be the credibility of those making the assertions. For example, if credible analysis can show that one proposed system has significantly more military utility, or will cost significantly less over the service life than the other, or if a credible case can be made that a dual approach can provide the jobs, development expertise, and independence needed, enough support can be generated for one approach over the other. If Gates, on the other hand, attempts to force the competitive approach based solely on his position and authority, unless he possesses more credibility than McNamara did when he attempted to force the commonality approach, the effort will likely fail.

The Balanced Approach

The tanker program provides a current example of how the model of undocumented inputs to weapon system needs determination can provide a way of addressing a complex procurement problem. As stated, however, the model also applies with the Air Force's DME at the *system*-level. It has previously been established that the Air Force changed its DME from one of strategic nuclear bombardment, to one of close-in air-to-air combat with a multirole capability. This has influenced the development of fighter aircraft over the past four decades. The newest fighter, the F-35, was developed in response to this DME, and is still one of the top acquisition priorities.

The conditions which existed in the early to mid 1960s decreased the appropriateness of the bomber oriented DME enough to bring about a change to the fighter oriented DME. It is unlikely that after more than forty years the appropriateness of the fighter oriented DME is still at the same level. A different global political structure, comprised of a single superpower versus the Cold War bipolar structure; changing threat conditions, from conventional forces to terrorists and insurgents; greater capabilities of space assets, and greater reliance on them; a generational shift in the American public and their political leaders; a different economic situation that is far more globally integrated; a different relationship with allies, brought about by the fall of the Soviet Union and a more unified Europe; and great leaps in technology matched by great leaps in weapon system cost are among the numerous changes to the conditions that affect the appropriateness of the DME. Revisiting the graphic of the lifecycle of a DME (Figures 6.1. and 6.2.) it is clear that the current DME is no longer at the top of the bell curve.

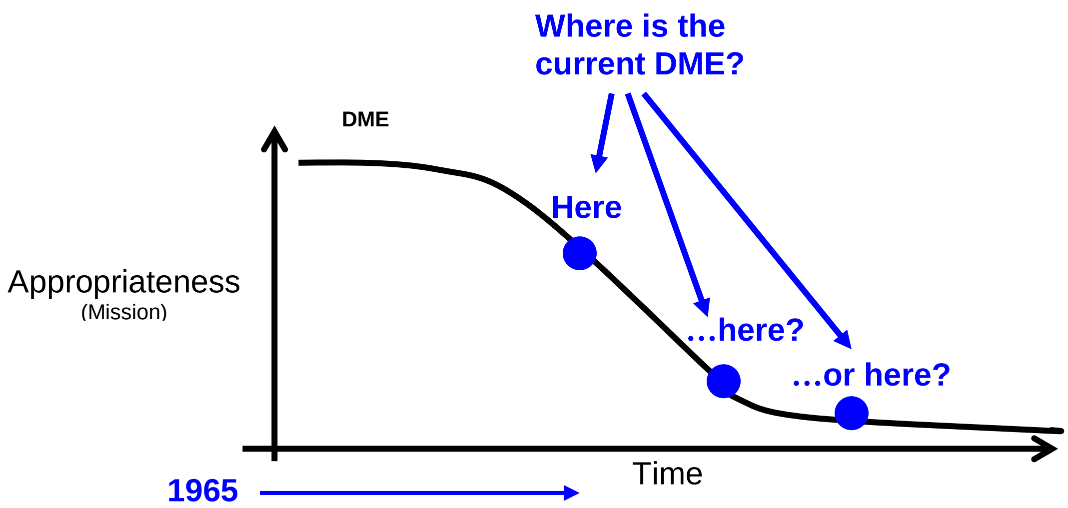

Figure 8.1. Changing appropriateness of the DME.

The actual position of the DME on the bell curve must be determined by a majority of the participants. It is clear that the level of technology, and related capability of new aircraft such as the F-22 and F-35, far outpace that of their predecessors. Similarly the costs of weapon systems have increased dramatically. The cost of a new F-22 is easily triple that of an F-15 when it was first produced (using same year dollars), and the same is true for a new F-35 compared to an F-16.*

One example of someone who believes the current DME is at the bottom right side of the bell curve is defense analyst John Pike, who heads the independent defense analysis group GlobalSecurity.org. He asserts that while cost has increased dramatically, the changing threat situation has rendered high technology fighters superfluous. Pike stated that the F-22 "seems to be an awfully expensive solution to a problem that no longer exists."[14]

* Cost estimates were arrived at using data from *Jane's All the World's Aircraft*, as well as program records, and adjusting for inflation.

A research report released by the Lexington Institute, another defense think tank, provides an opposing view. While acknowledging conditions have changed, the report equates the role of conventional forces to that of nuclear forces during the Cold War, which is deterrence. Simply by being in the inventory the F-22 discourages potential enemies from developing and employing an air-to-air threat, or any other challenge using conventional forces. The cost is justified by the fact that the leap in capability will allow the F-22 to maintain dominance, and therefore effectively deter enemy aggression, for up to five decades if procured in sufficient numbers – at least 250 are prescribed. By minimizing the impact of cost and establishing the relevance of the system, the report places the DME, which produced the F-22 and similar aircraft, near the top of the bell curve despite changing conditions.[15]

Secretary Gates is an important example of someone who believes a change in DME is warranted. He is advocating a strategy that emphasizes a more balanced approach. It would deemphasize the reliance on what he terms “kinetic operations,” subordinating them to “measures aimed at promoting better governance, economic programs that spur development, and efforts to address the grievances among the discontented, from whom the terrorists recruit.”[16]

Gates recognizes the indicators, such as budgets and organizations, that point toward the current DME, which influences the need for modern conventional weapon systems. For the Air Force those equate to systems such as the F-35 and the tankers that support them. In a recent article in *Foreign Affairs* he mentions some of these indicators, and laments the lack of support for his new proposed DME:

> Support for conventional modernization programs is deeply embedded in the Defense Department's budget, in its bureaucracy, in the

> defense industry, and in Congress. My fundamental concern is that there is not commensurate institutional support -- including in the Pentagon -- for the capabilities needed to win today's wars and some of their likely successors.[17]

Gates further advocates that his new approach should influence weapons procurement decisions, labeling current systems as “baroque” and “too costly,” as well as being overly oriented toward a mission that he believes should receive less emphasis. He states, “Given that resources are not unlimited, the dynamic of exchanging numbers for capability is perhaps reaching a point of diminishing returns.”[18] He suggests that consideration needs to be given to systems such as UAVs that can better support the nation-building efforts, which must at times be conducted under fire.

The model presented in this study prescribes using the indicators of a DME as the knobs to affect change. Some of these are evident in Gates’ effort to change the DME. His *Foreign Affairs* article, as well as several speeches and interviews constitute the verbal indications and intellectual writings from the list of indicators. Furthermore he has codified these ideas into the 2008 National Defense Strategy:

> The use of force plays a role, yet military efforts to capture or kill terrorists are likely to be subordinate to measures to promote local participation in government and economic programs to spur development, as well as efforts to understand and address the grievances that often lie at the heart of insurgencies.[19]

Gates has also sought to control the “knob” of positions of authority, another DME indicator. While he ascribed last year’s forcing out of the sitting Air Force Chief of Staff, General T. Michael Moseley, and Air Force Secretary Michael W. Wynne, primarily to their lack of leadership as it related to the safeguarding of nuclear weapons, also cited were the failure to assign more Unmanned Aerial Vehicles (UAV) to ongoing operations in Afghanistan and Iraq, as well as disagreement over the number of F-22s that should be procured. The Air Force was asking for approximately 380, more than double the 183 Gates had specified.[20]

Gates replaced Moseley, a career fighter pilot, with General Norton Schwartz, who had served much of his career in the Special Operations career field. Although this research has shown that a change in leadership is not necessary to implement a change of DME, it also showed that filling leadership positions with people who have expertise related to the new DME was effective. The work with indigenous populations in combat areas, done by special operations forces, is closely related to the work of developing local leadership and programs to improve stability.

The move further set a precedent for the promotion of those in career fields that support the new DME. Gates encouraged the expansion of this practice:

> One of the enduring issues the military struggles with is whether personnel and promotions systems designed to reward the command of American troops will be able to reflect the importance of advising, training, and equipping foreign troops – something still not considered a career-enhancing path for the best and brightest officers.[21]

According to the model there are some other actions that can be done to help implement the new DME. Setting up organizations that support the new DME, establishing training programs and incorporating the DME into professional military education, and committing resources to further the new DME can contribute to its acceptance.

As the Secretary of Defense, Gates has authority to direct actions that control many of the DME indicators. He can act unilaterally in the exercise of that authority, such as giving speeches, writing articles, and even making personnel changes. The key to the acceptance of the DME, however, will be to establish the credibility to convince enough people to support it. It appears that he was unable to convince Moseley and Wynne, and although it can be assumed that their removal and replacement with people of his choosing will add two more supporters, Gates must establish broad support to have lasting change.

If a change of DME were to occur it would be manifest by the indicators discussed. Instead of the limited introductory efforts at controlling the indicators, they would show substantial support. For example, new smaller scale training programs would become well-established, well-funded, competitive programs. Instead of pushing to promote some people from DME-related career fields to show they are valued, people would be attempting to steer their careers into those fields which would be seen as the most relevant. Instead of working to divert some money to programs in support of the DME, high priority programs would be a natural result of the DME, and the Air Force's top priorities. For fighter aircraft that could possibly be an unmanned aircraft such as a follow-on to the MQ-9 Reaper, or a more capable updated CAS aircraft similar to the A-10.

For illustration purposes this discussion has been presented from the point of view of Gates, someone attempting to change the DME. The same principles apply to those people who still believe in the current DME, and are working to keep it in place. While Gates has the advantage of holding a position of authority, those working to keep the DME in place have the advantage of the momentum that exists for the current DME.

The purpose of discussing Gates proposed DME, of development efforts in trouble spots, was not to advocate a position for or against it. It was to show the application of the model developed in this research to current situations. This cursory application was done using sources available in the open media. To make any effective recommendations regarding this situation, more data would be necessary.

Future Research

The three case studies conducted for this research provide important insights about mission emphasis and the determination of needs for new weapon systems. Future research can continue to shed light on the subject in order to strengthen the model. This research could be expanded in several different directions, but only three of the most direct possible next steps will be presented.

This study has focused on fighter aircraft in order to reduce the scope to a manageable level, as well as addressing arguably the most relevant Air Force weapon systems. An expansion of the study to other weapon system cases would also be very instructive. Similar studies could be done with bomber aircraft, or even support aircraft as the subject. Research could also be expanded to non-aircraft systems, for example space and missile systems. Extending the study into the other services to determine if other undocumented inputs or other factors should be added to the model could render it more complete.

While the motivation for this research was to improve the weapon systems acquisition process, preliminary research of large, complex, non-military engineering *systems* suggests that the model is applicable in these settings as well. Historical examples include the interstate freeway system or Boston's "Big Dig." Future applications, once the model is validated in this area, could include projects such as airports, nuclear power plants, subway systems, or other large socio-technical systems.

Further research within the Air Force would also be useful. An example of its application was shown using Gates' proposed DME of development of trouble spots, but other possible DME proposals could also be explored. One such possibility is a DME of high endurance armed intelligence, surveillance, and reconnaissance (ISR). During past combat operations aircraft used in the ISR role, such as the RC-135, the E-8, and the E-3, were employed together with strike aircraft to destroy targets in a more timely manner. With the change in combat scenarios from relatively short periods of active combat, to prolonged periods of low intensity conflict, the need for persistent ISR and a more responsive strike capability has become increasingly important.

In response to this emerging mission, more sophisticated and more capable UAVs have been developed. The rapid increase in UAV technology, and the variety of applications that are becoming apparent, have increased the employment of the systems, further expanding the mission. Inherent advantages of UAVs, such as lower production and maintenance costs, lower fuel costs, lower training costs, reduced infrastructure requirements, no potential for aircrew to be captured or killed, the removal of human limitations such as endurance or life support restrictions, etc. have combined with the previously mentioned factors to create advocates for a DME of persistent, armed, ISR using UAVs. Investigation of the determination of appropriateness of such a DME, and the possibility of adopting it if it is deemed appropriate represent another opportunity for future research.

In the course of this research the idea of the DME came out of the investigation of undocumented inputs. Another idea that also became apparent was that of missions which received emphasis, but were subordinate to the DME. These also affected their associated hardware, as well as being affected by the DME. One example can be labeled the "space mission," which throughout the period studied was seen as a support to the DME, while still remaining somewhat separate. Space capabilities, such as GPS, communications, and ISR impacted what fighter aircraft were capable of doing, as well as being influenced by the projected needs of fighters. Future research in this area would be useful to help understand the emergence and acceptance of these areas of subordinate mission emphasis, how they affect the acquisition of weapon systems, and their relation to the DME. Other examples of possible subordinate mission emphasis areas for investigation are cyber warfare and space combat.

Conclusion

In a recent move, the President has suggested postponing development of a new tanker for five more years. Statements by Air Force leaders, OSD officials, and members of Congress have addressed the need for these systems. "We're placing our crews in jeopardy by having them fly in airplanes over fifty years old," said Representative Todd Tiahrt of Kansas.[22] Representative Jerry Moran, also from Kansas added

> We're talking a lot about stimulating the economy here in Washington D.C., a number of items of legislation have passed, designed to put people to work. It would be a terrible mistake on my part to not provide a piece of equipment the Department of Defense, the Air Force needs.[23]

Representative Neil Abercrombie of Hawaii, Chairman of the House Armed Services Air and Land Subcommittee added that buying both EADS and Boeing tankers would make strategic sense, since "they both do different things."[24] Representative Rick Larsen of Washington asserted, "Unless something new and different has happened in the last four months, we still need a next generation tanker today, and not five years from now."[25] Numerous other citations similar to these could be provided.

Similar quotes abound addressing the need for more F-22s. The Air Force asked for 381, but only 183 have been funded. Recently there has been talk of procuring more, with sixty being a suggested number. Of the need for the extra F-22s General Schwartz remarked, "We looked at this in a dispassionate and analytical way [and produced a number that] I feel is credible."[26]

Discussion among the general public abounds in editorials, on blogs, and in other forums. Some contend that there is no pressing need for more fighters, or new tankers, and others insist that the need for one or the other, or both, is urgent. Rationale provided for the opinions is varied, and often the same data or studies are cited to support opposing views.

The ability to make rational decisions when confronted with the enormous amounts of data, the unknowable variables, and the innumerable opinions relating to weapon systems decisions requires a bounding mechanism. This study identifies the inputs, both documented and undocumented, that contribute to bounding the problem and providing a solution. It also presents a model that explains how those inputs are taken into account in the establishment of mission emphasis and the determination of needs for new weapon systems.

Notes for Chapter Eight

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Appendix A
Cross Case Analysis: Relating Undocumented Inputs to the DME Model

The case studies reveal that the same undocumented inputs that influenced decisions regarding the weapon systems the Air Force procured, also influenced the DME. Establishing the existence of that influence strengthens the DME model, increasing its usefulness as a tool to describe and understand current and future situations.

One of the steps in the process of building theory from case study research is to search across cases for patterns.[1] This cross case analysis is presented in this appendix in two formats. The first is narrative format, identifying and explaining the information that supports the assertion that the undocumented inputs, which were previously identified in conjunction with weapon system idea formulation, also influence the emergence of the DME. Vector charts comprise the second format of the analysis.

Both formats draw primarily on the information presented in the case studies (chapters three through five), although some additional references are introduced in the narrative. Previously established information will be used in this appendix without references since those are contained in the body of the thesis, and the focus of the appendix is on the analysis of that data. While it is recognized that there will be some overlap between the two formats, both are included for completeness. This allows for more complete capture of the research process, as well as more complete archival of data and analysis used to build the DME model presented in the body of the thesis.

Evidences of Influence on the DME by Undocumented Inputs

While considering the influence undocumented inputs exert on the decisions regarding new weapon systems, it is apparent that those same inputs also influence the DME. Much of the influence on weapon system decisions, in fact is applied through the DME. Each of the undocumented inputs will be addressed to illustrate its relationship with the DME.

Strategy and Doctrine

It may seem obvious that the DME is a result of strategy and doctrine, and some would assert that the DME is driven directly by them. For example, some people have explained the DME of strategic nuclear bombardment, and the dramatic de-emphasis of tactical forces during the 1950s, as a natural extension of the national security strategy of massive retaliation.[2] That strategy and doctrine are inputs to the DME, however, is not a given, and in fact they comprise only one of many inputs. They can be, and have been, overridden by other inputs.

The shift in national policy from massive retaliation to flexible response was not enough to cause everyone in the Air Force to change their views on which mission should be emphasized. For example, there were those who disagreed with the need to fight a limited war. By placing artificial limits on itself, they contended, the U.S. would only give its enemies an unnecessary advantage. General David Burchinal, for example, who served in influential positions on the Air Staff in the 1960s and later commanded U.S. European Command, summed up his opinions and those of LeMay, Ryan, and others when he said that nuclear weapons “won” the Cuban missile crisis before it started, and that the Soviets withdrew their missiles from Cuba, not because of the tactical forces, but because of the threat of nuclear bombardment. While Kennedy felt an acute lack of options, Burchinal believed he only needed one.[3]

Similarly in the Vietnam War, which the President saw as a limited war situation, LeMay stated that he saw no need to keep it limited and avoid escalation. He stated in 1965 that he would prefer to use massive bombardment even if it provoked the Chinese into entering the war. Of that eventuality he stated:

> I don't worry particularly about [the Chinese entering the war]. We would have to be prepared to take care of them – by air also. This would be a sizeable chore with conventional tonnages. It would probably be more efficient in a big war with the Chinese Communists to use a few nuclear weapons in carefully selected places to do the job. … Maybe it would be a good thing if the Chinese came to the support of North Vietnam. We could set back the Chinese nuclear program, or knock it out for good.[4]

Others, including Zuckert, who was Air Force Secretary beginning in 1961, believed that the limited war option that Kennedy sought could be achieved simply by using nuclear weapons of limited size; or tactical nuclear weapons.[5] While it is obvious that strategy and doctrine have some influence on the DME, it is also true that the amount of influence can vary.

Upbringing

The above discussion of upbringing and its influence on weapon systems applies to the DME as well. The reason decision makers use their upbringing as a basis for determining the characteristics of a new system is that they have a belief that the mission in which they were brought up was the most appropriate for the national defense. Everest participated in winning World War II as a bomber pilot, while Agan did so as a fighter pilot, which affected their beliefs on which missions would be most appropriate in the early 1960s.

Personalities

Just as the personalities of McNamara, Boyd, and Seamans shaped systems, the personalities of people also affected the emergence and acceptance of the DME. Billy Mitchell was completely convinced of his ideas of strategic bombardment, and publicized and promoted them very blatantly. Besides the numerous enemies he made with his confident confrontational personality, he also created an influential group of devoted followers, such as Milling, Arnold, de Seversky, and those who attended the ACTS. These followers were instrumental in planning and implementing the strategic bombardment campaign in World War II, and eventually establishing an independent Air Force based on that mission. SAC personalities such as LeMay and Power were extremely influential, and committed to building SAC and its mission. Chennault set the stage with his flamboyant personality for those who would eventually promote the DME of close-in air-to-air combat. Boyd's personality was instrumental in disseminating his views of aerial combat through his EM theory. Like Mitchell, his adversaries and his followers were uncommonly devoted.

Competition

Competition, especially for resources, influence, and relevance shapes the DME. This competition can be with organizations external to the Air Force, especially with other services, as well as between organizations within the Air Force. General White, who was the Chief of Staff from 1957-1961, agreed that there were instances where the competition for funds dictated or influenced changes in strategic thinking among the services, and stated that this type of situation "stems from services' recognition that adoption of certain types of strategy is desirable if it will make it look good."[6] Similarly, in an internal TAC memorandum introducing a new planning manual, TAC leadership concluded that the command needed to take a more active part in establishing the role of tactical air power, "if [TAC was] to have a meaningful and effective role in serving the U.S. National interests in the future." The memorandum further explained the rationale for more deliberate planning efforts: "Now and in the future both the Air Force and TAC will be in intense competition with the other Services for priorities and resources with OSD reserving the authority to decide which Service will develop and operate specific weapon systems."[7] The necessity to maintain relevance and secure budget share is therefore an input to the planning of roles and missions, and the selection of a DME.

Technology

The missions emphasized by the Air Force are heavily dependent on the technology it possesses. Similar to its role in the conception of weapon system needs, technology can influence the DME either by the application of a technology to fulfill a mission, thus perpetuating a DME, or by the possibility of a new DME being brought to light by a technology. The three cases are in themselves examples of the first case. The mission was determined first, and the technology was developed, in the form of a new fighter, to support that mission. The second case is evident too, however. As noted, the new technologies of the AWACS, improved weaponry, and miniaturized digital computers propelled what was to be a low technology fighter into a leading position in the emerging close-in air-to-air fighter DME, thus influencing its acceptance.

The reliance on advanced technology and science which Arnold established during and after World War II will ensure that in the future technology will continue to influence DME. This was what Arnold had in mind when he set up the Air Force research and development capability based on the recommendations of a team led by the eminent scientist, Theodore Von Karman. Recognizing how critical technology is to the employment of air power, Arnold commissioned a team led by von Karman to survey existing technology of allies and enemies at the end of World War II, and make recommendations for the future of technology in the Air Force. In his report, von Karman stated that, "Scientific planning must be years ahead of the actual research and development work."[8] Because it is impossible to know what the security needs will be far in the future, basic research efforts necessarily begin earlier than the determination of which missions will need to be emphasized. Available technology, the research for which often begins in advance of mission needs determination, narrows the choices of possible mission emphasis, thus influencing the DME.

Budget Priorities

No mission is viable if the technology to implement it is too expensive. Budget constraints limit the options for the DME, as well as encouraging exploration and acceptance of new DMEs. One of the primary reasons the U.S. adopted a defense strategy of nuclear bombardment after World War II was the fact that it was more economical. After years of deficit spending Truman wanted to balance the budget, and relying on the relatively inexpensive nuclear bombardment capability provided the possibility of achieving that goal. As the strategic bombardment DME required higher technology to maintain its appropriateness, the associated cost made it prohibitive.

The proposed B-70, the development of which began in the mid 1950s and continued into the 1960s, provides another example of budget constraints influencing the DME. The bomber was designed to fly at extremely high altitudes and at speeds above Mach 3 in order to penetrate Soviet defenses, but it became so expensive that it would have prevented the development of several other systems. Despite the fact that it represented the pinnacle of bomber technology, far surpassing any projected threat system, its high cost made enough people look for other options, thus de-emphasizing the bomber mission. The decision was made to develop a strategic bomber version of the F-111, to be used in conjunction with missiles. Proponents of the B-70 stressed the flexibility of manned bombers over missiles, the fact that missiles had never been tested in combat, and that the B-70 would have significantly more capability than a plane such as the FB-111. Despite all of these advantages of the B-70, it was cancelled and the FB-111 was developed, thus taking a step away from the strategic nuclear bombardment DME. The primary factor in the decision to cancel the B-70 was not the move to limited wars, the changing threat, the development of missiles, or other such factors, though they all played a part. The primary factor was the cost.[9][*] Similarly, it has been shown that

[*] Critics of the B-70 pointed out that the prototype aircraft actually cost more than their weight in gold.

the budget was also the driving factor in the development of the LWF, and the resulting F-16, which influenced the new DME.

Politics

Politics influence the DME at two levels. The first is the politics of organizations, such as the need of TAC to vie for influence and resources with SAC, or the interservice rivalries competing for the same assets. The second level, national politics, can affect the DME as well. The political limitations imposed in the Vietnam War, which provided sanctuaries for enemy air bases, led to the inability to gain air superiority with bombardment. This necessitated confronting the enemy in the air, leading to an emphasis on air-to-air combat. Similarly the reluctance to use nuclear weapons, and the political need to minimize collateral damage led to the increased use of tactical aircraft for weapons delivery, since greater bombing accuracy could be achieved. The politics behind the FMS sales of F-16s played a role in the acceptance of the F-16, which strengthened the close-in air-to-air fighter DME. Basing issues, as a result of politics have also influenced the DME. Fighters can be deployed more liberally, due to the greater ability to shelter and disperse them, giving them increased access to potential combat areas, which supports the fighter DME.

Biases

Just as personal bias played a part in weapon system decisions, it did so in the choice of DME as well. There was a clear bias for bombers in the ACTS, which was one of the reasons Chennault chose to leave the military. He claims that it was so strong that even attempts to demonstrate his ideas about fighters were thwarted by exercises and tests being set up in favor of bombers.[10] This bias for bombers affected war plans which in turn affected research and development efforts, thus perpetuating the strategic bombardment DME. Beginning in the 1970s there was a backlash of feelings against SAC, based on the preferential treatment of bomber pilots, as perceived by fighter pilots.

In 1991 an unsanctioned "brown paper" titled "TAC-umcizing the Air Force: The Emerging Vision of the Future" was distributed around the Air Staff, and eventually got passed around the whole Air Force. The basic premise of the paper was that the time had come for fighter pilots to secure their domination of the Air Force. It concluded that "first, manly men [fighter pilots] must dominate Headquarters USAF. Second, they must command all Air Force major commands. Last, USAF must have a wing structure [favoring fighter units] which will grow and nurture the future leaders of the Air Force."[11] Even though the paper was satire, its popularity reflected a recognition that there was a tangible bias that existed in the Air Force toward fighter pilots and their mission. Such a bias inhibits the introduction and acceptance of potential new DMEs.

Analysis

The role of analysis gained importance during the 1960s, and heavily influenced the DME, when McNamara established a credible analysis capability in OSD. In 1963 to 1964 Glenn Kent was assigned to DoD's Office of Research and Engineering and conducted analysis studying the ability to limit damage in the event of a nuclear war. The study effectively made the case that in such a war both the Soviet Union and the U.S. would not be able to avoid national destruction. According to Harold Brown, "That result dictated that the basis for U.S. nuclear strategy through the end of the Cold War … had to be the preservation of stable nuclear deterrence in the shadow of assured mutual destruction if deterrence failed."[12] This analytical establishment of the Mutually Assured Destruction strategy guaranteed that future wars would be conventional, which favored the new fighter-oriented DME that was more adapted to conventional limited wars.

In reaction to the OSD analysis capability, the Air Force chose to develop its own studies and analysis capability to be able to respond to OSD conclusions. The development of TAC Avenger, which simulated one versus one fighter engagements, has been discussed. More sophisticated computer simulation models were later developed that could model combat at the campaign level. Such analysis can be used to provide answers to questions relating to mission emphasis. One example is the Bohn Study, which, although it predated computer simulations, determined that a high-low mix was a viable option, thus opening the door for the FX program and later the LWF program, both of which contributed to the establishment of the fighter DME. Many other examples could be given.

It is important to note that analysis has limitations as well. Early analysis, such as the Thyng Study, relied heavily on the experience and judgment of those doing the study. Computer modeling was considered to be more objective, but even using computers there is substantial opportunity to introduce subjectivity. An early attempt to use computer modeling for quantity versus quality tradeoffs concluded that, "The scope of [such a study] and the complexity of the problem almost precluded definitive results."[13] The complexity of analysis at the level required to answer questions about mission emphasis requires the introduction of assumptions in order to simplify the problem enough to model it. With the introduction of assumptions, the results of the analysis are already determined to some degree. For example, the Bohn Study recommendation to procure A-7s instead of F-5s, or some other aircraft, was affected by the assumption that the threat would not be a factor due to low altitude target ingress. By assuming away the air threat, the higher payload of the A-7 made it more advantageous, despite its relative slow speed.[14] While analysis can offer useful information that can help determine an appropriate DME, it can also be manipulated to favor one over another. Whether objective or subjective, analysis influences the choice of DME.

Feedback

Feedback from the implementation of a DME is an important input to its establishment. An inordinate amount of credibility is given to results from actual combat. The results of strategic bombardment in World War II were accepted by many as definitive evidence that it was a war winning technology. Von Karman made the statement after World War II, "Until recently it was not generally recognized that destruction from the air is the most efficient method for defeating an enemy. This fact has now been proved by the results obtained in Germany and Japan."[15] Based on this feedback, the strategic nuclear bombardment DME was held firmly in place. Similarly, the feedback from the Vietnam War, in the form of kill ratios in aerial combat, influenced a change to the close-in air-to-air combat DME.

The credence is given to combat results despite the problems previously mentioned with determining what results were actually achieved, how they were achieved, and what the results imply for future missions. For example, one combat result of the Korean War was the achievement of air superiority by the Air Force. Everest attributed that to bombing their airfields sufficient to diminish enemy air power. Boyd credited the maneuverability of the F-86. Still others believed Korea was an anomaly, and that there would not be such limited wars in the future. Thus the wide range of possible interpretations affects the influence combat results exert.

Another drawback to using feedback to determine the DME is the danger of basing actions on the previous war, instead of future wars. The strategic nuclear bombardment DME was only viable in a total war scenario such as World War II, the previous war. As mentioned, even the Korean War did not dissuade most decision makers from putting emphasis on a mission that was appropriate for a previous war, instead of the next war. The next war was, of course, Vietnam, for which the DME was not completely appropriate. The varied interpretation of the feedback provided by the Cuban missile crisis is another example.

Feedback can come in other forms besides combat. As mentioned, analysis can provide feedback, insofar as it adequately models scenarios. Testing and exercises are other sources of feedback. As with the Arab-Israeli war that was cited, feedback can come from the experiences of others as well.

At the *system* level, feedback does not only come from the results of modeling, exercising, or actually accomplishing the mission. Other cues, such as the ability or inability to acquire funding based on a DME, an increase or decrease in the level of influence an organization can exert based on the accepted DME, or the reaction of allies or potential enemies are other forms of feedback. This non operational feedback is equally important.

Vector Chart Analysis

Drawing on the information found in the case studies, as presented in chapters three through five, as well as some of the information discussed above within this appendix, three major representative factors from each undocumented input were selected. For each factor a determination was made of the effect of each on the DME. Arrows representing the influence, as well as a qualitative assessment of the strength of the influence, were determined for each factor, along with a net assessment of the influence of each undocumented input. The results are given below, along with a verbal explanation of the assessment depicted by the arrow. Following the vector charts, a summary of the net influences of each input for the three cases is presented in a separate chart. The summary of net influence shows a transition over the three programs from the strategic bombardment DME to one of close-in air-to-air combat. A key is provided to aid in understanding the charts:

Key of Symbols

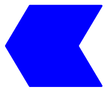
For the Vector Charts

An arrow pointing to the left (blue) indicates that the factor supports the strategic nuclear bombardment DME

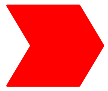
An arrow pointing to the right (red) indicates that the factor supports the close-in air-to-air combat DME

A line, with no arrow, (gray) indicates that the factor supports either both DMEs equally, or it does not significantly support either DME

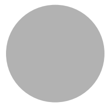
For the Net Influences Summary Chart



An block arrow pointing to the left (blue) indicates a net effect of an input influencing the DME toward strategic nuclear bombardment



An block arrow pointing to the right (red) indicates a net effect of an input influencing the DME toward close-in air-to-air combat



A circle, (gray) indicates a neutral input, the net effect of which supports either both DMEs equally, or it does not significantly support either DME

Figure A1.1. TFX Case Vector Chart

TFX Case Study (part 1 of 5)

Politics	Relevance and budget share for TAC	Relevance / budget share for USAF	Establish control over acquisition	Net influence
	←	←	→	←
	Because of national and USAF emphasis on strategic nuclear bombardment, supporting that mission allowed TAC to compete for budget, and gave it relevance.	The existence of the Air Force was based, in large part, on its unique ability to carry out the nuclear bombardment mission. Therefore fighters that supported that mission were supported Air Force relevance and competed better among the services for resources.	The acquisition of the TFX was somewhat of test case which could set a precedence of who would make future acquisition decisions. McNamara's flexing of his political muscle pushed toward a smaller, more tactical solution (supporting his conventional warfare buildup).	
Technology	Tactical nuclear weapons	Missile technology	Variable geometry wing	Net influence
	←	←	←	←
	Tactical nuclear weapons allowed fighters to participate in the strategic nuclear bombardment mission, which was being emphasized.	It was thought that air-to-air missiles allowed a bomber-type fighter to be an air-to-air fighter too. It could also provide air superiority by dropping nuclear weapons on airfields. Also the threat of surface to surface missiles encouraged fighters that were longer range – more like bombers.	The variable geometry wing enabled the mission envisioned by Everest, which allowed an aircraft to fulfill the expectations of a fighter while approximating a bomber.	

TFX Case Study (part 2 of 5)

Biases	Bigger, faster, higher, farther bias	Bomber mission and aircraft bias	Bias for advanced technology	Net influence
	←	←	—	←
	Large payload (bigger), high speed for rapid intercept or weapons delivery (faster), high altitude (for survivability), and long range (for escort, interception, or weapons delivery), all defined "high performance" for the strategic bombardment mission.	Beginning with Billy Mitchell, and having been perpetuated through his followers, the ACTS, and perceptions of combat effectiveness, there was a longstanding preference for bombers over fighters.	The Air Force was a technology dependent force, and systems that employed advanced technology were favored. This was true of bombers, such as the B-70, or fighters, such as the F-111. For this reason the bias for technology could push various DME options.	
Personalities	Everest	LeMay	McNamara	Net influence
	←	←	→	←
	Everest was the source of the idea for the TFX, and its primary backer. His main objective was to get a new fighter, and have a meaningful role in the overall mission. His background and combat experience were in bombers, which was reflected in the fighter he conceived.	LeMay was a strong personality and was in positions of authority. His ideas and attitudes had great influence on the Air Force. LeMay saw little need for fighters, or any system that did not add capability to the strategic nuclear bombardment mission.	McNamara was the first Secretary of Defense with the authority and the willingness to challenge the services' procurement decisions. Using his political power, his inherent authority, and his control of resources, he pushed for a fighter that could be used by the Navy. The Navy had no requirement for a strategic bomber.	

TFX Case Study (part 3 of 5)

Analysis	Feasibility analysis: Stack / WADD Studies	USAF/USN / DoD req'ts	Combat Lancer combat tests	Net influence
	←	—	→	—
	Stack's NACA analysis provided credible evidence that Everest's concept, which allowed a fighter to successfully contribute to the strategic bombardment mission, while fulfilling its other expected roles, was feasible. The subsequent WADD study backed this up.	Air Force analysis showed that a bomber-type fighter was needed, and that it would not meet Navy needs. Navy analysis upheld fleet air defense fighter requirements that could not be met by the TFX. DoD analysis supported a common fighter. The conflicting results were inconclusive.	Poor results during the Combat Lancer tests were interpreted by many as evidence that a large non-maneuverable fighter was inadequate for wars that would be fought in the present and future. This was a step away from fighters supporting the bomber mission.	
Budget Priorities	Bomber capability was the top AF budget priority	Multi-mission using bombing is economical	Save money through common-ality	Net influence
	←	←	→	←
	The top USAF budget priorities were for systems that supported the strategic nuclear bombardment mission. Therefore, a fighter that did not support the mission would not compete well for funding.	The most economical way to perform almost any mission was to employ nuclear weapons against the associated targets. This was true whether the target was enemy fighting forces, industrial targets, or enemy fighters and airfields. This philosophy made fighters that were capable of bombing, greater priority.	A common USAF – Navy fighter would have required the Air Force to build an aircraft with more fighter qualities, rather than the almost strictly bomber qualities the TFX had. McNamara's desire for commonality also in support of a conventional force, which did not call for strictly bomber qualities.	

TFX Case Study (part 4 of 5)

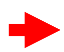
Competition	Dominant roles/ missions implications	Threat of a Navy plane pushed USAF mission	CAS capability kept USAF mission from Army	Net influence
	← (blue)	← (blue)	→ (red)	← (blue)
	The strategic nuclear delivery mission was the national priority. Therefore, the Service that fulfilled the mission was arguably the most relevant, and had greater claim on resources. The Navy actively competed for dominance in this mission. Systems that supported the mission received emphasis by the Air Force.	The Air Force had a strong aversion to accepting a Navy airplane. The emphasis on the nuclear bombardment mission – a mission unique from any other service – was rationale for not procuring a Navy aircraft.	There was a real threat that the Army would take over the CAS mission. While some (such as LeMay) did not care, many felt the Air Force needed a fighter that could also do CAS. Such an aircraft would not support the strategic nuclear mission.	
Strategy/ Doctrine	New national strategy was flexible response	AF doctrine was nuclear bombard-ment	USAF still embraced massive retaliation	Net influence
	→ (red)	← (blue)	← (blue)	← (blue)
	Flexible response required a conventional warfare capability. This required fighters that were more tactical, less strategic, and less bomber oriented.	Despite the Kennedy administration's flexible response strategy, Air Force Doctrine did not change until later. One reason for the lag was that there was a belief that flexibility could be achieved with nuclear weapons, such as tactical weapons with lower yields.	Many USAF leaders did not agree with the need for a change in strategy. They believed massive retaliation would deter enemies from engaging in any form or aggression. They viewed events such as the Cuban missile crisis as evidence that nuclear weapons would deter Soviet and other aggression.	

TFX Case Study (part 5 of 5)

Feedback	WW II results, Korea was an anomaly	Nuclear bombard-ment succeeded at deterring	Early Vietnam War results	Net influence
	←	←	→	←
	Many people saw the surrender of Japan, after employment of atomic weapons, as validation for the strategic bombardment preached by Mitchell. Korea was a limited war with extensive use of fighters, but lessons were ignored, and it was not considered representative of future wars.	Ignoring Korea, the lesson learned from the first decade and a half of the Cold War was that nuclear deterrence worked, and therefore should be continued. Systems procurement decisions were made based on that feedback.	Enemy aircraft operating from sanctuaries required air-to-air combat, which USAF aircraft were ill equipped to win. Combat Lancer results further showed the inadequacy of USAF fighters in limited conventional wars. A maneuverable air-to-air fighter was needed.	
Experience/ Upbringing	Extensive bomb exp. by USAF leaders	Some TAC leaders had bomber experience	DoD staff had no military, WWII exp.	Net influence
	←	←	—	←
	USAF leaders, extending quite far down into the ranks, had received most of their formative experiences, especially in combat, in bombers during World War II. Even those in fighters had seen the primary role that was accomplished by bombers, including the dropping of atomic bombs and the results.	The fact that many TAC leaders, including the commander, General Everest, had a bomber upbringing, created an environment where they were accepting of the emphasis on the bomber mission, and the support of it by fighters.	The DoD staff, and especially the analysts who influenced McNamara, had no military or combat experience. While this fact influenced the systems they oversaw, it did not influence them to push for one DME over another.	

Figure A1.2. FX Case Vector Chart

FX Case Study (part 1 of 5)

Politics	Limited war political limitations	Relevance / budget share for USAF	Establish control over acquisition	Net influence
				
	Vietnam revealed how political constraints could lead to sanctuaries from which enemy aircraft could operate. Air superiority could not be gained through bombardment. Fears of collateral damage and other constraints led to more emphasis on air-to-air combat.	Budget associated with the introduction of the flexible response strategy, as well as indications that future action would be carried out by conventional forces, led to increased emphasis on fighters, which were seen as more compatible with conventional warfare.	Because the Navy was not pursuing the development of maneuverable air-to-air fighters, the USAF, by doing so, had a unique set of requirements that could not be met by a Navy fighter, thus helping to avoiding the threat of having to procure one, through commonality efforts.	
Technology	Look down shoot down radar	Use of titanium	Leap in engine thrust	Net influence
		—	—	—
	This new technology increased fighter capability, and therefore had a slight effect on the emphasis of the mission, but not enough to negate dominance of the strategic bombardment mission.	This technology had an effect on the systems that could be procured, but it could just as easily have been applied to bombers, and therefore did not significantly encourage emphasis on one mission over another.	Like advancements in materials, jet engine technology advances did not lead to emphasis of mission over another. Both bombers and fighters, as well as other aircraft, benefitted from engine technology advancements.	

Biases	Bigger, faster, higher, farther bias	Bomber mission and aircraft bias	Bias for multi mission	Net influence
	←	←	—	←
	The bias toward bigger aircraft that could fly faster, higher, and farther still existed during the FX program, and was related to emphasis on the bombardment mission. The F-15 emerged somewhat in opposition to the existing bias.	The bias toward bomber aircraft, along with the idea that strategic bombardment could have more effect in combat, were still in existence during the FX program, which was a contributor to the emphasis on that mission. The F-15 emerged in opposition to this existing bias.	The primary reasons people agreed to the development of a single mission (air-to-air) aircraft, despite an existing bias toward multi mission aircraft, were to avoid commonality of missions with the Navy, and because of the belief that more missions could be added later.	
Personalities	Agan	Boyd	McConnell	Net influence
	→	→	→	→
	Agan worked to establish a doctrinal basis for air-to-air combat. He commissioned studies in support of the air-to-air role, and he worked to convince others of the necessity of more emphasis on the mission.	Besides his development of EM theory, and his use of the theory to increase the maneuverability of fighter designs, Boyd was very outspoken on the need for a maneuverable air-to-air fighter. EM theory provided a way to help others understand the position he advocated.	Although he was a career bomber pilot, McConnell agreed with the idea that a maneuverable air-to-air fighter was needed, and that the mission was valuable. He used his authority and position to help establish and maintain the program.	(Several others, including Disosway, Myers, Sprey, Burns, and Welch could have been represented on this chart as well.)

FX Case Study (part 3 of 5)

Analysis	EM analysis	TAC Avenger analysis	Thyng Study	Net influence
	→	→	→	→
	EM analysis was used to convince people that high performance was to be defined by maneuverability, the measures being thrust-to-weight ratio and wing loading, instead of size and maximum speed, altitude, and range – which were associated with the bombardment mission.	TAC Avenger simulations showed people the outcome of air-to-air engagements, in which maneuver-ability was shown to be more im-portant than size, speed, altitude, and range. This supported the idea of the need for air-to-air success as a factor in reaching targets.	Qualitative studies, such as the Thyng "Aces" Study, presented evidence of the importance of emphasizing the air-to-air mission.	
Budget Priorities	Money was available due to Vietnam War	Budget priority in USAF was strategic mission	Money was available for con-ventional build up	Net influence
	—	←	→	—
	As during all wars, defense spending increased. While this was a factor in the ability to start new programs, that money could have been spent on either bombers or fighters. The availability of funds, therefore, did not encourage the emphasis of a particular mission over another.	Other than the relatively short term priority of funding the war, the mindset among many decision makers was that nuclear bombardment was still the top budget priority. Although the FX program was funded, that happened as a lower priority than the strategic bombardment mission, in the minds of many.	McNamara wanted to build a conventional force to support the Flexible Response strategy, and tactical fighters were seen as a contributor to that. Therefore, the DoD and national budget priorities incentivized an a greater emphasis on tactical fighters, with greater maneuverability.	

FX Case Study (part 4 of 5)

Competition	Threat of Navy fighter	Resources/ relevance for USAF	Resources/ relevance for TAC	Net influence
	→	→	→	→
	The Air Force already had two Navy planes in its inventory: the F-4 and the A-7. The rivalry between them motivated the Air Force to pursue a mission that could not be fulfilled by another Navy aircraft.	Competition with the Navy for budget share drove the Air Force to generate requirements that could not be met by a Navy fighter. This condition was met by requirements pursuing the air-to-air mission.	Within TAC, there was support for the air-to-air mission because it gave the command a purpose, and a need for resources not subordinate to SAC's mission. SAC's dominance over the rest of the Air Force, including TAC, was a source of discontent among many in TAC.	
Strategy/ Doctrine	AF kept nuclear bombard-ment strat. /doctrine	National strategy was flexible response	Defensive / offensive counter air missions specified	Net influence
	←	→	—	—
	Air Force Doctrine, still subordinated other missions to the strategic nuclear bombardment mission. Wide acceptance of the validity of this doctrine existed.	The Flexible Response strategy introduced by the Kennedy administrations emphasized fighters over bombers.	Air Force doctrine called for the achievement of air superiority by bombing aircraft, airfields, and other facilities on the ground (offensive counter air), with some defensive counter air (air-to-air combat) necessary for eradicating those aircraft that got airborne. Thus counter air doctrine did not favor one mission over another.	

FX Case Study (part 5 of 5)

Feedback	Lessons learned from Vietnam	Arab-Israeli wars showed importance of fighters	Lessons learned from F-111	Net influence
	→	→	→	→
	Areas of political sanctuaries and the inability to employ nuclear weapons made offensive counter air efforts in Vietnam ineffective. Furthermore, the advantages even older MiGs had over USAF fighters caused many to support emphasis for the air-to-air mission.	The success Israel had at achieving air superiority, and the advantage it gave them, caused a greater emphasis on the air-to-air mission (even though the Israelis destroyed much of the enemy air forces on the ground).	Because of the perceived failure of the F-111, there was a general attitude that future aircraft would not be "another F-111", which was not considered to be well suited to then current warfare.	
Experience/ Upbringing	AF leaders were bomber pilots	Some TAC leaders had bomber experience	Some ftr pilots held leadership positions	Net influence
	←	←	→	←
	Most of the high ranking leaders in the Air Force had spent their careers flying bombers. Some had participated in World War II, and all of them had been in SAC. The FX program was a departure from the experience of most of the Air Force leadership.	The subset of Air Force leaders that led TAC were put in place by bomber pilots. Some TAC leaders had spent their careers in bombers and drew upon that experience and upbringing as the source for solutions to problems with which they were confronted.	People with fighter upbringing, such as Agan and Disosway began to have some influence. Disosway combined the influence of the three four-star generals who commanded fighter commands in his twelve-star letters.	

Figure A1.3. LWF Case Vector Chart

LWF Case Study (part 1 of 5)

Politics	Foreign military sales (FMS) opportunities	Force structure	Basing issues	Net influence
	→	→	→	→
	The potential for FMS opportunities created the opportunity to have a force in Europe that was more common and aligned with allied forces. This pushed toward a force based more on fighters that could better fight together with allied air forces.	Emphasizing fighters justified increasing the force structure (adding more wings), which was seen as increased relevance, and was accompanied by an increase in budget share in comparison to the other services.	Foreign sales of the LWF was contingent upon basing of USAF aircraft in Europe. The ability to base and disperse fighters in foreign countries, close to the enemy, which was not a realistic option for nuclear armed bombers (for political and security reasons) increased fighter emphasis.	
Technology	Computer miniaturi-zation	Precision guided munitions	AWACS	Net influence
	→	→	→	→
	Improvements in computer technology, especially decreases in size (and cost) allowed for much increased combat capability from a fighter. This made the it economical to procure fighters which could fulfill a variety of missions, especially as opposed to procuring large bombers.	Precision guided munitions allowed a fighter to provide a combat capability comparable to that of a bomber with unguided gravity bombs, as well avoiding the collateral damage. It could provide this capability at a lower cost due to its smaller size and smaller crew.	The Airborne Warning and Control System (AWACS) airborne radar gave a small fighter the ability to respond to air-to-air threats far beyond the range that would be possible with a radar small enough to be carried on a fighter. This enhanced combat capability made fighters more lethal, and therefore a more practical weapon.	

Biases	Backlash against SAC and bomber pilots	Bias for advanced technology	Bias for multi-mission aircraft	Net influence
	→	→	—	→
	As fighters became more accepted in the Air Force, there was a backlash against SAC, and the perceived advantages they had enjoyed. Institutional changes away from a bomber bias toward a fighter bias helped establish an emphasis on fighter missions.	New technologies adapted to fighters made them more accepted than bombers, to which newer technologies were not as readily adapted.	The USAF bias for multi-mission aircraft was satisfied by the LWF which was optimized for air-to-air combat, but which could fulfill other missions. It was also satisfied by the F-111, which emphasized a different primary mission. This bias did not increase the emphasis of one mission over another.	
Personalities	Boyd	Sprey	Riccioni	Net influence
	→	→	→	→
	Boyd was disappointed with the results of the FX program, and felt the F-15 was too large and not maneuverable enough. He was even more outspoken during the LWF program in his attempts to increase the maneuverability and decrease the size of the aircraft. He also worked with contractors providing valuable inputs to the design.	Sprey pushed strongly for a very small, very maneuverable fighter that achieved low cost through a decrease in technology used. Although his vision of a new fighter was not accepted, his efforts focused enormous attention on the problem, and contributed to the idea of fighter emphasis.	Riccioni believed the way to win a war in Europe was the employment of numerous small, maneuverable, low cost fighters (similar to Sprey). Like Sprey, while his exact fighter design was not adopted, he greatly influenced the LWF, which increased the ability of fighters to conduct war, and therefore increased emphasis on fighter aircraft.	

LWF Case Study (part 3 of 5)

Analysis	Riccioni Study	LWF technology demon-stration program	Tactical Fighter Modern-ization Study	Net influence
	—	→	→	→
	This study influenced the LWF program, but did not have a large effect on the emphasis of the fighter mission.	The LWF technology demonstration program resulted in two prototype fighter designs that captured the attention of people. When they saw how much capability a small inexpensive fighter could provide, emphasis of the fighter mission increased.	This study was instrumental in deciding what capability a fighter needed if it was going to meet the future combat needs of the Air Force. The capability of the F-16, which was the result of this study, and the aircraft's subsequent success, increased fighter emphasis.	
Budget Priorities	Budget drawdown at end of Vietnam	Bombing capability cost less using fighters	Not enough money to replace all F-4s	Net influence
	→	→	→	→
	The end of the Vietnam War brought about a decrease in the defense budget. Fighters, and especially relatively inexpensive yet highly capable fighters like the LWF, were seen as a way to provide combat capability in that budget environment.	Bombing capability, as a secondary mission for fighters with the primary mission of air-to-air combat, was sufficient, yet less expensive than using strategic bombers.	The F-4 had become the frontline weapon during the Vietnam War, but it was aging. The LWF was seen as the only feasible way of replacing the combat capability that would be lost with the retirement of the F-4.	

LWF Case Study (part 4 of 5)

Competition	Competition with the Navy	Competition with the F-15 program	Competition for military sales with allies	Net influence
	→	—	→	→
	Similar to the FX, the Air Force was motivated to develop a maneuverable multi-role fighter to differentiate its requirements from those of the Navy, which required a single mission interceptor.	The competition for funds between the F-15 program and the LWF program had an impact on the aircraft that resulted from the LWF program, but the fact that the programs were in competition did not significantly influence the level of emphasis placed on a particular mission.	The competition between the U.S. and other fighter producing countries for the contract to develop the new fighter for the European consortium compelled the U.S. to commit to buy and employ the fighter, which added strength to the emphasis on the air-to-air fighter mission.	
Strategy/ Doctrine	Convention-al war was equal to nuclear deterrence	Defensive counter air (air-to-air) had more prominence	Offensive counter air could be done with fighters	Net influence
	→	→	→	→
	Air Force Doctrine no longer placed the strategic nuclear war (and deterrence through preparation for it) as being more important than conventional war. This downgrading of its importance equated to a de facto promotion of conventional operations, for which tactical fighters were considered more suited.	The greater attention given to defensive counter air (the air-to-air) mission, in the doctrine manual corresponded to greater emphasis of the mission by Air Force leaders.	Offensive counter air was still contained in the doctrine, however, air-to-air fighters were considered to be capable of accomplishing the mission. In fact, the de-emphasis on nuclear weapons in the doctrine made fighters better suited for the mission.	

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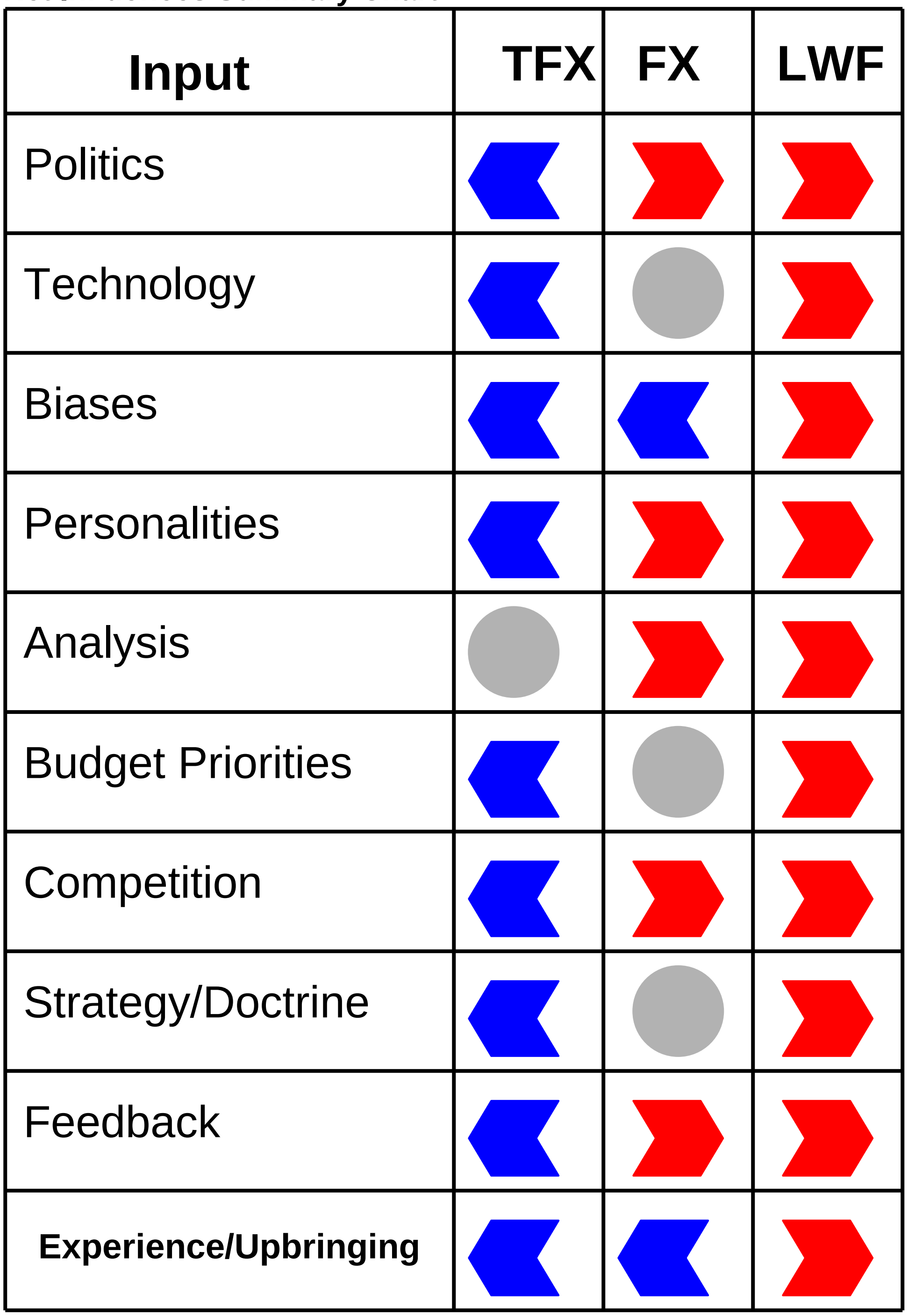
Feedback	Vietnam used fighters not bombers	Constraints (political, others) on unlimited warfare	Europe was seen as a conventional battlefield	Net influence
	→	→	→	→
	Fighters proved to be more flexible and survivable than bombers in Vietnam.	Greater accuracy of fighters, especially when using precision guided munitions. This made them more useful in situations where nuclear weapons were not an option, where collateral damage was unaccept-able due to political constraints such as the fear of escalation.	Feedback from arms control efforts, public attitudes, and other sources made the use of nuclear weapons increasingly unlikely. Fighters offered a more realistic combat capability on the anticipated conventional battlefields in places such as Europe.	
Experience/ Upbringing	Ftr pilots in more leadership positions	More fighter pilots across the force	Recent wars were fighter wars	Net influence
	→	→	→	→
	The larger fighter force that was built up during the Vietnam War produced leaders with combat experience in fighters, and who gave more serious consideration to the use of fighters for future combat scenarios.	Because of the increased responsibility given to fighters and fighter pilots, the rank and file officers saw that as the career field in which to have more impact.	The Vietnam War added another data point to that of Korea, which suggested that combat in future wars would be more fighter dependent. (Korea was not just an anomaly).	

Figure A1.4. Cross Case Analysis Summary

Net Influences Summary Chart



Notes for Appendix A

1. Kathleen M. Eisenhardt, "Building Theories from Case Study Research," *The Academy of Management Review* 14 (1989): 532.

2. Garland Interview, 115-116.

3. Burchinal Interview, 115-116; Burns Interview, 1986, 149-150; Ryan Interview, 49-50.

4. LeMay Interview, 1965, 16.

5. Sharp Interview, 36-37; Zuckert Interview, 1965, 41.

6. White Interview, 3-4.

7. "Memorandum for 9AF, 12AF, 19AF, USAF SAWC, USAF TARC, USAF TWFC, UASF TAWC, USAF TALC, Subject: TAC Concepts and Capability Objectives Manual", by TAC Deputy Chief of Staff, Plans, for the Commander, TAC, 8 Sep 1967. In USAF Collection, AFHRA. Declassified on author's request, 1 Jul 2008.

8. Gorn, 179.

9. Gary Beatovich, "A Case Study of Manned Strategic Bomber Acquisition: The B-70 Valkyrie" (Masters Thesis, Air Force Institute of Technology, 1990).

10. Boyne, "The Tactical School".

11. Anonymous, *TAC-umcizing the Air Force: The Emerging Vision of the Future,* quoted in Worden, ix-x.

12. Kent, 4.

13. J. Bracken and H.E. Strickland, Jr., *WSEG Report 250: Quantity-Quality Tradeoffs* (Arlington, VA: Institute for Defense Analyses and Weapons System Evaluation Group, 1975).

14. Burns Interview, 1973, 21.

15. Gorn,. 96.