Analysis of the Joint Strike Fighter Program: Astronomical Time and Cost

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Everybody in the United States pays taxes, but the average American likely doesn't know exactly where their money goes. A common answer that most citizens might give is military spending, and they would be correct. The United States spends massively on the military and national security. According to the Center on Budget and Policy Priorities, thirteen percent of the 2022 federal budget, approximately $768 billion, was used on national defense activities ("Policy basics," 2022). This spending was largely used by the Department of Defense for operations and maintenance, military personnel, procurement of weapons, and research, development, and testing. Each year the Department of Defense funds many programs, yet one program in particular has garnered the attention of everyone in the defense acquisition space: the Joint Strike Fighter (JSF) program. Its goal is to develop three different versions of the F-35 Lightning II strike fighter aircraft for the United States Air Force, Marines, and Navy (Hoehn & Gertler, 2022). The JSF program is by far the largest procurement program in the history of the Department of Defense (DoD) in terms of total cost (Hoehn & Gertler, 2022). The estimated operating and support (O&S) costs for the F-35 Lightning II strike fighter aircraft over its 56-year life cycle total around one trillion dollars (Russell, 2014). This astronomical figure will have to be paid by American taxpayers throughout the life of the F-35.

A strike fighter aircraft is intended to operate as both an attack aircraft (air-to-ground combat) and an air superiority aircraft (air-to-air combat) ("Strike Fighter Squadron (VFA) 131," n.d.). The F-35 Lightning II aircraft is a fifth-generation fighter. The classification of fifth-generation indicates that the aircraft includes major technologies developed during the first part of the 21st century, namely "multi-spectral low observable design features such as radar, infrared sensors, and visual situational awareness tools, along with self-protection and radar jamming capabilities that delay or deny enemy systems the ability to detect, track, and engage the aircraft" (Hood, 2017).

The JSF program was originally meant to develop an affordable fifth-generation fighter aircraft with very similar versions for the Air Force and Navy to replace legacy fourth-generation aircraft developed near the end of the Cold War. However, in 1994 Congress required that the Marine Corps' efforts to develop a replacement of the AV-8B Harrier aircraft be merged with the Air Force/Navy program with the intention of avoiding high costs of developing, procuring, operating, and supporting three separate tactical aircraft designs (Hoehn & Gertler, 2022). Three variants were to be developed. The conventional take-off and landing (CTOL) variant, the F-35A, will replace the Air Force's F-16 Falcon and A-10 Thunderbolt II aircraft. The short take-off and vertical landing (STOVL) variant, the F-35B, will replace the Marine Corps' F/A-18C/D Hornet and AV-8B Harrier aircraft. The F-35C is referred to as the carrier-suitable variant (CV) and will complement the Navy's F/A-18E/F Super Hornet. The Marine Corps will also acquire a limited number of F-35C CV aircraft (Russell, 2014). Lockheed Martin was chosen as the aircraft contractor and Pratt & Whitney as the engine contractor, with Rolls Royce operating as a subcontractor to Pratt & Whitney by developing the vertical lift system in the F-35B (Hoehn & Gertler, 2022).

Fifth-generation fighters are a necessity in maintaining military dominance in today's threat environment; however, the poor structuring and planning of the JSF program significantly delayed F-35 production and exacerbated the costs associated with designing, manufacturing, and sustaining the three variants. To present this argument, first I provide a literature review on the following: the case for fifth-generation aircraft, prior and future programs related to the JSF program, and F-35 planning and structuring problems. My analysis on the JSF program will give insight into how aircraft acquisition programs should be approached in the future.

Literature Review

The United States has seen a rise in both domestic and foreign threats in the 21st century. According to Deptula (2019), America's military power began to erode after the end of the Cold War, creating doubts in America's ability to defend itself and its allies against growing global threats. A reemergence of "great power competition" has occurred and will continue to be a huge strategic challenge for the United States (Deptula et al., 2019). In particular, "China and Russia are asserting their power around the world and modernizing their militaries" (Deptula et al., 2019). Additionally, "regional crises simmer and flare in the Middle East, the Korean Peninsula remains unpredictable, and violent extremists demand US attention" (Deptula et al. 2019). The variety and scale of threats that face the United States require a strong and adaptable military.

The United States' older Cold War technology will not be able to compete with the modernized militaries of Russia and China. The United States Air Force's fighter aircraft inventory is made up of many old fourth-generation fighters that are not survivable in the advanced threat scenario of the present day. This is because these fighters lack the all-aspect stealth, superior aerodynamic performance, and advanced automated sensors and information fusion present in fifth-generation aircraft (Deptula et al., 2019). To make matters worse, "China has developed and introduced into service the first credible non-US-made LO, or fifth-generation, fighter in the form of the J-20A Mighty Dragon" (Bronk, 2022). LO stands for low observability, commonly used interchangeably with the word stealth. Bronk (2022) claims that "subsequent developments are likely to increase its LO characteristics and sensor capabilities, as well as engine performance." In response to the Chinese J-20, the United States must develop new technology, either in the form of a fighter or a different air superiority aircraft, to rival it. Additionally, the creation of a Chinese fifth-generation fighter brings "the possibility of technology transfer from China to Russia in the combat air domain" and "could potentially increase the threat level posed to NATO by Russian airpower in the longer term, should such a dynamic emerge" (Bronk, 2020).

The JSF program isn't the first attempt at a joint fighter program. The joint Tactical Fighter Experimental (TFX) program in the 1960s attempted to save billions in life cycle costs by using a common airframe and engine to meet both the Navy and Air Force's operational requirements (Bevilaqua, 2009). The TFX program ultimately failed as a joint program. The Navy withdrew from the program due to the aircraft being too heavy for carrier operation, and "the Air Force was left with an F-111 too small to be an effective bomber and not maneuverable enough to be a competitive fighter" (Bevilaqau, 2009). Due to the history of the TFX program, the JSF program was met with a considerable amount of skepticism. However, new developments in STOVL technology, combined with the promise of lower costs due to the convenience of a similar airframe and engine, led the DOD to pursue the JSF program.

Analyses on the JSF program have previously been done, focusing particularly on identifying the root causes for the growth of program average unit cost (PAUC) over time. PAUC can be defined as the total program costs divided by the sum of procurement and research, development, testing, and evaluation (RDT&E) quantities, with quantities referring to the number of aircraft (Arnold et al., 2009). Members at the Institute for Defense Analyses concluded that "the underestimation of airframe unit weight, the use of faulty labor rates, as well as the move to a contract structure based on a prime and sub relationship instead of a teaming arrangement with a shared fee pool" resulted in twenty three percent PAUC growth, with the root cause of these factors being unrealistic cost estimates (Arnold et al., 2009). Redesign efforts "based on reductions in materials manufacturing efficiency, increase in non-recurring tooling and equipment, negation of affordability plans, and the increase in RDT&E effort" account for an additional twenty six percent PAUC growth over estimates (Arnold et al., 2009). Lastly, another five percent PAUC growth is attributed to "the delay in ramp up to peak production" and the "lowered procurement rate" (Arnold et al.,2009). This analysis does an excellent job at identifying causes for the JSF program continually coming in over budget; however, it does not make recommendations on how to approach mitigating these problems in the future.

Methods

This paper makes use of many sources, ranging from journalistic takes to academic articles to think tank reports. Here I will provide an overview of some of my most frequently used sources. The first of these frequently used sources is the Congressional Research Service (CRS). The CRS essentially operates as a think tank for Congress, providing on-demand research and analysis to support the legislative duties of Congress. This source serves to provide in-depth background information and up-to-date timelines and statistics. Another frequently used source is the Government Accountability Office (GAO). The GAO is an investigative agency that supports Congress in improving the performance and accountability of the federal government. This source serves to provide in-depth background and cost statistics. A third frequently used source is a media article written by retired Air Force veterans who have decades of experience in the Air Force and defense world and are able to convey the case for fifth-generation airpower. Lastly, I frequently cite an academic journal article by Paul Bevilaqua, a Lockheed Martin aeronautical engineer. His invention of the Lift Fan Propulsion System made it possible to build a stealthy, supersonic STOVL fighter. His experience with the development of this technology serves to provide insight into the design process of F-35B and how it affected the other variants.

My content analysis of the Joint Strike Fighter program will be carried out through the lens of Actor-Network Theory (ANT). ANT is notoriously difficult to define since everything is both an actor and a network. In general, ANT focuses on how human and nonhuman actors are enrolled in the construction of technological systems (Pinch & Oudshoorn, 2005). Together these human and nonhuman actors form heterogeneous networks. Law and Callon (1988) describe the application of ANT in the following way: "…we are not primarily concerned with mapping interactions between individuals…we are concerned to map the way in which they [actors] define and distribute roles, and mobilize or invent others to play these roles" (p.285). This process is referred to as translation. Translation is essentially the connections and transformations that must occur for things (actors) that were previously different to come together into a relationship. Latour (1992) focuses, in particular, on a form of translation called delegation, resulting in a distribution of competences between humans and nonhumans.

One common critique that ANT faces is that ANT is often a fluid and chaotic means of analysis. However, ANT provides a research trajectory that can reveal complexities and contingencies that are often overlooked, deeming it useful in analysis of large networks (Cressman, 2009). Another critique of ANT is that it ascribes agency to non-living things. This, however, I see as perfectly reasonable. Pinch and Bijiker (1984) argue that technology does not determine human action, but that rather, human action shapes technology. This is the basis for the Social Construction of Technology (SCOT) framework. I agree that human action shapes technology. However, once created, technologies can also have agency of their own, sometimes performing in manners unintended by the designers.

Analysis

Fifth generation fighters are needed to maintain air superiority over the United States' foreign opposition. These fighters are designed to balance stealth and aerodynamic performance. The stealth provided by fifth-generation fighters significantly reduces radar, infrared, and electromagnetic signatures, increasing the survivability of pilots entering hostile airspace. Additionally, the automated sensing and visual awareness tools in fifth-generation fighters help pilots to identify threats first, allowing them to take early action. These features are accompanied by the ability for supersonic cruise and advanced maneuverability. Aerodynamic shaping and stealth shaping are often contradictory, so compromises in design and tactics require more maintenance and cost than conventional aircraft. However, this is the price that must be paid to maintain air superiority and allow pilots to complete their missions. Fifth-generation fighters are an absolute necessity for maintaining military dominance, especially with both China and Russia working to modernize their militaries and expanding their influence globally. Given this, the extremely long development time for the F-35 variants put the United States at risk.

The significant amount of time it took to develop the F-35 variants are a result of structural and planning problems within the program. Russell (2014) claims that many cost, schedule, and performance problems with the F-35 can be traced back to "a highly concurrent acquisition strategy with significant overlap among development, testing, and manufacturing activities." For a program that intends on producing aircraft that will have a long lifetime, sustainment should be prioritized from the very beginning of the program. The overlap among development, testing, and manufacturing within the JSF program indicates that a sustainment plan wasn't developed early on. There will always be some overlap among development, testing, and manufacturing, but the F-35 had a significantly long system development and demonstration

(SDD) period, leading to delays for each variant to reach initial operational capability (IOC). The F-35B had an IOC goal of March 2012, followed by the F-35A in 2013 and F-35C in 2015; however, the F-35B didn't reach IOC until July 31, 2015, pushing back IOC for the F-35A to August 2, 2016 and the F-35C to February 28, 2019 (Hoehn & Gertler, 2022). The F-35 was first flown on December 15, 2006. This means it was a little over 12 years between the first F-35 variant being flown and the last F-35 variant reaching IOC. In comparison, "The F/A-18 Hornet completed its first flight in 1978 and entered operational service with the Marine Corps in 1983 and the U.S. Navy in 1984" ("F/A-18A-D Hornet," 2021). The difference in development times of the F-35 and F/A-18 are representative of the more sophisticated systems within the F-35, but they are also indicative of poor planning and program structure on behalf of the DOD.

Better control of the weight throughout the production design of the F-35B would have prevented setbacks and lowered costs. The problem with STOVL fighter development was creating a body around a two-cycle engine concept capable of stealthy supersonic flight, as it is a necessity for meeting the operational needs of various missions. The Defense Advanced Research Projects Agency (DARPA) used weight as an independent variable as a program management tool to control the cost of the STOVL strike fighter in the conceptual design phase. Designers were then forced to optimize performance within this weight (and therefore cost) instead of the traditional approach of the Pentagon releasing a set of specific performance requirements and choosing the lightest and therefore most affordable design (Bevilaqau, 2009). However, once contracts were awarded, Lockheed Martin's Skunk Works did not use the weight limit as an independent variable for the design of the production aircraft. The desire to improve performance and reduce manufacturing costs then added significantly to the weight of the airframe (Bevilaqau, 2009). Ideally the most technically simple variant of the joint fighters, the

CTOL F-35A, would have been developed first, but the Marine Corps' Harrier fleet was reaching the end of its life first. This meant that the "most complicated variant," the F-35B had to be developed first, and "the technical challenges unique to STOVL aircraft delayed all of the variants" (Hoehn & Gertler, 2022). Hoehn & Gertler (2022) point out that "because the F-35B takes off and lands near-vertically, weight is a particularly critical factor, as aircraft performance with low- to no-airspeed depends directly on the ratio of engine thrust to aircraft weight". Choosing to not use the weight as an independent variable in the production design of the F-35B resulted in the aircraft being 3,000 pounds overweight, delaying the JSF program three years (Hoehn & Gertler, 2022). The DOD should have been monitoring the production design more closely, restricting the weight to control the cost and prevent setbacks.

Projections for the operating and support (O&S) costs of the F-35 are an indicator that the DOD did not place enough emphasis on sustainment, management, and reliability at the beginning of the development process. The estimated annual O&S costs of the F-35A/B/C in 2010 are $19.9 billion, while that of legacy aircraft (F-15C/D, F-16C/C, AV-8B, F-18A-D) total $11.1 billion (Russell, 2014). Of course, the F-35 must maintain more sophisticated systems than legacy fighters; however, this alone couldn't possibly account for annual O&S cost of the F-35 being nearly double that of all the legacy fighters combined. It is clear that sustainment plans were a reactionary response to any changes made in the production plans, continuing to increase in cost as any changes to the capabilities of the aircraft were made. Development, production, and sustainment of fifth-generation fighters must be affordable and occur at a reasonable pace for the United States to acquire a sizable fleet and remain operable for the foreseeable future.

Despite the F-35 still not officially reaching full-rate production, there are talks of the development of a 6th-generation aircraft for the Air Force. The Next-Generation Air Dominance

(NGAD) program is “intended to ‘develop a portfolio of technologies enabling air superiority’” (Gertler & Hoehn, 2022). The details of the program are still classified; however, it is known that the NGAD program plans to replace the F-22 fighter jet. This doesn’t necessarily have to be accomplished through the development of a new fighter. According to Gertler and Hoehn (2022), “NGAD could take the form of a single aircraft and/or a number of complementary systems—manned, unmanned, optionally manned, cyber, electronic—forms that would not resemble the traditional fighter.” The NGAD program is largely funded through research and development, while the F-35 is funded largely through procurement; however, the F-35 and NGAD program must both fit within the Air Forces budget, “which could lead to pressures to favor one program over another in funding decisions” (Gertler & Hoehn, 2022). The NGAD program is also an attempt by the Air Force to restructure its acquisition process by splitting design, production, and sustainment contracts. This would open the possibility for the Air Force to work with companies that are not traditionally military aviation prime contractors, making it more viable to produce short runs of different aircraft rather than long, single aircraft producing programs such as the F-35 JSF program (Gertler & Hoehn, 2022).

Conclusion

If the DOD approaches acquisition with the new strategy that the Air Force has devised of separating contracts into design, manufacture, and sustainment, more competition will emerge, driving down costs and catalyzing the process to reach full operational capability (FOC). With aircraft reaching FOC faster, more time and money can be allocated to new programs to replace these aircraft once new, more advanced technology is inevitably developed. One could argue that this approach would result in a concurrent strategy, similar to the F-35, in which significant overlap between development, testing, and manufacturing leads to cost, schedule, and performance problems; however, I argue that this would not necessarily be the case. The delegation of tasks among the relevant actors would expand the pool of resources available to the program and promote communication between the actors, leading to a more cohesive product and better understanding of how the design, manufacture, and sustainment are one heterogeneous network.

A shift to short production runs of different aircraft, rather than long programs for developing a single aircraft, would increase the efficiency of the DOD's acquisition process and greatly increase the adaptability of the United States' armed forces. Innovation in military technology moves at a rapid pace; therefore, it is not efficient to develop a single aircraft over a long period of time and continually upgrade its capabilities. This would result in a bottomless pit of sustainment costs and a fleet that is not as strong as it could be. The DOD's attempt at risk aversion by focusing on a big program for the development of one aircraft has actually made them more vulnerable. They will always be playing catch-up, taking F-35s out of operational use and updating them with new technology.

Like many other high-technology programs before it, the JSF program came in above its original budget and behind the planned schedule. It seemed reasonable to assume that the cost of developing and maintaining a single common airframe would be lower than three separate tactical airframes. However, commonality between the three variants fell well short of the initial goal and predicted sustainment costs for the F-35 are astronomical. By implementing the suggestions mentioned above, the DOD will reduce sustainment costs of future aircraft programs and increase the adaptability of the United States' armed forces.

I hope that officials at the DOD read this and are prompted to have a debate about risk aversion and adaptability. Projects shouldn't strive to meet baseline requirements that are defined at the birth of the program, only to be updated in the future. A program should be defined by budget, using weight as an independent variable, and optimized to meet the capabilities that are possible within that budget and include the most advanced technology available. One could argue that this would produce aircraft that are only effective for a short period of time, but that is precisely the point. It would be more beneficial to take risk in rapidly prototyping and testing technology to determine problems faster rather than spending time and money updating existing aircraft that have only reached initial operational capability. Short runs of aircraft with the most current most advanced technology would greatly increase the adaptability of the armed forces. It is also important to produce a realistic timeline and budget given the risks taken in a program, something which the JSF program did poorly. Congressmen should also take more interest in ensuring that the DOD is operating efficiently in these programs since they have the power of the purse and have a responsibility to make informed choices in the best interest of the country.

Of course, the Joint Strike Fighter program is a massive project, and its difficulties are not solely a result of technical challenges and program planning and structure. There are many other factors that influenced the development of the program. Future research could be done on how acquisition policy and political pressures affected the progress of the program. The JSF program serves as a learning experience for future aircraft acquisition programs, such as the Air Force's NGAD program that is currently still in the R&D phase

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