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This study is a comparative analysis of the effect that joint development has had on the TFX and JSF aircraft development programs. The two programs have been compared to determine the degree of interservice commonality present, the methods used to achieve the common designs, and the effects the demand for commonality have had on the design and performance of the aircraft. In 1961, Secretary of Defense Robert S. McNamara initiated the Tactical Fighter Experimental (TFX) program for the US Navy and Air Force. The program was designed to save $1 billion in development costs by using a common airframe to fulfill the Navy?s fleet air-defense fighter requirement and the Air Force?s long range nuclear and conven-tional tactical fighter requirement. In 1968, the Navy TFX program was canceled due to the test aircraft?s poor performance and incompatibility with carrier operations. After 1968, the Air Force was left with a TFX design that was compromised by McNamara?s original commonality requirement. Ultimately, the Air Force fielded the TFX as different variants of the F-111 at five times the planned unit cost per airframe. The aircraft never developed the performance capabilities proposed in the original program. The failure of the TFX can be directly attributed to the restrictions and requirements imposed by the common development program. The Joint Strike Fighter(JSF) program is also based on the concept of saving de-velopment costs by building a common ?family of aircraft? to fulfill the strike fighter re-quirements for the US Air Force, Navy, and Marine Corps and the UK Royal Navy. While the JSF program was designed to avoid some of the problems that plagued the TFX, other problems of the earlier program have emerged in the JSF program as well. The recent announcement of cuts to the Navy?s F/A-18E/F and the Air Force?s F-22 pro-grams proposed in the Pentagon?s Quadrennial Defense Review increases the services? reliance on the JSF. As a result of the QDR and service requirements, the emerging budgetary and institutional issues that surround JSF program may undermine the spirit of compromise that is central to the success of this joint development program.

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THE QUEST FOR COMMONALITY:

A COMPARISON OF THE TFX AND JSF PROGRAMS

BY

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The conclusions and opinions expressed in this document are those of the author. They do not reflect the official position of the US Government, the Department of Defense, the United States Marine Corps, the United States Navy, the United States Air Force, or Air University.

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Abstract

This study is a comparative analysis of the effect that joint development has had on the TFX and JSF aircraft development programs. The two programs have been compared to determine the degree of interservice commonality present, the methods used to achieve the common designs, and the effects the demand for commonality have had on the design and performance of the aircraft.

In 1961, Secretary of Defense Robert S. McNamara initiated the Tactical Fighter Experimental (TFX) program for the US Navy and Air Force. The program was designed to save $1 billion in development costs by using a common airframe to fulfill the Navy's fleet air-defense fighter requirement and the Air Force's long range nuclear and conventional tactical fighter requirement. In 1968, the Navy TFX program was canceled due to the test aircraft's poor performance and incompatibility with carrier operations. After 1968, the Air Force was left with a TFX design that was compromised by McNamara's original commonality requirement. Ultimately, the Air Force fielded the TFX as different variants of the F-111 at five times the planned unit cost per airframe. The aircraft never developed the performance capabilities proposed in the original program. The failure of the TFX can be directly attributed to the restrictions and requirements imposed by the common development program.

The Joint Strike Fighter(JSF) program is also based on the concept of saving development costs by building a common "family of aircraft" to fulfill the strike fighter requirements for the US Air Force, Navy, and Marine Corps and the UK Royal Navy. While the JSF program was designed to avoid some of the problems that plagued the

TFX, other problems of the earlier program have emerged in the JSF program as well. The recent announcement of cuts to the Navy's F/A-18E/F and the Air Force's F-22 programs proposed in the Pentagon's Quadrennial Defense Review increases the services' reliance on the JSF. As a result of the QDR and service requirements, the emerging budgetary and institutional issues that surround JSF program may undermine the spirit of compromise that is central to the success of this joint development program.

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Chapter 1

Introduction

On September 8, 1961, Secretary of Defense Robert S. McNamara initiated a bi-service strike fighter program for the US Air Force and Navy. This program, designated Tactical Fighter Experimental (TFX), was designed around a philosophy of commonality in an attempt to reduce costs to the services. The program was problematic from its inception. Eventually, the Navy canceled its version of the TFX and pursued development of its own aircraft. The Air Force fielded the TFX as the F-111, but only after costly upgrades were incorporated to give the aircraft acceptable combat capability.

In 1993, Secretary of Defense Les Aspin initiated a modernization program for Department of Defense aviation based on the 1993 Bottom-Up Review. One of the key programs in this modernization effort is the Joint Strike Fighter (JSF). The JSF has emerged as a tri-service and multinational attempt to design and build an affordable strike fighter for the US Air Force, Navy, and Marine Corps, and the UK Royal Navy. The program will also attempt to reduce costs by using a common family of aircraft to fill the multiple missions required of the aircraft. However, the results of the Pentagon's 1997 Quadrennial Defense Review indicate that the Navy and Air Force may lose parts of their F/A-18E/F and F-22 programs in favor of further JSF development. This event is contextually similar to the Navy's forced involvement in the TFX program after McNamara canceled its Missileer aircraft program. Thus, there is a possibility that the JSF program will face development problems similar to those encountered in designing and fielding the TFX.

This thesis will examine the effects the demand for commonality had on the shape and results of the TFX program and whether these effects are also visible in the JSF pro-

gram. The TFX and JSF programs will be compared in relation to the degree of inter-service commonality present in the aircraft designs and requirements, the methods used to achieve common designs, and the effects of the resulting commonality. Examination of the genesis of both programs provides added insight into the establishment of commonality requirements in these aircraft programs. The concept of commonality is defined as it relates to each program and the results of the commonality requirement are examined and compared, where they are applicable. Finally, conclusions based on the historical analysis of the TFX program are applied to the JSF program.

Although the requirement for commonality is a thread that runs through the TFX and JSF programs, similarities in the application of the National Security Strategy in defining the programs, institutional self-interests, and budgetary constraints have emerged from the research. Decisions based on these issues certainly affected the outcome of the TFX program. An examination of the JSF program reveals that many of the same issues that influenced the decision makers in the TFX program are again present.

This paper is divided into four chapters. Chapter 2 investigates the TFX program and establishes the historical baseline for the thesis. Chapter 3 examines the JSF program from its genesis to the present. Chapter 4 concludes the project by comparing and contrasting the significant commonality issues between the two strike fighter programs.

Chapter 2

The TFX Program

During the early 1960s, the US National Security Strategy shifted from massive nuclear retaliation to flexible response. President Kennedy directed Secretary of Defense Robert McNamara to procure low cost weapons to support the new strategy. McNamara combined existing Air Force and Navy aircraft development programs into a bi-service strike fighter program. This aircraft, designated Tactical Fighter Experimental (TFX), was designed around a philosophy of interservice commonality in an attempt to reduce costs. The assumption that a single aircraft could fulfill both the Navy and Air Force missions proved to be inaccurate. The Navy and Air Force held fast to their original design requirements throughout the design process and compromises necessary to successfully field a common strike fighter were not made. When the aircraft experienced problems in the test phase the Navy lobbied Congress to cancel its version of the TFX and fund development of the F-14. The Air Force fielded the TFX as the F-111, but its performance was permanently degraded by the effects of the common development program.

Precursors

During 1959 the commander of Air Force Tactical Air Command (TAC), General F. F. Everest, was searching for a new fighter to replace the Republic F-105 Thunderchief.[1] TAC's mission consisted of three main tasks: gaining and maintaining air superiority, interdicting enemy forces and supplies, and providing close air support for ground forces. Everest envisioned a fighter that could perform all these tasks better than anything in the Air Force inventory. Incorporating the requirements associated with these missions into a single fighter would push the technology of the period to its limit. The air

superiority role required the aircraft to be capable of high speed and high altitude maneuvering for aerial combat. The interdiction mission required a large bomb load, either conventional or nuclear, carried over long distances, and a low-level, supersonic dash to the target to avoid enemy radar and air defenses. The close air support mission necessitated the ability to carry a large and varied ordnance load while loitering near the battlefield for long periods.[2]

In 1959 TAC had access to 94 overseas bases. Due to runway length and condition requirements, only 44 of these were suitable for F-105 operations.[3] Intelligence reports indicated that most of these were targeted by the Soviets and would be vulnerable to missile attack. General Everest sought to decrease the vulnerability of his fighters while increasing their employment flexibility by placing two more requirements on the multimission fighter. He demanded the aircraft have the capability for short take off and landing from unpaved airfields and for flying non-stop across the Atlantic Ocean without refueling.[4] A long-range nuclear capability was already provided by the F-105 but the TFX was needed to further solidify this mission capability for TAC.

During this period the Navy was also looking for a new fleet air defense fighter as a replacement for the McDonnell F4H Phantom II. This design was designated the F6D Missileer. The aircraft was to be a subsonic, single-mission fighter built around an advanced air-to-air radar and missile system.[5] A 60-inch diameter radar dish, coupled with the Eagle air-to-air missile was to provide the capability of detecting and destroying targets at a range beyond 20 nautical miles.[6]

At this time, the fleet air defense mission required an aircraft capable of patrolling for several hours at a distance of approximately 120 nautical miles from the carrier.[7] The Missileer design provided this capability but sacrificed speed. More important to the Navy, the aircraft was designed for carrier operations. The subsonic design allowed the aircraft to be compatible with all carrier catapult and arresting gear. The size and weight established in the aircraft design was also compatible with carrier hangar deck and elevator capabilities.

Navy support for the Missileer was not unanimous. Opponents thought a subsonic aircraft was a step backward in aircraft design and that the lack of speed would hurt

the fighter's survivability. Proponents admitted to the aircraft's lack of speed but felt the advanced missile system, the aircraft's ability to loiter on station, and its handling characteristics around the carrier overcame this disadvantage.[8] The Missileer program was canceled in favor of a joint development TFX program. However, the Navy used the characteristics developed in the Missileer program as benchmarks for its version of the TFX.[9]

Change in Strategy

1959 to 1961 was a transitional period for US National Security Strategy. The Eisenhower administration's strategy of massive retaliation relied heavily on nuclear weapons and delivery platforms with a strategic capability. This position, championed by Secretary of State John Foster Dulles, led to the reduction of conventional tactical aviation programs in the Air Force during the 1950s.[10] Despite the National Security Strategy of massive retaliation, the Eisenhower administration did study tactical aircraft requirements for the Navy and Air Force. The Director of Defense Research and Engineering and the Assistant Secretary for Research and Development examined the possibility of a single aircraft development program that could accommodate both services' tactical fighter requirements.[11] Undoubtedly, Secretary of Defense Robert S. McNamara was exposed to this work when he took office in January 1961.

John F. Kennedy's election in 1960 led to a change of National Security Strategy from massive retaliation to flexible response. The flexible response strategy required conventional as well as nuclear weapons so the US could respond to Soviet aggression anywhere along the continuum of conflict. President Kennedy instructed Secretary McNamara to substantially expand US conventional forces--ground, sea, and air--to cope with the varied threats confronting the US from around the world. McNamara was instructed to accomplish this expansion at the lowest possible cost.[12]

The combined developmental costs for the Air Force TFX and Navy Missileer programs concerned McNamara. In light of his mission to enhance the tactical fighter forces at a low cost, the idea of common development was attractive. The influence of the Eisenhower administration commonality studies and the ongoing integration of the

Navy's F-4 Phantom II into the Air Force inventory led Secretary McNamara to decide that a single fighter could fulfill both the Navy and Air Force requirements.[13] On September 1, 1961, in a memorandum for the Secretaries of the Air Force and Navy, McNamara instructed that "A single aircraft for both the Air Force tactical mission and the Navy fleet air defense mission will be undertaken." [14] This decision established the requirement for commonality that would eventually result in high costs, the Navy program failure, and performance degradation of the Air Force version of the TFX.

TFX Program Objectives

Secretary McNamara testified before the Senate Subcommittee on Investigations in 1964 that he had three objectives for the TFX program. The first objective was to introduce an advanced fighter for the Air Force and Navy to replace the F-105 and F-4 as the backbone of the services' tactical fighter forces. The second objective was to maximize the dependability of the new fighter and the third objective was to minimize the cost of the program.[15]

McNamara decided the best, and least costly, replacement for the Air Force F-105 and the Navy F-4 could be developed from the TFX program. He explained during the Senate hearings that ". . . one way to reduce costs and to increase reliability is to insist that weapons systems be developed that can be used by more than one service, where this can be done without degradation of essential military requirements."[16] The technological advances planned for incorporation in the TFX design certainly provided the possibility of offering substantial advantages over the F-105 and F-4. The increased speed, range, payload, and all-weather attack capabilities proposed for the TFX program were beyond anything in the inventory at the time. Thus, as long as the production aircraft met the design requirements, the TFX program would meet McNamara's first goal of upgrading the services' tactical capabilities.

McNamara thought his second and third objectives, maximizing dependability and minimizing program cost, could be met if the Air Force and Navy operated the same aircraft. He believed Navy and Air Force aircraft readiness rates were a function of the availability of spare parts for the various aircraft types. Low readiness was caused by a

shortage of unique spare parts. High readiness rates were attained only by units stockpiling excessive and costly part inventories.[17] He concluded that a single aircraft type with a single parts supply system would be more responsive and would provide a higher readiness rate and better dependability than different aircraft operated by the two services.

Minimizing program and average unit cost was crucial because the president had directed low cost procurement and the TFX program was projected to provide a large number of aircraft.[18] McNamara theorized that developing a common aircraft to fulfill the requirements of the Air Force and Navy would be less expensive than two separate development and production programs. He believed common development would enable the realization of substantial savings in the development, test, and production stages and throughout the life of the aircraft in terms of logistics, maintenance, training, and operating costs.[19]

The idea of commonality began as a cost saving tool for the TFX program. However, as the program evolved, Secretary of Defense McNamara was adamant that adherence to a common design was necessary to reap the savings inherent in a joint development program. Thus, commonality itself became a program objective. Unfortunately, the attempt to design an aircraft to successfully meet the requirements of multiple missions, while strictly adhering to a common design, exceeded the limits of the available technology. As the program evolved, the requirements of the two services became more disparate. The more the design was changed to please one service, the less it matched the needs of the other. The quest for commonality ultimately caused the TFX program to fail to meet any of the three objectives McNamara had originally sought to accomplish.

Commonality Defined

The theme of commonality runs strongly throughout the history of the TFX. Commonality in the TFX program was explicitly defined by Secretary McNamara in memoranda to the services and the contractors competing for the TFX contract. In his September 1, 1961 memorandum to the Secretaries of the Navy and Air Force McNamara indicated that he desired the Navy and Air Force versions of the TFX to be as close to the same airframe as possible.

> I believe that the development of a single aircraft of genuine tactical utility to both services in the projected time frame is technically feasible. A single aircraft for both the Air Force tactical mission and the Navy fleet air defense mission shall be undertaken. The Air Force shall proceed with the development of such an aircraft…. Changes to the Air Force tactical version of the basic aircraft to achieve the Navy mission shall be held to a minimum.[20]

The Work Statement for the TFX that was delivered to contractors in October 1961 contained the following instructions on commonality:

> Paragraph 1.0—Common design and common equipment will be used whenever possible, to satisfy the requirements of both services. Paragraph 1.3—A single aircraft for both the Air Force tactical mission and the Navy fleet air defense mission will be undertaken. Paragraph 1.3-6—Changes to the Air Force tactical version of the basic aircraft to achieve the Navy mission will be held to a minimum.[21]

General Dynamics and Boeing presented the only designs that were judged worthy of further consideration after the TFX Request for Proposal competition. To avoid any doubt as to the objective of the program, Secretary McNamara instructed Assistant Secretary of Defense Roswell Gilpatric to write to General Dynamics and Boeing to explain the conditions the contractors had to meet before the TFX contract would be awarded. Gilpatric's letter, dated July 13, 1962 established the following three conditions.[22]

1. Satisfaction of both Navy and Air Force that a significant improvement to their tactical air capabilities is represented by the winning design.
2. 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.
3. Demonstrably credible understanding of costs both for development and procurement of the complete TFX weapon system, which costs must be acceptable in view of the capability added to our military strength by the weapon system.

There is little doubt that Secretary McNamara defined commonality to mean being nearly *identical* in terms of tooling, structures, equipment, and other construction and maintenance requirements. The virtue of the absolute similarity between the Air Force and Navy versions of the TFX, according to McNamara's theory, was the reduced cost of the development and procurement program.

Assumptions

Secretary McNamara's TFX decisions were influenced by the successful integration of the Navy's F-4 into the Air Force inventory. McNamara's testimony before the Senate Subcommittee on Investigations in 1964 stated that he used the F-4 as proof that the services' objections were unfounded and the possibility for successful joint TFX development existed.

> For over a year each of the services argued that their military requirements could not be met by a single aircraft. Only in November of 1962, by the way, after the Air Force had accepted the F4H, an airplane originally designed solely for Navy use, as the basic Air Force fighter—only . . . after that experience did each of the services conclude that their previous position had been in error, and that a single plane could meet their joint military requirements . . . it became clear therefore that we could meet all three objectives—an advanced aircraft with high dependability and low cost, and we could do this with the resultant saving of about $1 billion by the adoption of a single versus dual aircraft program.[23]

Using the F-4 as a model for the TFX program led McNamara to make two very important assumptions: the Navy and Air Force would compromise requirements to acquire a common aircraft and the fleet defense and the tactical fighter missions could be successfully accomplished by this aircraft. Fulfillment of these three assumptions led McNamara to believe that a common development program would be cheaper than separate Air Force and Navy programs. This final assumption drove the TFX commonality requirement.

The McDonnell F-4 did not begin as a joint program, however. The aircraft was designed as a Navy attack airplane in 1954. Originally designated AH-1, the attack bomber was reconfigured as a fighter during 1955 and redesignated the F4H Phantom II. The first 696 F-4s entered Navy service during 1955 for use as fleet defense fighters.[24] The F-4 emerged from its mixed lineage as a unique aircraft during this period. It was the only US military jet of its day that was both an excellent air-to-air fighter and a highly capable ground attack airplane.

During this period, the Air Force needed a tactical fighter. The F-105 program was suffering significant technical problems during its introduction into service in 1961.

The first F-105s were unreliable and difficult to maintain and the aircraft was not an effective air-to-air fighter.[25] When the F-105 began having problems, the Air Force needed an aircraft to fill out the tactical force structure. The F-4 was offered to the Air Force to fill the space left by the F-105. After only eleven changes to the airframe of the Navy F-4B, the F-4C became part of the Air Force inventory.[26]

The essential characteristics which made the F-4 acceptable to both the Navy and the Air Force were not a result of common development. The F-4 requirements were written by the Navy, therefore carrier compatibility was central to the aircraft design. The F-4 was designed to fit aboard carrier decks, in hangar decks, and on deck elevators. Weight was held to a minimum to reduce wind-over-the-deck requirements to ensure compatibility with carrier catapult and arresting systems.[27] These considerations resulted in an aircraft designed with low wing loading and a high thrust-to-weight ratio. These characteristics gave the F-4 essential fighter capabilities: good high and low speed maneuverability, Mach 2 speed, and credible climb performance.

Secretary McNamara's use of the F-4 as a model to justify the feasibility of a joint development airplane meeting the military requirements of the Navy and Air Force was erroneous. The F-4 was not a joint development program. It began as a Navy aircraft. Also, unlike the TFX, the Navy and Air Force used the F-4 for the same mission. Interestingly, the Phantom II was designed, though not intentionally, in compliance with the Air Force philosophy that tactical fighters should have both an air-to-air and air-to-ground capability. This characteristic, the immediate need for an Air Force tactical fighter, and the aircraft's outstanding flying qualities were more responsible for the acceptance of the F-4 into the Air Force inventory than the services' desire to field a common fighter.[28]

Compromise

Secretary McNamara assumed the Navy and Air Force would compromise the requirements for their respective programs to acquire a joint development aircraft. Contrary to this assumption, both the Air Force and Navy felt compromises in essential mission requirements would result in less capable aircraft for their services. Paul B. Fay, Jr.,

Acting Secretary of the Navy, made this point clearly in an August 22, 1961 memorandum to Secretary McNamara.

> The Air Force and the Navy have been mindful of your interest in the TFX, and have used every means to respond to your guidance. However, in the case of the TFX, it has not been practicable to reach an agreement on the characteristics of the TFX and at the same time fulfill the stated service military mission requirements. . . . In light of the fundamental differences in basic requirements for the Navy versus Air Force fighters, it is not surprising that a compromise design between Navy and Air Force requirements would produce an aircraft that would be considerably below optimum for either service.[29]

However, once the decision to proceed with the joint program was mandated by Secretary McNamara, in September 1961, the Navy and Air Force followed orders and worked together in hopes of making the program succeed.

Air Force and Navy officers made up the Source Selection Board for the TFX program. The board held four rounds of competition to determine its recommendation for awarding the TFX contract. Nine contractors participated in the first round. All designs were judged to be inadequate, but Boeing and General Dynamics provided designs that showed the most promise and were selected to compete for the contract. During the next two rounds, the Air Force recommended the Boeing design while the Navy claimed neither contractor's design met its requirements.[30] At this point, McNamara relaxed the commonality requirement to aid the achievement of a successful design. After the fourth and final round in November 1962, the Air Force and Navy concurred that both designs were acceptable but recommend the TFX contract be awarded to Boeing based on its design's proposed operational performance advantage.[31]

On November 24, 1962, the Office of the Secretary of Defense announced that the TFX contract was awarded to General Dynamics, not Boeing as recommended by the military.[32] Secretary McNamara, after conferring with the service secretaries, overruled the Source Selection Board's recommendation to select Boeing to build the TFX based on three points. He felt Boeing did not meet the fundamental requirement for minimal divergence from a common design. Roughly 61 percent of the parts in the Boeing design were identical in both versions of the aircraft versus approximately 84 percent of the parts in the General Dynamics design.[33] The Boeing design also used unproved technology

and materials (thrust reversers and titanium), which was riskier than the more conventional General Dynamics design. Finally, McNamara felt the Boeing cost figures were unrealistically optimistic.[34] Citing the Source Selection Board's findings that both contractors provided acceptable designs and dismissing the operational advantages the military saw in the Boeing proposal as "bonus performance," Secretary McNamara overruled the military's recommendation for the TFX contractor based on commonality and cost.[35] This decision left the services feeling that they had been saddled with the second-best aircraft in a program they never wanted.

Once the TFX, designated F-111A and B, for the Air Force and Navy respectively, began failing in the test phase, the spirit of compromise dissolved and the Navy sought to cancel its part of the TFX program. During 1963 NASA engineers at Langley AFB discovered during wind tunnel tests that the F-111 design exhibited poor directional stability and maneuverability characteristics at supersonic speeds, and it probably could not meet the supersonic dash requirement specified in the Air Force primary mission statement. An extremely serious weight gain problem also threatened the carrier compatibility of the Navy's F-111B and the range and speed capabilities of the Air Force's F-111A.[36] In February 1964, the Navy proposed either redesigning the F-111B to reduce weight and improve the aircraft's capabilities around the carrier or stopping the Navy's participation in the program.[37]

Project Icarus

Between August 1966 and February 1968, Secretary of Defense McNamara ordered weekly meetings to attend to the serious deficiencies coming to light during the test phase of the F-111 program. These meetings were attended by secretary-level personnel and by top officials from the General Dynamics Corporation and Pratt and Whitney.[38] Ironically, these meetings were held under the name "Project Icarus." [39] The "Memorandums of Conversation" from these meetings illuminate the fact that the problems with the F-111 were known at the secretarial level of the Department of Defense. However, McNamara continued to support the common development program even when it interfered with fixing the deficiencies in the F-111.

The topic of discussion at the first Project Icarus meeting on August 25, 1966 was the "F-111 problem list" of sixteen deficiencies that had been discovered in the F-111A, F-111B, and the FB-111A.[40] This list is presented in Figure 1.

F-111A	F-111B	FB-111
1. Total radius, Mach 1.2 to Lo Lo Hi. Specifications: 800/210 NM AF estimate: 800/119 NM	5. Combat ceiling. Specifications: 55,000 ft. Navy estimate: 48,800 ft. AF estimate: 48,800 ft.	14. No firm performance specifications for the FB-111 version.
2. Total radius, Hi Lo Hi. Specifications: 1920 NM AF estimate: 1665 NM	6. Wind over deck for launch. Specifications: -8 m.p.h. Navy estimate:+15 m.p.h. AF estimate: -7.2 m.p.h.	15. Single engine rates of climb inadequate at maximum gross weights on hot days.
3. Ferry range. Specifications: 4180 NM AF estimate: 3610 NM	7. Loiter altitude. Specifications: 35,000 ft. Navy estimate: 30,000 ft. AF estimate: 35,000 ft.	16. Combat range, Hi Lo Hi, with one refueling. Classified
4. Combat altitude at Mach 2.5. Specifications: 62,300 ft. AF estimate: 58,050 ft.	8. Buffet limit/G load. Specifications: .60/2.0. Navy estimate: .74/1.67. AF estimate: .77/1.67.	
	9. Acceleration. Mach .6 to Mach 2.0. Specifications: 5.5 minutes Navy estimate: 8.2 minutes AF estimate: 4.82 minutes	
	10. Single engine climb rate. Specifications: 595 f.p.m. Navy estimate: 267 f.p.m. AF estimate: 465 f.p.m.	
	11. Wind over deck for landing. Specifications: +5 knots Navy estimate:+15 knots AF estimate: +7.2 knots	
	12. Landing weight. Specifications: 50,068 lbs. Navy estimate: 55,300 lbs. AF estimate: 55,300 lbs.	
Note: The Air Force estimates of the performance characteristics decreased as project Icarus continued.	13. Control. Deficiencies in stability, yaw, and visibility.	

Figure 1. F-111 Problems List

Flight tests confirmed that the F-111 was underpowered, unstable, and poorly designed. McNamara acknowledged this with a quote in the Memorandum of Conversation for the first Project Icarus meeting: "We have a serious problem here . . . The basic problem is an unsatisfactory aircraft (all versions)."[41] During Project Icarus, McNamara pushed for further design efforts to solve the problems in the F-111 but balked at sacrificing commonality. A "package of fixes" for the Navy's F-111B was presented at the September 6, 1966 meeting. McNamara and Dr. Harold Brown, Director of Defense Research and Engineering, agreed that "fixes" which reduced the commonality of the program should be included only as alternatives.[42] Despite the program's obvious problems, the idea of commonality remained a Department of Defense goal for the TFX.

By 1968, the impending failure of the F-111B was evident. During one Project Icarus meeting McNamara stated, "With the F-111A the problem essentially was when to go into production. The F-111B problem on the other hand was whether we had an aircraft at all."[43] The Navy refused to further compromise its F-111 requirements. Weight and drag reduction programs were marginally effective, but in 1968, the F-111B was still 20,000 pounds over the originally specified maximum takeoff weight.[44] The commonality level between the F-111A and F-111B had been reduced from 80 percent to 29 percent due to the weight reduction redesign program. The aircraft provided inferior performance to the Navy's F-4J and failed to meet the Navy's essential operational requirements.[45] In 1968, the Navy presented these insurmountable shortfalls to Congress and successfully lobbied for the cancellation of the Navy TFX (F-111B) program.[46]

One Aircraft for Two Missions

The third assumption, that a single fighter could successfully perform the Navy's fleet defense mission and the Air Force's long-range tactical fighter mission, also grew from the successful integration of the Navy's F-4 Phantom into the Air Force inventory. McNamara's proposed $1 billion savings through commonality hinged on one aircraft performing both missions. However, as events proved, these two missions and their associated operating environments were too disparate for one aircraft to accomplish.

Memoranda to McNamara from the Secretaries of the Air Force and Navy dated August 22, 1961 indicated that neither service thought the TFX program could provide one aircraft to meet the needs of both services.[47] The Secretary of Defense overruled these objections with his September 1, 1961 memorandum in which he ordered that "A single aircraft for both the Air Force Tactical mission and the Navy fleet defense mission will be undertaken. The Air Force shall proceed with the development of such an aircraft."[48] The performance requirements for the Air Force tactical fighter version of the TFX (also referred to as the *basic design*) were contained in the Specific Operational Requirement for an Armed Forces Fighter Aircraft, Number 183 (SOR-183).

SOR-183 specified the development of three variants of the TFX: the Air Force Tactical Fighter, the Air Force Long Range Interceptor, and the Naval Fighter.[49] The Air Force Tactical Fighter was to be the basic airframe and engine combination with added constraints. These constraints, added in an attempt to satisfy the Air Force and Navy requirements, included a mold line able to accommodate a 36-inch radar dish in the nose, a maximum airframe length of 73 feet, a maximum weight, with full internal fuel and 2,000 lb. of ordnance, of 60,000 lb. (55,000 for the Navy version), and the structural ability to accommodate loads associated with carrier operations.[50]

The operational requirements delineated in SOR-183 were ambitious. Figure 2 contains the performance requirements for the Air Force Tactical version and Naval Fighter version of the TFX.[51] These requirements, when coupled with the constraints imposed to maintain a common design for the two services' aircraft, posed a difficult challenge for the aircraft industry.

Requirement	Air Force	Navy
Speed- Max Sea level Sustained Cruise Max Speed	Mach 1.2 Mach 2.2 at 50,000 feet Mach 2.5+ at 50,000 feet	Mach 1.0 with 2,000 lb of ordnance Mach 2.0 with 6 missiles
Ceiling	60,000+ feet	60,000+ feet
Take off/Land	3,000 feet over a 50 foot obstacle, on an improved sod runway	3,000 feet over a 50 foot obstacle Compatible with CVA-19, CVA-43, and CVA-59 class carriers
Range/Endurance (Internal Fuel Only)	3,300 NM at Mach 0.8 800 NM radius with 200 NM Mach 1.2 dash at sea level	Loiter on station for 3.5 hours, 150 NM from the carrier Loiter on station for 1.0 hour, 750 NM from the carrier
Radar	Terrain Following Track-while-Scan	Track-while-Scan, capable of detecting a 5 square meter aerial target at 100 NM between sea level and 90,000 feet

Figure 2. SOR-183 Requirements

The Air Force mission required a deep interdiction tactical strike aircraft. To accomplish this mission in the face of the Soviet threat at the time, the Air Force determined the following requirements for the F-111A:

(a) The ability to deliver significant bomb loads on distant targets;
(b) The ability to deploy rapidly over long distances, including nonstop, unrefueled, transatlantic ferry capability;
(c) The ability to fly at very low level to avoid radar detection as well as the ability to penetrate a sophisticated electronic defense;
(d) The ability to make precision weapon deliveries at night and in all weather; and
(e) The ability to operate alone in highly defended areas.[52]

The Navy mission requirements were very different from those of the Air Force. The Navy required ". . . an advanced air superiority fighter aircraft to be used to gain and maintain control of the air over extensive sea and land combat areas with particular emphasis to the air-to-air mission in limited war situations."[53] The following are the major characteristics the Navy desired in the F-111B:

(a) Fully compatible with CVA-59 *Forrestal* class, CVA-41 *Midway* class, and CVA-19 *Essex* class carriers.
(e) Designed primarily as an air-to-air fighter to gain and maintain air superiority. To have a secondary capability of attacking surface targets; and of reconnaissance.[54]

The wide disparity in missions and requirements between the services hindered the development of a common aircraft to perform both the Navy and Air Force missions. The Air Force requirement for high speed was countered by the large diameter nose required for the Navy's air-to-air radar dish. The radar dish was reduced from its original 60 inch diameter in the Missileer to 36 inches to facilitate supersonic performance in the TFX. This adversely affected the radar's range and detection capability. The length and weight restrictions and structural strength necessary for carrier compatibility meant less room for fuel tanks. This adversely affected the Air Force mission requirement for long range and high speed.

The common development program caused the failure of the Navy's F-111B and hindered the successful development of the Air Force F-111A. The problems that plagued the F-111 program were caused by a poor aircraft design that was made difficult to change by the program's commonality requirement.[55] By May 1963, NASA engineers at Langley AFB had logged over 1,100 hours of wind tunnel tests on 1:24 scale F-111 models. These early tests revealed the aerodynamic design problems that would seriously affect the performance of the aircraft. In March 1963 the NASA engineers reported that the F-111 design exhibited the following characteristics to the Assistant Secretary of the Air Force (R&D).[56]

1. The F-111 design would not meet the Air Force specification for the primary mission dash requirement.
2. The airplane would not develop the maneuver capability at supersonic speeds specified by the contractor.
3. Its directional stability was extremely low at supersonic speeds. The primary mission dash shortcoming was associated with a high drag level which would require significant design changes to solve. Regaining the maneuverability would also require significant design changes.

The growth in the empty weight of the F-111 also became apparent during 1963 through contractually required weight reports from General Dynamics Corporation. This

weight gain was critical because it adversely affected the aircraft carrier suitability of the Navy's F-111B. The Navy proposed a redesigned F-111B to remedy the known aerodynamic and weight problems in an effort to salvage a usable aircraft from its part of the program.

Any effort by the Navy to change the basic aircraft design was seen by McNamara as an indictment of his decision to choose General Dynamics Corporation as the prime contractor for the TFX and also as a threat to the common development program. Between February and November 1963, the Senate Subcommittee on Investigations was conducting the first hearings on the controversy surrounding the TFX contract awarded to General Dynamics Corporation. McNamara had testified that he overruled the Service Selection Board recommendation for the Boeing design based on General Dynamics' better adherence to the requirement for commonality, less risky design, and more realistic cost proposal.[57] Once the aerodynamic and weight problems were discovered in the General Dynamics design, McNamara could refute his own testimony, admit to a bad policy decision and cancel the TFX program or try to make the program succeed as promised. He chose to attempt to save the TFX. Therefore, any effort by the Navy or any other participant to reduce commonality or to change the original design was not acceptable to him. Ironically, had the redesign effort proposed by NASA and the Navy been implemented, the TFX program might have succeeded.

The problems identified in the original NASA wind tunnel tests and in the Navy's 1964 design reevaluation plagued the Air Force F-111 throughout its development. The October 13, 1969 Senate Defense Appropriations Hearing on the Air Force F-111 program traced the evolution of the aircraft models from F-111A to F-111F. Testimony revealed five basic problems with the F-111A.

> (1) The engine air inlet is too small, limiting possible thrust increases with the engine.
> (2) The airplane is grossly under powered, because of a combination of weight growth of the airframe without any compensating increase in thrust and a change in mission emphasis from nuclear interdiction to one of carrying conventional bombs under the wings which produce high drag.
> (3) The avionics bombing system, based on an analog computer, is obsolete compared with modern digital computer avionics.
> (4) The wing carry through box, the structural shoulders of the airplane to

which the wings attach at the pivots, failed to meet its required fatigue life requirements, resulting in premature test failures and requiring a costly modification program.

(5) The wing area was not increased to offset the weight growth, resulting in very high wing loading implying limitations on maneuverability. (The F-111 originally was intended in 1963 to be the sole tactical fighter in the Air Force in the 1970's. Since it does not have fighter maneuverability, it cannot be used as a fighter aircraft. It is suitable only as a ground attack bomber. A new fighter--the F-15--is now in development.) [58]

Many of the deficiencies in the F-111A were eventually overcome by incorporating new engine inlet designs, installing more powerful engines, and incorporating digital computer avionics in subsequent models. The F-111 evolved into a high performance tactical bomber in the F-111F model. Unfortunately, the original requirement for fighter maneuverability was never recovered. However, the evolution was costly. The Air Force procured 407 F-111A, E, D and FB-111 model aircraft, which were all deficient in thrust, maneuverability, avionics, or structural integrity, before it bought the F-111F.[59] Increases in costs resulted in the Air Force being able to purchase only 82 F-111Fs rather than the original 1,473 aircraft the program was designed to provide.[60]

Cost

Secretary McNamara's fourth assumption was that a joint development program would result in substantial savings over separate Navy and Air Force programs. He proposed the TFX program as a way to fulfill the fighter requirement for the Navy and Air Force and save $1 billion by building a joint-use aircraft for both services.[61] At the time of the contract award to General Dynamics, the TFX program was scheduled to provide 22 research and development aircraft plus 1,704 production aircraft. The Navy was to receive 231 F-111Bs for fleet defense and the Air Force was to receive 1,473 F-111As as its sole tactical fighter. The $1 billion savings over the fixed program costs of a separate Navy development would have to be gained with the 231 F-111B airframes. For McNamara's cost objective to be met, a savings of $4.3 million per F-111B airframe was required. The total TFX program cost was projected as $5.8 billion ($.7 billion for

R&D plus $5.1 billion for production). The average cost per aircraft was to be $3.4 million.[62]

The results were much different. No Navy F-111B production aircraft were ever built. Roughly $378 million was spent on the canceled F-111B program.[63] The Air Force Selected Acquisition Report of December 31, 1969 estimated the cost for the production run of 489 F-111A, D, E, F aircraft at $9.2 billion, or $16.6 million per airplane.[64] The program that was to save money through a common aircraft for the Navy and Air Force ended by providing roughly one third of the proposed aircraft at five times the projected cost per airplane.

Conclusions

The TFX program failed to meet its original goal of developing and fielding a common fighter for the Air Force and Navy at a low cost. Three major events played important roles in this failure.

First, the program was forced on the Navy and the Air Force by Secretary of Defense McNamara. From the beginning, neither service thought the program could succeed. Air Force and Navy recommendations to allow separate development programs were based on the evaluation of the disparity between the missions and requirements of the two services' programs. Despite objections from the service experts, McNamara ordered them to begin work on the TFX.

Second, McNamara overruled the Source Selection Board's recommendation and selected General Dynamics as the contractor for the TFX. McNamara's decision was based on the goals set for the program: joint development and reduced costs from a common design. One cannot say that the Boeing aircraft would have been more successful than the General Dynamics F-111A/B because none were built. However, because of this decision, the Air Force and Navy felt they had been saddled with the second best design. Once the General Dynamics design was shown to be faulty by NASA and the flight test program, McNamara doggedly chose to pursue joint development in an effort to salvage the program. Efforts to redesign the F-111 were rejected because they indicated something was wrong with the General Dynamics proposal and compromised common-

ality. Eventually, the combination of aerodynamic deficiencies and increases in the airframe weight made the F-111B unacceptable for the Navy. These same deficiencies haunted the F-111A and subsequent models throughout their Air Force service.

Third, the design was a compromise between the Navy and the Air Force. Therefore, it was not the best design for either mission. The mission requirements for fleet defense, carried forward from the Eagle/Missileer program, were very different from those proposed by the Air Force TFX. As the F-111B program progressed, the Navy refused to compromise its program requirements in an effort to maintain the aircraft's carrier capability. The requirement for commonality between the two versions of the F-111 drove the Air Force to accept changes to its design to help meet the Navy's requirements.

When it became apparent that neither service's requirements were being met by the compromised design, the Navy seized the opportunity to escape from the program and lobbied for the cancellation of the F-111B. The Air Force was left with an aircraft design that was not optimized for its mission. A lengthy and costly evolution led to the recovery of the original air-to ground requirements for the TFX in the F-111F model, but the proposed air-to-air capabilities were never attained. The common development program forced the Navy to accept an aircraft design that was never capable of performing the fleet air defense mission it required. Efforts by Secretary of Defense McNamara to salvage the common development program after testing proved the General Dynamics design was faulty forced the Air Force to accept an aircraft that had been compromised to the point it was incapable of performing its intended mission.

Notes

[1]Robert J. Art, *The TFX Decision: McNamara and the Military* (Boston: Little, Brown and Company, 1969), 15.

[2]Art, 17.

[3]Ibid., 16.

[4]Ibid., 17. These capabilities were further defined in the TFX Specific Operational Requirement (SOR-183) as take off and land in less than 3000 feet on a sod runway and an unrefueled ferry range of 3,300 nautical miles at 0.85 mach.

[5]Senate, *TFX Contract Investigation: Hearings before the Committee on Government Operations,* 88th Cong., 2d Sess., 1964, pt. 6:1382. Testimony of Fred Korth, Secretary of the Navy.

[6]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 6:1382-1383.

Notes

[7]Ibid., pt. 6:1382.

[8]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 6:1382.

[9]Ibid., pt. 6:1382.

[10]Mr. Robert Horne Charles, Assistant Secretary of the Air Force for Installations and Logistics, transcript of oral history interview by Lt. Col. Lyn R. Officer, 21-22 January 1974, Air Force Historical Research Association, Maxwell AFB, Ala., 22.

[11]Dr. Joseph V. Charyk, transcript of oral history interview by Dr. James C. Hasdorff, 15 January and 24 April 1974, Air Force Historical Research Association, Maxwell AFB, Ala., 6.

[12]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 2:375. Written statement of Robert S. McNamara, secretary of defense.

[13]Ibid., pt. 2:429. McNamara testified that, despite their argument to the contrary, he felt the Navy and Air Force accepted that one aircraft could meet the needs for both services. "Only in November of 1962, by the way, after the Air Force had accepted the F-4H, an airplane designed solely for Navy use . . . did each of the services conclude that their previous position had been in error, and that a single plane could meet their joint military requirements."

[14]Ibid., pt. 6:1514. Exhibit no. 42, Secretary of Defense memorandum, 1 September 1961.

[15]Ibid., pt. 2:429. Testimony of Robert S. McNamara.

[16]Senate, *TFX Contract Investigation*, 88th Cong., 1964, pt. 2:376. Written statement of Robert S. McNamara.

[17]Ibid., pt. 2:376.

[18]Senate, *TFX Contract Investigation, Second Series,* 91st Cong. 2d Sess., 1970, pt. 1:74. The program was to consist of 22 research and development aircraft and 1,704 production models. The Air Force was to receive 1,473 F-111As as its sole tactical fighter and the Navy was to receive 231 F-111B fleet air defense aircraft.

[19]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 2:376.

[20]Ibid., pt. 6:1514. Secretary of Defense memorandum, September 1, 1961.

[21]Senate, *TFX Contract Investigation, Second Series,* 91st Cong., 1970, pt. 1:29.

[22]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 2:380. Written statement of Robert S. McNamara.

[23]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 2:429.

[24]Bill Yenne, *U. S. Airpower* (New York: Portland House, 1989), 12.

[25]Lieutenant General John J. Burns, USAF, transcript of oral history interview by Hugh N. Ahmann, 5-8 June 1984, US Air Force Historical Research Center, Office of Air Force History, Washington D.C., 165-167.

[26]Ibid., 169.

[27]Aircraft cannot usually be launched and recovered without some wind coming over the deck of the aircraft carrier. Wind-over-the-deck requirements are optimally limited to a margin less than the top speed of the ship so aircraft can take off and land on a calm day, using only the wind generated by the ship's movement through the water. As aircraft weight increases, launch and recovery speeds increase. Since carrier launch and recovery equipment have finite capabilities, wind-over-the-deck must be modulated to ensure the

limitations of this equipment are not exceeded. As aircraft weight increases, wind-over-the-deck requirements increase. Since the maximum speed of the ship determines the maximum usable wind-over-the-deck, it is imperative to limit aircraft weight as much as possible to successfully operate within these constraints.

[28][28][28]Lieutenant General John J. Burns interview, 168.

[29]Senate, *TFX Contract* Investigation, 88th Cong., 1964, pt. 6:1464. Secretary of the Navy memorandum, August 22, 1961.

[30] Art, 180-181.

[31]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 1:146-147.

[32] Art, 181.

[33]Senate, *TFX Contract Investigation*, 88th Cong., 1964, pt. 1:270.

[34]Ibid., pt. 2:385.

[35]Ibid., pt. 2:430.

[37]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 1:58.

[38]Ibid, pt. 2:540.

[39]In Greek mythology, Icarus was the son of the Athenian architect Daedalus. To enable their escape from imprisonment on the island of Crete, Daedalus fashioned wings from wax and feathers for himself and his son. Daedalus safely escaped to Greece by flying at low altitude. Icarus, ignoring his father's warnings, flew very high and the sun's heat melted his wings. Icarus fell to the sea and was killed.

[40]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt: 2:542-543. The FB-111A was a strategic bomber version of the F-111A that McNamara proposed to replace early model B-52s. At the time of the first Project Icarus meetings, the FB-111A was a drawing board project. The contract to produce the FB-111A was signed on May 10, 1967.

[41]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 2:544.

[42]Ibid., pt. 2:549.

[43]Ibid., pt. 2:548.

[44]Senate, *TFX Contract Investigation, Second Series,* 91st Cong., 1970, pt. 1:61. 79,002 lb. in 1967 vs. 55,000 in SOR-183.

[45]Senate, *TFX Contract Investigation, Second Series,* 91st Cong., 1970, pt. 1:62-63.

[46]Ibid., pt. 1:74.

[47]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 2:333.

[48]Ibid., pt. 6:1514. Exhibit no. 42, Secretary of Defense memorandum, September I, 1961.

[49]Department of the Air Force, *Specific Operational Requirements for an Armed Forces Fighter Aircraft,* no. 183 (Washington, D.C.: Headquarters United States Air Force, 14 July 1960 [Revised 8 September 1961]), 3. The long range fighter version was canceled after the F-111 performed poorly in the maneuverability and performance portion of the test program.

[50]Department of the Air Force, *Specific Operational Requirements for an Armed Forces Fighter Aircraft,* no. 183, 2. The mold line of an aircraft is the full-size line drawing of the outer shape of the aircraft.

Notes

[51]SOR-183, Annex A, Annex C.

[52]Senate, *TFX Contract Investigation, Second Series*, 91st Cong., 1970, pt. 2:298.

[53]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 6:1465. Excerpt from *Navy Report on TFX Military Mission Requirements.*

[54]Ibid., pt. 6:1465.

[55]The US Air Force developed and produced the following variants of the F-111: F-111A/D/E/F,

FB-111A, EF-111.

[56]Senate, *TFX Contract Investigation, Second Series,* 91st Cong., 1970, pt. 1:55.

[57]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 2:430.

[58]Senate, *TFX Contract Investigation, Second Series,* 91st Cong., 1970, pt. 1:75-76.

[59]Senate, *TFX Contract Investigation, Second Series,* 91st Cong., 1970, pt. 1:76. The FB-111, and the RAAF F-111C are essentially F-111As with the 3.5 foot wing tip extensions from the Navy F-111B.

[60]Ibid., pt. 1:74

[61]Senate, *TFX Contract Investigation,* 88th Cong., 1964, pt. 5:1229.

[62]Senate, *TFX Contract Investigation, Second Series,* 91st Cong., 1970, pt. 1:74.

[63]Ibid., pt. 1:75.

[64]Ibid., pt. 1:82.

Chapter 3

The JSF Program

Secretary of Defense Les Aspin's 1993 *Bottom Up Review* (BUR) established the necessity to replace the aging US tactical fighter inventory. In response to this requirement, the Department of Defense initiated the Joint Advanced Strike Technology (JAST) program, aimed at reaching an affordable solution to maintaining the nation's technological advantage in strike fighter aircraft. Since Fiscal Year 1995, legislation has combined the Advanced Research Projects Agency's Advanced Short Take-off and Landing (ASTOVL) program with JAST.[65] The resulting Joint Strike Fighter (JSF) program is the Department of Defense's attempt to define an affordable next generation tactical fighter aircraft for the US Air Force, Navy, and Marine Corps. To reduce potential development and life cycle costs, the JSF program is emphasizing a degree of airframe commonality not seen since the TFX (F-111) program of the early 1960s.

Precursors

In 1993 the US Air Force, Navy, and Marine Corps were operating seven different tactical fighter aircraft. Most of these were designed and bought in the 1970s and 1980s.[66] Secretary of Defense Les Aspin was concerned with the aging tactical air fleet. One of his reasons for ordering the Bottom-Up Review in 1993 was to help maintain the technological superiority of US weapons and equipment by designing "a balanced modernization program that will safeguard this edge and the necessary supporting industrial base without buying more weapons than we need or can afford."[67]

Secretary Aspin, formerly the Chairman of the House Armed Services Committee, was well acquainted with the modernization programs for the tactical air forces during the

Bush administration. Five programs to modernize fighter and attack aircraft existed: the Multirole Fighter (MRF), the A/F-X, the F-22, the F/A-18E/F, and the Short Take-off Vertical Landing Strike Fighter (SSF).[68] The high cost of developing and sustaining the aircraft represented by these programs was not affordable, according to the administration. The *Bottom Up Review* was an attempt at restructuring these programs into an affordable but effective modernization plan.

As a result of the restructuring, the MRF and A/F-X programs were eliminated. The STOVL Strike Fighter (SSF) remained in development. Identified as the Advanced Short Takeoff Vertical Landing (ASTOVL) program, it was targeted at replacing the Marine Corps' AV-8B Harrier. In 1994, ASTOVL was absorbed by the JAST program. JAST, originally developed to explore new technology and acquisition methods that would make a joint strike fighter aircraft program feasible, became an acquisition program for the Joint Strike Fighter (JSF) in May 1996.[69]

The Clinton Administration approved the continuation of the F-22 and the F/A-18E/F programs and added the JAST program to round out the modernization plan that is programmed through 2030. The F-22, which began development in 1991, is planned to replace the Air Force's F-15C fighter fleet between 1999 and 2010 with a total purchase of 438 aircraft.[70] The 1000 F/A-18E/Fs will replace the Navy's current F/A-18A-C multirole fighters between 1997 and 2015.[71] The Joint Strike Fighter, from the JAST program, is expected to replace Marine Corps F/A-18s and AV-8Bs, the Air Force's F-16s and A-10s, and to complement the Navy's F/A-18E/F with a survivable strike fighter aircraft.[72] The tentative plan is to purchase roughly 3000 Joint Strike Fighters between 2005 and 2030.[73] This plan is second in size only to the venerable F-4, at over 5000 aircraft, in the number of jet fighters that will be purchased. The Pentagon's Quarterly Defense Review (QDR) seems to underscore the importance of the JSF program to the Department of Defense. The results of the QDR, released on 19 May 1997, indicate that both the Air Force's F-22 and the Navy's F/A-18E/F programs will be cut and the JSF will be introduced earlier than 2010 as originally planned.[74] Clearly the JSF will comprise a large percentage of the US tactical air forces in the 21st century. The

success or failure of this program will significantly affect the future military capabilities of the United States armed forces.

Change in Strategy

Several significant world events occurred in the years preceding the 1993 *Bottom Up Review* that indicated the US Cold War strategy was becoming obsolete. The fall of the Berlin Wall and the collapse of communism in Eastern Europe during 1989 reduced the US requirement for a containment strategy. The Iraqi invasion of Kuwait signaled a new era of regional conflicts that the US military would fight, often as part of a coalition force. Finally, the survival of democracy in and the break-up of the Soviet Union in 1991 virtually eliminated the USSR as a threat to the United States.[75] The Cold War strategy and force structure needed to be updated so they could meet the uncertain dangers of the post-Cold War world.

The post-Cold War era led to a changed US National Security Strategy. The Bottom-Up Review identified the requirement for the US to field sufficient forces to fight and win two simultaneous Major Regional Conflicts (MRCs).[76] Facing two conflicts, possibly with only short prior notice, identified the need to keep US forces ready to fight by providing the best training and equipment available. It also stressed the necessity of maintaining the technological superiority of US weapons and equipment that was demonstrated in Operation Desert Storm.

The modernization requirement, in an era of smaller post-Cold War defense budgets, made joint programs attractive. The separate modernization plans for the aging US tactical fighter forces were identified as being too expensive by the Bottom-Up Review. Consequently, the JAST program was chartered to define the next generation of affordable strike fighter aircraft for the Navy, Air Force, Marine Corps, and some US allies.

JSF Program Objectives

The objective of the Joint Strike Fighter Program, formerly JAST, is to define the next generation of strike fighter aircraft for the Navy, Air Force, Marines, and the UK Royal Navy. The focus of the program is affordability. The JSF plans to fulfill the serv-

ices' needs with a single family of affordable aircraft by using a high degree of airframe commonality to reduce developmental, production, and maintenance costs.[77]

With a planned production of 3000 aircraft, the JSF will account for nearly two thirds of the tactical air force modernization plan outlined in the *Bottom Up Review*. This single family of aircraft will be required to fulfill many missions for the US services and allied forces. The Navy requires a survivable, carrier-based strike fighter to complement its F/A-18E/F. The Air Force requires a multirole fighter to replace the F-16 and A-10. The Marine Corps desires a Short Takeoff Vertical Landing (STOVL) fighter to replace the AV-8B and F/A-18. Finally, the Royal Navy desires a STOVL fighter to replace the Sea Harrier.[78]

Deficiencies and Requirements

To satisfy the wide range of requirements while maintaining the degree of commonality necessary to keep the JSF program affordable has required a change in weapon development philosophy. The JSF development philosophy purposely contrasts with the development of the TFX. The TFX program focused on joint development but only after Secretary of Defense McNamara canceled the F6D Missileer program and forced the Navy to accept the Air Force's TFX to fulfill its fleet air defense requirements. The TFX was not jointly managed. Although Navy personnel worked in the TFX office, the program was run by the Air Force. Finally, Air Force and Navy TFX performance requirements were determined without industry participation. The aircraft contractors were handed the difficult task of meeting both the services' requirements and McNamara's requirements for low cost and a high degree of commonality between the Air Force and Navy TFX variants. Ultimately the program failed to meet any of these requirements.

Conversely, the JSF program was established with a focus on jointness. The Program Director assignment alternates between the Navy and Air Force. Integrated teams of military and industry personnel are used, beginning in the initial concept development phase, to define the requirements of the JSF while reducing risk and the associated cost of the future strike fighter. Cost is being treated as an independent variable in the program. This means that affordibility is a requirement on equal footing with any performance ad-

vantage over current fighters. The services will be required to balance their desires for JSF performance with the associated cost of certain capabilities. Finally, the JSF program has undergone a significant requirements definition phase in which all the involved services and industry representatives have used virtual war games to jointly identify the requirements for future strike fighter aircraft based on the National Military Strategy, probable MRC scenarios, and the needs of Joint Force Commanders on future battlefields.

Using the scenarios identified in the *Bottom Up Review* as guidance, the JSF Program Office created a Virtual Strike Warfare Environment using interactive modeling and simulation computer software. The Virtual Strike Warfare Environment is used to demonstrate and evaluate JSF concepts and technologies to illustrate their utility on the actual battlefield before any production begins.[79] The JSF office has used five virtual MRC war simulations to examine the ability of future strike fighters to meet the National Military Strategy in the 2010 time frame. Representatives from the involved services and the aerospace industry participated in these war games together. From the results of these virtual MRCs, a Joint Mission Area Analysis (JMAA), which identified the probable deficiencies of the future strike fighter mission, was completed. These deficiencies were grouped into three areas under the overarching requirement of affordability. The three requirement "pillars" are: survivability, supportability/deployability, and lethality.[80]

Survivability was determined to be a critical deficiency in future strike fighter designs. Virtual war gaming done by the JSF program office indicated that future strike fighters would be susceptible to high attrition from mobile radar and infra-red Surface-to-Air Missiles (SAMs). Due to high attrition, strike forces were discovered to be unable to interdict enemy ground forces without the help of significant Suppression of Enemy Air Defense (SEAD) forces. The increased necessity for SEAD resulted in diverting assets from their primary force application mission to execute the SEAD mission. This resulted in higher friendly ground force losses and failure to deny the enemy ground forces their objectives.[81]

Supportability and deployability were determined to be another critical deficiency in future strike fighters, especially if two regional conflicts occur simultaneously. Present theater air forces deploy with a large logistics footprint. These force deployments require

large maintenance and supply organizations to support theater air operations. The size of these forces stresses the nation's airlift capability, lengthens the time required for force build-up, and precludes a rapid response to a conflict that escalates with only short warning. JSF Program war game and historical analysis indicates that "a weapon system with a lean footprint and an enhanced sortie generation rate can deliver impressive combat power."[82] JSF program office analysis indicated that combined improvements in the reducing the logistics footprint by 50 percent and increasing the sortie generation rate by 25 percent over current tactical fighters has the best effect upon winning the campaign.[83]

The third requirement pillar, lethality, was identified using virtual strike forces in war games against the expected dangers identified in the *Bottom Up Review* and Defense Planning Guidance. In these scenarios, strike fighters experienced difficulty destroying highly mobile targets, enemy shipping, and nuclear, chemical and biological weapons. Adverse weather had a significant effect on weapon delivery and accuracy. Target engagement analysis from the war games indicated that the ability to rapidly target and engage mobile targets (tanks, armored personnel carriers, artillery, ships) and fixed tactical targets (supply depots, air fields, lines of communication) had a large impact on the success of the campaigning. The JSF analysts determined that these targets were vulnerable to a variety of 1000-pound weapons.[84]

The military members of the JSF team continue to work closely with aerospace industry team members to identify affordable solutions to the three strike warfare deficiency categories. A common family of strike fighters is the JSF program team's answer to rectifying these deficiencies while keeping costs low. Because affordability is the overarching requirement for the program, individual service requirements are evaluated for both their operational value and their cost. This results in a continuous trade-off between a desired capability and its cost.

The result of the virtual war gaming analysis, the trade offs between service requirements and their associated costs, and the identification of strike warfare deficiencies have been combined to create the Joint Initial Requirements Document (JIRD) for the JSF. This document has been signed by the three services and is supported by the Joint Requirements Oversight Counsel (JROC) and the aerospace defense contractors who are

involved in the JSF program.[85] The JIRD established the requirements that will determine the outer mold line of the aircraft designs (Figure 3).[86]

The family of JSF aircraft will be comprised of three variants. The conventional take-off and landing Air Force version, expected to be the least expensive, will account for roughly 2,036 of the 3,000 JSF aircraft. A more rugged, and possibly stealthier, deep strike carrier version will provide roughly 300 JSF aircraft for the Navy. The Marine Corps plans to purchase 642 of the most complex STOVL version of the JSF, with the possibility of the Royal Navy receiving 60 of these aircraft.[87]

Requirement	USAF	USN	USMC
Sortie Generation	Significantly greater than current F-16	Significantly greater than current F/A-18	Significantly greater than current AV-8
Logistics Footprint	Significantly smaller than current F-16	Not applicable	Significantly smaller than current AV-8
Payload-Internal plus 4 external stations	2-1000 pound class, AIM-120 and Gun	2-2000 pound class/JSOW AIM-120	2-1000 pound class AIM-120
IR/RF Signature	Classified	Classified	Classified
Range	450-600 NM	Minimum of 600 NM	450-550 NM
Speed and Maneuverability	Comparable to current multirole fighters such as the F-16 and F/A-18	Same as USAF	Same as USAF
Carrier Suitability	No	Yes	Yes, STOVL
Basing Flexibility	No	No	Yes
Desired Cost-Unit Flyaway Cost in millions of 1994 dollars	$28	$31 to $38	$30-$35

Figure 3. Initial JSF Requirements

Commonality Defined

Like the TFX, the JSF program emphasizes commonality as a cost saving tool. However, to meet the requirements of the US Air Force, Navy, Marine Corps, and the UK Royal Navy, a common "family of aircraft" is being pursued rather than one airframe for all involved. Testimony by Program Directors Major General George K. Muellner, USAF, and Rear Admiral Craig Steidle, USN, emphasize that the JSF will be made up of "a multi-service family of variants -- high commonality and modularity between conventional take-off and landing (CTOL), aircraft carrier capable (CV), and STOVL variants is expected."[88] These briefings also indicate that the JSF Program Office expects the level of commonality to be in the range of 70 and 90 percent among the three variants.

The "family of JSF aircraft" will exploit the projected savings of using common engines, avionics suites, and portions of the fuselage and other major structures. Aerospace industry contractors involved in the JSF program are studying the possibility of producing all three variants from common airframe, avionics, and engine production lines with branches for the construction of service specific variations. Should the 70 to 90 percent commonality goal be reached, the JSF program office predicts a 25 percent savings in unit flyaway costs over three separate strike fighter programs.[89] Interestingly, the program office is using the 70 to 90 percent commonality figure as the basis for its program cost predictions.

Assumptions

The JSF program has not defined the final requirements for each strike fighter variant. However, there is an underlying assumption that the individual services' missions can be accomplished by a family of common aircraft. To date, the focus of the program has been determining methods of achieving affordability in a joint strike fighter for the 21st century. Underlying these efforts have been four key assumptions. First, the JSF program assumes a high level of commonality between the proposed aircraft variants. Second, the program's joint organization leads to the assumption that the services will compromise requirements and make capability trade-offs to reduce the overall cost of the program. Third, the program's focus on using mature technology to reduce the risk and

cost of development assumes inherent savings in existing programs. Finally, the average unit cost is based on the US and UK actually buying the 3000 aircraft specified in the original program.

Interestingly, the TFX program was based on assumptions strikingly similar to those listed for the JSF. McNamara sought to produce the Air Force and Navy fighter aircraft for the 1970s at a low cost by insisting on a high level of commonality between the variants. Although the TFX program was not truly a joint organization, the Air Force and Navy were expected to compromise requirements to ensure the commonality and cost goals of the program were met. General Dynamics' use of proven technology was one of the reasons Secretary McNamara cited when he overruled the Source Selection Board recommendation for the Boeing design. Finally, the TFX program promised saving $1 billion over separate Navy and Air Force development programs based on actually buying the proposed 1,704 production aircraft. When only 489 F-111s were purchased the unit cost tripled. The outcome of the TFX program offers an example of the impact that failure in achieving the program's underlying assumptions could have on the success of the JSF.

Commonality

The JSF program assumes that the use of common structures, avionics, and engines in the proposed variants will result in 25 percent savings in development and life cycle costs over three separate strike fighter development efforts. The logic of this assumption is sound. Common airframe structures could be built on one production line with variants being further assembled on branches from the main line. Common avionics and engine modules could be produced in the same manner. Substantial savings over three separate aircraft programs would result by reducing development and production costs, enabling a common supply system for all variants, and allowing the use of a common Maintenance Depot for the entire JSF fleet.

The history of common development programs indicates that reaping the desired savings from commonality is more difficult than originally expected once production begins. The F-111 was the first major common development program attempted by the De-

partment of Defense. The program's early estimate of 89 percent commonality between the Air Force's F-111A and the Navy's F-111B was reduced to 29 percent to enable construction of an acceptable aircraft for both services. The commonality percentage was reduced to zero when the Navy, citing inadequate performance, canceled its portion of the program.

More recent programs, such as the Navy's F/A-18 E/F and T-45A, have provided early estimates of 60 to 70 percent commonality to existing predecessor aircraft only to produce much lower commonality percentages once the aircraft were finally built. The F/A-18E/F was originally intended to maintain between 60 and 70 percent airframe commonality with its F/A-18C/D predecessors. However, the production F/A-18E/F has very little airframe commonality with the older F/A-18s.[90] Although roughly 90 percent of the avionics remain the same between the F/A-18 models, the expected savings from commonality were not realized. The T-45A Goshawk was expected to maintain 64 percent airframe commonality with the British Aerospace Hawk jet that was modified for use as a carrier-capable trainer for the US Navy. The commonality between the two versions dropped to between 8 and 10 percent once the T-45A entered production.[91]

Commonality for the JSF is based on a "family of aircraft" concept which proposes the variants will share common structural, propulsion, and avionics components. This concept implies the services have a level of freedom in altering the JSF design to meet their individual needs. However, the program office estimate of 70 to 90 percent commonality among the JSF variants does not offer much leeway. The TFX program managers experienced difficulty maintaining between 80 and 90 percent commonality using the same basic airframe and engine for only two conventional take-off and landing variants.[92] The addition of the Marine Corps STOVL variant increases the complexity of the JSF commonality problem. If history can be used as a guide, the 70 to 90 percent commonality estimate for the JSF will probably not be met. Unfortunately, the cost of the program will increase as the level of commonality between the three variants decreases.

Joint Programs Require Compromise

The JAST program, which preceded the JSF, was established under a charter which emphasized a joint development program. Unlike the TFX program, members from the Navy, Air Force, and Marine Corps have enjoyed equal status in the development of the JSF. The directorship of the program alternates between the Air Force and the Navy to help ensure that one service does not dominate the program. These efforts have produced a truly joint development program but they do not guarantee each service will be willing to compromise essential capabilities in favor of reducing costs or achieving a common design once aircraft production begins. However, the Air Force, Navy, and Marine Corps all plan to use the JSF for interdiction and close support missions. This congruence in missions between the services should ease the compromises required to define a common aircraft.

Roughly 3000 JSF aircraft are planned for production. The Air Force variant is expected to be the lightest and least expensive of the JSF family. The Navy's stealth, range, payload, and carrier requirements are expected to result in the heaviest and most expensive variant. The Marine Corps and UK Royal Navy STOVL version will require the most complex propulsion system. Should any of the capabilities desired by the Navy or Marine Corps experience development difficulties which result in increased program costs or degradation of the entire program, the Air Force may choose leave the program based in its high stake in the total production run. General Joseph Ralston, USAF, told *Defense Daily* in 1995 that the Air Force may not be able to afford JSF aircraft built to the Navy's requirements.[93] The disengagement of any of the services would have a significant effect on the final number of aircraft built and the cost of the JSF program.

To prevent individual service requirements from driving up the cost of the entire program, the JSF office has established a capabilities versus cost trade-off procedure. According to the JSF Master Plan, "all requirements are being evaluated not only for their operational value, but cost as well. Performing continuous Cost of Operational Performance Trades will enable the program to optimize return on investment for DOD and remain within allocated total obligation authority."[94] While this philosophy will attempt to force the services to define their actual requirements for the JSF rather than simply seek-

ing nebulous advantages over current fighters, it does not prevent a service from pressing for expensive requirements, such as stealth technology, that it views as being necessary to the mission.

The services usually expect new aircraft to have some advantage over the present inventory and the cost of these advantages has been accepted as part of the updating process. To date, the Navy has made concessions in accepting a single engine JSF to reduce costs, but it has held fast to its minimum range requirement of 600 nautical miles and the desire for the fighter to carry 2000-pound weapons internally. The Marine Corps and Air Force range and payload requirements are less demanding than the Navy's.[95] Compromise may rectify these issues, or in an effort to maintain a high percentage of commonality, one service's requirements may drive the overall design of the JSF and cause the overall cost of the program to increase.

Mature Technologies

The JSF is using proven technologies in the construction of the future strike aircraft in an effort to reduce risk and the associated cost of cutting edge products. The technology maturation programs for the JSF are managed by Integrated Product Teams (IPT) that combine military and industry membership to identify those technologies that could allow affordable and low risk entry into the production phase of the program. The technology areas that have been selected for maturation study are the structures and materials program, flight systems, propulsion, avionics, weapons integration, supportability and training, and manufacturing and producability.[96]

Secretary McNamara eschewed unproved technologies in the TFX program. Boeing produced a design which incorporated engine intakes on top of the wings, thrust reversers, and the extensive use of titanium in the wing and fuselage. McNamara chose the design offered by General Dynamics over Boeing based partly on its use of less risky technology. However, the similarities between these two aspects of the TFX and JSF programs end there. The aircraft industry was not involved in the TFX program until the final aircraft requirements were determined and cost and performance requirements were based only on Department of Defense estimates. Ultimately, the TFX program required

more than the industry could technically deliver. Had the military and industry developed and designed the TFX together, the program may have been more successful.

Many of the technologies planned for use in the JSF are to be proven in the F/A-18E/F and F-22 programs that are now beginning production. The F/A-18E/F Advanced Lightweight Aircraft Fuselage (ALAFS), which is part of the JSF Structures and Materials program, will attempt to achieve 20 percent weight savings and a reduction of life cycle costs of major fuselage and wing sections by 30 percent by combining the center fuselage and inner wing as an integral assembly.[97] The JSF program has identified the Pratt and Whitney F119 engine, planned for use in the F-22, as the propulsion unit for the JSF. Use of this engine could benefit both programs. The high cost of the F-22 could be reduced by increasing the production run and lowering the unit cost of the F119 engine and the JSF program could save engine development costs. The avionics and integrated subsystems components that are planned for use in the JSF are also to be proven in the F-22. The majority of these technologies remain unproved until the F/A-18E/F and the F-22 complete full scale production and are integrated into services' operational units. The level of maturity of these technologies when they are applied to the JSF may be questionable.

The emphasis on exploiting mature technologies in the JSF to increase affordability raises questions about the ability of the services to ignore the state-of-the-art in an aircraft that is planned to be the backbone of the US tactical fighter fleet. Reductions in potential capability to control cost and reduce risk may be difficult for the services to accept. Just as trading capabilities and requirements for the sake of commonality may be harder to achieve than expected, compromises on potential performance advantages for the sake of employing mature technologies may be hard for the individual services to make.

Conclusions

The JSF program is the product definition phase of the JAST technology exploration program. The JSF team has employed technology and industry practices in an effort to streamline the definition and acquisition process of producing an affordable joint strike

fighter aircraft for the 21st century. Controlling cost is a program objective. The services and industry have been integrated from the beginning of the program to ensure a joint definition of what the JSF should be and that it could be affordably produced. The program emphasizes commonality, using mature technology, and using affordability as a requirement to control the program costs.

The Air Force, Navy, and Marine Corps all plan to use the JSF for interdiction and close air support missions. This congruence certainly should make defining a common airframe for all three services easier than attempting to support diverse mission requirements with a single airframe. However, even though only the initial requirements for the JSF have been established, there is a substantial difference of opinion among the participants in terms of requirements for range, payload, and the use of stealth technology.

The JSF program defines commonality as a "family of aircraft" but intends the level of commonality to be between 70 and 90 percent among the variants. Performance and capabilities will have to be compromised in order to reach these commonality and cost goals. The services may be willing to compromise on requirements for the "paper JSF" but the same compromises may be harder to make once flying demonstrators are produced. Because the JSF program bases its cost estimates on maintaining 70 to 90 percent commonality among the variants, any reduction in this percentage could have a significant effect on the program cost. Substantial cost increases could cause the Air Force, which plans to buy over 2,000 Joint Strike Fighters, to be priced out of the program.

The Joint Strike Fighter Master Plan indicates that substantial development and production cost savings could be realized by using mature technologies on the JSF. Most of the technologies mentioned are scheduled to be proved on the F/A-18E/F and the F-22. Should the technologies planned for these programs fail, the JSF will either inherit the burden of proving the new technologies or be forced to resort to older technological solutions. In either case, the JSF will suffer. The program cost may be substantially increased by the added burden of proving state-of-the-art technology. The use of older technology may be hard for the services to justify on an aircraft that is to be the backbone of the US tactical fighter fleet. Both of these possible scenarios may cause one or more service to disengage from the JSF in favor of its own development program.

Making affordability an equal requirement to all other performance capabilities may cause problems among the services. Forcing the services to trade capabilities for costs requires a great deal of compromise. The Air Force plans to purchase 2,036 JSF aircraft, the Navy 300, and the Marine Corps 642. Any of the three services could stubbornly adhere to certain requirements that would affect the aircraft capabilities and cost for the other two. The Navy could insist on a stealthy, long-range variant that could drive the production costs out of the range of affordability for the Air Force. Assuming that the services will accept a marginal increase in performance and capabilities over current fighters to maintain affordability ignores the history of aircraft development.

The JSF program has introduced many new techniques and technologies into the fighter acquisition process. The joint program is enjoying a level of cooperation between the services and the aerospace industry that has rarely been seen. However, this spirit of cooperation and compromise that is so evident while the JSF exists only on paper may quickly change when production begins and the services are forced to make choices that directly affect the aircraft that each plans to be its premier multirole fighter for the 21st century.

Notes

[65]Joint Strike Fighter Program Master Plan 1996. On-line. Internet. Available from http://www.jast.mil.com.

[66]Congress of the United States, *A Look at Tomorrow's Tactical Air Forces* (Washington, D.C.: Congressional Budget Office, January 1997), 4. USAF -- F-16, F-15A-D, F-15E, A-10. USN -- F-14A-D, F/A-18A-C. USMC -- F/A-18A-D, AV-8B.

[67]Aspin, Les. *The Bottom-Up Review: Forces For A New Era*, Washington, D.C., Office of the Secretary of Defense, September 1, 1993, 4.

[68]CBO, *A Look at Tomorrow's Tactical Air Forces*, January 1997, 4.

[69]Memorandum from Assistant Secretary of Defense Paul Kaminski to the Service Secretaries, May 23, 1996.

[70]Ibid., xii. The Pentagon's Quarterly Defense Review proposed further cutting approximately 100 aircraft from the F-22 program.

[71]Ibid., xii. Following the Quarterly Defense Review, the Pentagon proposed cutting the F/A-18E/F procurement from 1000 aircraft to between 548 and 745 F/A-18E/Fs.

[72]Joint Strike Fighter Master Plan 1996, 1.

[73]CBO, *A Look at Tomorrow's Tactical Air Forces*, January 1997, xiii.

[74]Thomas E. Ricks, "Defense Firms Little Damaged By U.S. Review," *Wall Street Journal*, 19 May 1997.

[75]Aspin, *The Bottom-Up Review*, 1993, 1.

Notes

[76]Ibid., 10.

[77]JSF Program White Paper, March 1996, 1-2. The "family of aircraft" concept allows service needs to be satisfied while maintaining a high degree of airframe commonality. This is accomplished by using a modular design that may incorporate common engines, wing structures, avionics packages, etc. while allowing certain structural differences to meet individual service requirements.

[78]JSF Program White Paper, March 1996, 1.

[79]JAST Study Plan. On Line. Internet. Available from http://www.jast.mil.com. Virtual Strike Warfare Environment, A.7.1.

[80]JSF Master Plan, Requirements Definition, 5.2.1.

[81]Ibid., 5.2.2.

[82]Ibid., 5.3.1.

[83]Ibid., 5.3.1.

[84]JSF Master Plan, Requirements Definition, 5.3.2.

[85]Ibid., 5.2.4.

[86]Ibid., 5.3 and CBO, *A Look at Tomorrow's Tactical Air Forces*, 42.

[87]CBO, *A Look at Tomorrow's Tactical Air Forces*, 5.

[88]Statement of Rear Admiral Craig Steidle, before the Senate Armed Services Committee on Tactical Aviation, March 15, 1996. 4. Major General George Muellner, made a similar statement before the same committee on March 29, 1995.

[89]CBO, *A Look at Tomorrow's Tactical Air Forces*, 43.

[90]CBO, *A Look at Tomorrow's Tactical Air Forces*, 48.

[91]Ibid., 48.

[92]The Navy F-111B differed from the Air Force F-111A in a few areas. The F-111B had a folding tail and radome as well as a more substantial landing gear system to enable carrier operations. Also, 3.5 foot wingtip extensions were bolted to the F-111B wing to improve slow speed handling. These extensions were later added to the Air Force FB-111A.

[93]Tanya Bielski, "Navy's JAST Requirements Make Program Too Expensive," *Defense Daily*, November 1, 1995, 141.

[94]JSF Master Plan, Requirements Definition, 5.3.7.

[95]According to the Joint Initial Requirements Document, Air Force and Marine Corps variants will carry 1000-pound weapons internally for a desired range of 450-600 NM and 450-550 NM respectively.

[96]JSF Master Plan, Technology Maturation, 6.2.1-6.8.4.

[97]JSF Master Plan, Technology Maturation 6.2.2.

Chapter 4

Conclusions

Theo Farrell, in his book *Weapons Without a Cause: The Politics of Weapons Acquisition in the United States*, writes that most acquisition programs are driven by strategic, institutional, and budgetary issues. Strategic issues are the strategic rationale given for a beginning development for a particular weapon. Institutional issues are the government and military service politics that surround the acquisition of a weapon. Budgetary issues are the costs of the program.[98] Even though JSF program managers have consciously attempted to avoid the mistakes of the TFX program, similar influence from strategic, institutional, and budgetary issues is present in both programs.

National Strategy Issues

Both the TFX and JSF programs were conceived in response to a change in the US National Security Strategy. The TFX was developed as a conventional and nuclear weapon platform for President Kennedy's flexible response strategy. According to the Department of Defense, the change in emphasis from massive nuclear retaliation to response anywhere in the spectrum of conflict, from conventional to nuclear war, required a multirole aircraft that could execute the strategy. Therefore, the TFX was developed as a fighter and a long-range interdiction aircraft.

The genesis of the JSF program was the 1993 *Bottom Up Review* that was initiated to define the new US force structure for the post-Cold War era. The *Bottom Up Review* introduced the requirement for the US military to fight two simultaneous Major Regional Conflicts (MRCs). The JSF office distilled the initial requirements for the family of Joint Strike Fighter aircraft from strike warfare deficiencies discovered through virtual simula-

tions of possible MRC scenarios. This study resulted in defining the need to increase the survivability, supportability/deployability, and lethality of the JSF over current multirole fighters.

Both aircraft programs were based on a strategy-to-task philosophy which attempted to define the capabilities of the associated aircraft by determining what was necessary to prosecute the National Strategy. Both the TFX and JSF programs have implied that each aircraft was vital to the National Security Strategy of its era. However, the Kennedy administration's flexible response strategy was exercised throughout the Cold War with little participation from the F-111. The range and supersonic dash requirements, which drove much of the TFX design, were taken directly from the strategy's nuclear mission. The conventional warfare portion of the flexible response strategy was used to define the tactical fighter mission for the TFX. The nuclear response capabilities of the TFX were never exercised and the tactical fighter capabilities were never realized.

The JSF program's virtual MRC war gaming attempted to connect the aircraft's initial requirements to the present National Security Strategy. However, these requirements may change as the global situation evolves between the present and 2008 when the first production JSF aircraft are expected. There is the possibility that the initial JSF requirements, which will determine the basis for the entire JSF program , could be incongruent with the future. Should this occur, the program could experience great difficulty and expense in altering the baseline requirements for the JSF once it enters production.

Plans for supporting the two MRC strategy with the current inventory of aircraft have existed since shortly after the publication of the *Bottom Up Review* in 1993. Since the JSF program proposes accepting current generation fighter performance to help contain costs, its advantage must come from other new capabilities. The JSF program is based on four requirement pillars: cost, survivability, supportability and deployability, and lethality. Cost will be examined later in this chapter. Increasing the lethality of a weapon system and the ability for US aircraft to survive in war have been goals for nearly every aircraft development program and are not unique to the JSF. Therefore, the only really new objective the JSF program offers is the reduced maintenance and logistics requirement proposed by the supportability and deployability pillar.

Nearly every military acquisition program seeks ties to the National Security Strategy. The strategy-to-task approach is a means to justify the program and obtain funding. Both the TFX and JSF programs were born in an era of change and both programs claimed to offer necessary support to the new National Security Strategies of their time. The TFX never made good on its offer. Should the cuts in the F/A-18E/F and F-22 programs proposed by the recent Quadrennial Defense Review be implemented, the JSF's intended role as the centerpiece of the US strike fighter inventory for the 21st century will become even more important[99].

Institutional Issues

The requirements for the TFX and JSF programs, though the method for defining them differs, were largely based on institutional self-interests. Secretary of Defense McNamara's interest in cost control and commonality is a thread that runs throughout the TFX program. McNamara mandated the Navy's participation in the Air Force TFX program after he canceled development of the F6D Missileer. When the Service Selection Board chose the Boeing design for the TFX, he reversed the military's decision and awarded the contract to General Dynamics Corporation based on its low risk design, greater degree of commonality, and more realistic cost proposals. In 1963 the Senate Subcommittee on Investigations convened hearings on the controversial TFX contract. During the hearings, the TFX aircraft began experiencing problems in flight testing. McNamara's testimony highlighted the success of the TFX program even though he was aware of the test failures. He doggedly attempted to salvage the program until 1968 when the Navy canceled its participation in the TFX and McNamara left office as Secretary of Defense.

The requirements for the TFX were established by adapting the Specific Operational Requirements for the Air Force version of the aircraft to suit the Navy's carrier-based fighter mission. The disparate mission requirements pushed the limits of manufacturing technology in the 1960s. The result of using this method was a less capable and costlier production aircraft. Neither service was pleased with the results of the compro-

mise. The TFX did not fit the Navy's idea of a fleet air defense fighter and the Air Force TFX design suffered from being compromised to accommodate the Navy mission.

Navy self-interest was evident from the beginning of the TFX program. During the first three rounds of contractor competitions Navy members on the Service Selection Board voted that neither the Boeing nor General Dynamics design was acceptable for the Navy mission. The Air Force, on the other hand, accepted both designs during every round. Only during the fourth round of competition, after major design changes aimed at improving the aircraft's carrier compatibility had been made, did the Navy accept both contractor's designs. Throughout the TFX Contract Investigation conducted by the Senate Subcommittee on Investigations, Navy officers associated with the TFX testified that they thought the program would still produce a poor carrier aircraft. Finally, once TFX flight test failures and a weight problem emerged in 1963, the Navy began lobbying congress to cancel its participation in the program. The Navy finally escaped from its unwanted participation in the TFX when its portion of the program was canceled in 1968.

The Air Force was content with the original TFX design because it was conceived for an Air Force nuclear and conventional deep strike mission. However, the institutional self-interests of the Secretary of Defense and Navy derailed the Air Force program. The Air Force was forced by McNamara to salvage the compromised TFX after the Navy left the program in 1968. Essentially, after 1968, the Air Force was left with an underpowered, overweight aircraft whose design had been tailored to the requirements of both a Navy partner who had withdrawn from the program and to the Secretary of Defense who sought to salvage the program by pushing the F-111 into production.

To avoid the influence of institutional self-interests, the JSF program was established as a joint program from its inception. Industry representatives have worked closely with the military from the beginning of the requirements definition process. This cooperation has enabled service representatives to discover the costs of certain desired capabilities early in the definition phase of the program. Industry representatives provide insight into the risks and costs associated with materials, manufacturing techniques, and production scheduling. They also indicate the probable costs of service desires, such as

increasing the range or payload of the JSF, so educated capability trade-offs can be accomplished to keep the program within its cost parameters.

Despite efforts to avoid the pursuit of institutional self-interests, service personalities have emerged during the initial JSF requirements development phase. As with the TFX, the Air Force is planning to buy the bulk of the JSF aircraft.[100] Its conventional take-off and landing design is the simplest and least costly of the JSF variants. The Navy version will require ruggedness to withstand the stresses of carrier operations and the range to effectively reach land targets from the sea. Finally, the Marine Corps variant will be the most complex because of its STOVL requirement. The cuts to the Navy's F/A-18E/F and Air Force's F-22 programs, recommended in the Pentagon's Quadrennial Defense Review, may force the services to push for their own requirements in the JSF program even more. These service requirements, coupled with the program goal of maintaining 70 to 90 percent commonality among the variants could result in inter-service conflict. Institutional self-interest , especially the attempt to maintain a high degree of commonality, could leave the services with less capable and more expensive JSF variants than they originally intended to purchase.

Commonality

Commonality has played a central role in both the TFX and JSF programs. Both have sought to achieve savings in the development, production, life cycle costs by maximizing the use of common structures, engines, avionics, and production methods. The TFX program failed in producing a common aircraft for the Air Force and Navy. The conceptual differences between the TFX and JSF in terms of commonality may determine the success or failure of the JSF program once it enters production.

The TFX began as an Air Force program for a long-range, nuclear and conventional weapon capable, supersonic, multirole fighter. The Navy, which was developing an air superiority fighter, was forced to become a partner in the TFX program by Secretary of Defense Robert McNamara. The services' two requirements for the TFX, long-range fighter-bomber and carrier-based air superiority fighter, were widely separated. McNamara's insistence on accomplishing both missions with the airframe defined by the

Air Force requirement led to capability compromises by both services which ultimately degraded the effectiveness of the TFX.

The JSF program began as a joint venture under the JAST charter. The Air Force, Navy, and Marine Corps have been involved with defining the JSF requirements since the program began. With the exception of the Navy's desire for a deep interdiction capability, the general mission for the Air Force, Navy, and Marine Corps variant of the JSF as a multirole fighter is basically the same. Requirements for the JSF have not been fully defined but the concept of commonality differs from the TFX program. Rather than achieving savings by using one airframe for both missions, the JSF program plans to develop a "family of aircraft" which makes use of as many common parts and manufacturing practices as possible. This philosophy hopes to allow individual service requirements, such as the Navy's requirement for carrier capability or the Marine Corps desire for a STOVL capability, while reaping the savings from commonality where possible. However, these service requirements are more diverse than they appear on the surface. The STOVL capability will require extensive engine and control modifications over the Air Force conventional take-off and landing variant. By dropping the STOVL requirement, the JSF could use a variant of the proven F110 engine rather than the more costly F119. The modifications necessary to give the Navy variant the capability to withstand the stresses of carrier operations involve structural modifications as well as the incorporation of stronger landing gear. Depending on how JSF commonality is defined by the time the program enters production, each variant may have less structural commonality than originally expected.[101] Unless the individual service requirements can be made less diverse, it will be difficult for the JSF program to maintain the 70 to 90 percent commonality goal.

Budgetary Issues

The TFX and JSF programs both emphasized cost control as a primary objective. In both cases, limited defense budgets forced the Department of Defense to develop new aircraft with an emphasis on economy. The sheer number of aircraft provided by these programs make restraining the cost per airframe a necessity. The TFX program was ex-

pected to provide over 1,700 tactical fighters for the Air Force and the Navy and the JSF is planned to provide a total of 3,000 strike fighters for the Air Force, Navy, Marine Corps, and some allies. To affordably produce these large fleets of aircraft , the Department of Defense emphasized the use of common development and production in both the TFX and JSF programs to achieve savings over individual service programs.

The cost goals of the TFX program were never achieved. Secretary of Defense McNamara used the potential savings of $1 billion over two separate aircraft development programs to make the TFX a joint development program. Even though the Department of Defense budget was robust during the years immediately preceding the Vietnam conflict, the pre-war conventional force buildup and the effort the close the "missile gap" with the Soviet Union required careful spending. However, the TFX program was not economical. McNamara's efforts to control the cost of the TFX through the concept of commonality resulted in the degraded capabilities of the Air Force F-111A, the cancellation of the Navy's F-111B, and the production of roughly one third of the proposed TFX aircraft at five times the cost per airplane.

Defense budgets have declined since the 1980s, and are predicted to continue on this downward track. In response to these budgetary constraints, the JSF program has made controlling cost a primary objective. The program has integrated the services and the aircraft industry in every phase of the program to date to ensure program requirements can be economically reached. The use of technologies proved on current production aircraft is intended to reduce developmental costs and reduce risk. However, in its quest for controlling costs, the JSF program office has chosen not to pursue performance capabilities substantially beyond those of current F-16 and F/A-18 fighter aircraft. This decision may leave decision makers wondering why a new aircraft that has little performance advantage over current inventory fighters is needed.

Implications for the JSF

The history of aircraft programs based on the idea of controlling costs by emphasizing commonality has not been a success story. The TFX was a failure and programs such as the F/A-18E/F and the T-45A failed to have much in common with the variants

that preceded them. As the JSF development continues, the program seems to exhibit traits similar to those seen in the TFX program. The success or failure of the JSF may depend on how much these emerging traits are allowed to influence the program.

The TFX was a US Air Force program that was forced on the Navy by Secretary of Defense McNamara. This arrangement was facilitated by the cancellation of the Navy's F6D Missileer fleet air-defense fighter program. The Navy did not want the TFX and escaped from the program when it could. The Pentagon's Quadrennial Defense Review may lead to the development of a similar situation for the US Navy and Air Force in the JSF program. Even though the JSF began as a joint development program with equal participation from the Navy, Air Force, and Marine Corps, the Navy and Air Force planned to develop the JSF to complement the F/A-18E/F and F-22 programs. The QDR recommended cuts to both of these programs which, if enacted, will force these two services to depend on the JSF more than they originally planned. Since only the Marine Corps planned to use the JSF as the centerpiece of its tactical aviation before the QDR, if the Navy and Air Force come to feel that they are not getting the quantity and type of aircraft they need may affect their acceptance of the JSF.

A central concept in the JSF program is the willingness to sacrifice a significant performance advantage over current F-16/F-18 fighters to reduce program costs. Following the Quadrennial Defense Review, the Navy and Air Force may attempt to recoup some of the performance they hoped to gain with the F/A-18E/F and F-22 programs in the JSF. As the Navy's demands for carrier compatibility compromised the original TFX design, these increased demands, based on service requirements, may result in reduced commonality among the JSF variants and an increase in the unit cost of the aircraft.

The Air Force has the most influence on the ultimate cost of the JSF program because it plans to buy two thirds of the proposed aircraft production. The Air Force planned to buy 1,473 of the 1,704 production F-111s in the TFX program. Ultimately the Air Force purchased only 489 F-111s at five times the projected unit cost. Should the Air Force, or the other services, decide to buy fewer JSF aircraft than originally planned, the unit cost could become prohibitive.

During the source selection phase of the TFX program, the Navy and Air Force eventually reached a consensus that their requirements could be met by the aircraft designs submitted by the contractors. However, once research and development aircraft were built and performed poorly in the test phase, this consensus quickly dissolved and the Navy left the program. The JSF program has not finalized the requirements for the future strike fighter but hopes the joint nature of the program will continue through the production phase. If this occurs, the JSF could produce a capable and affordable strike fighter for the 21st century. However, there is a long road between requirements definition and the production of actual aircraft. At this early stage, the JSF program is already showing evidence of being driven by some of the same institutional and budgetary issues that derailed the TFX program. Perhaps the joint program organization can overcome the individual service biases and keep the JSF on track. In any event, the ultimate success of the JSF program in achieving its goals of producing an affordable family of strike fighters for the US and its allies cannot be assessed until the aircraft are manufactured and the bills are paid.

Notes

[98]Theo Farrell, *Weapons Without a Cause: The Politics of Weapons Acquisition in the United States*, (N.Y.: St. Martin's Press, Inc., 1997), 8.

[9999]The QDR proposed to cut the Navy's F/A-18E/F program from 1000 aircraft to between 785 and 548 aircraft. The proposed cuts to the Air Force's F-22 will decrease the program from 438 aircraft to 339 aircraft.

[100]The Air Force initially contracted for 1,473 of 1,704 production F-111s and has tentatively agreed to purchase 2,036 of the 3,000 JSF aircraft.

[101]Commonality can be defined in many ways. Methods include counting common parts, individual component systems (engines, wings, etc.), and parts that can be manufactured with common tooling.

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