REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
04-18-2018	Masters in Military Studies Research Paper	Feb - Jun 2018

4. TITLE AND SUBTITLE
Air Superiority:
No Longer A Guaranteed Asymmetric Advantage

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)
Major Thomas Hayes, USAF

5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
College of Naval Command and Staff
Naval War College
686 Cushing Rd
Newport, RI 02841

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSOR/MONITOR'S ACRONYM(S)
N/A

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
N/A

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A: Approved for Public Release Distribution Unlimited

13. SUPPLEMENTARY NOTES
N/A

14. ABSTRACT
The DoD is on the cusp of losing air superiority due to an increasing shortage of fighter aircraft inventory and capability. This issue is commonly referred to as the "fighter gap" and has been the subject of numerous research papers and studies over the past 20 years. The gap in airpower capability is the result of years of military budget cuts, a delay in 5th-gen fighter aircraft procurement, and a legacy fighter fleet approaching the end of its service life. As a result, America could find itself in a conflict where air superiority is not a given, a luxury operational commanders have enjoyed since the end of the Korean War. In 2009 the CBO commissioned a study on alternatives for closing the "fighter gap" and modernizing the U.S. fighter fleet. The CBO study outlined seven possible courses of action to correct the gap in airpower capacity and capability; however, in the subsequent decade, all but two of these possibilities remain viable options. Specifically, the two remaining options are to replace the majority of the aging fighter fleet with F-35 aircraft, or choose to limit F-35 production in favor of procuring new advanced legacy aircraft, such as the F-16E. This case study reveals the benefits of choosing the F-35 modernization option by contrasting the key benefits of the F-35 over legacy platforms.

15. SUBJECT TERMS
JSF, F-35, Fighter Gap, Advanced Legacy Fighter, F-16E/F, F-15SA

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Naval War College, CNCS
Unclassified	Unclassified	Unclassified	SAR	27	19b. TELEPHONE NUMBER *(Include area code)* (401) 841-1310

NAVAL WAR COLLEGE
Newport, R.I.

Air Superiority: No Longer A Guaranteed Asymmetric Advantage

By

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: _____

18 May 2018

CONTENTS

List of Figures

ABSTRACT

The Department of Defense is on the cusp of losing air superiority due to an increasing shortage of fighter aircraft inventory and capability. This issue is commonly referred to as the "fighter gap" and has been the subject of numerous research papers and studies over the past 20 years. The gap in airpower capability is the result of years of military budget cuts, a delay in 5th generation fighter aircraft procurement, and a legacy fighter fleet approaching the end of its service life. As a result, America could find itself in a conflict where air superiority is not a given, a luxury operational commanders have enjoyed since the end of the Korean War. In 2009 the Congressional Budget Office (CBO) commissioned a study on alternatives for closing the "fighter gap" and modernizing the U.S. fighter fleet. The CBO study outlined seven possible courses of action to correct the gap in airpower capacity and capability; however, in the subsequent decade, all but two of these possibilities remain viable options. Specifically, the two remaining options are to replace the majority of the aging fighter fleet with 5th generation F-35 aircraft, or choose to limit F-35 production in favor of procuring new advanced 4th generation legacy aircraft, such as the F-15SA, F-16E, or the F/A-18E/F. This case study reveals the benefits of choosing the 5th generation modernization option by contrasting the key benefits of the 5th generation F-35 over legacy platforms.

INTRODUCTION

Airpower has afforded the U.S. military an asymmetric advantage since the end of the Korean War. The success of airpower, specifically in the wake of Operation DESERT STORM, has made achieving air superiority an expectation for U.S. led military operations. However, the combined effects of an aging U.S. fighter fleet and the reemergence of near-peer adversaries are threatening America's advantage in the air. Russia and China are currently fielding their own versions of 5th generation fighter aircraft in addition to advanced surface-to-air missile systems (SAMs), which can easily outclass the current fleet of U.S. 4th generation aircraft. In order to close the "fighter gap" and ensure air superiority in future military operations, America must modernize its fighter fleet, both in size and capability.

The "fighter gap" is commonly considered a numbers problem, but acquiring aircraft with the right capabilities is of equal importance to operational commanders. Based on the 2009 Congressional Budget Office (CBO) report, *"Alternatives for Modernizing U.S. Fighter Forces,"* U.S. decision-makers have two viable options for closing the "fighter gap."[1] These options are to continue with the planned purchase of 2,456 F-35 Joint Strike Fighters (JSF), or reduce the planned purchase of F-35s in favor of buying advanced legacy aircraft. The "reduction" option could offer a slightly quicker fielding rate at a reduced cost, but leverages quantity over quality. On the other hand, the "continuation" option will provide theater commanders with the airpower capability to solve the growing issue of battlefield parity; however, it comes with increased risk due to delays in acquiring and fielding the JSF weapon system. Ultimately, the risk of waiting for the right capability is worth it because it allows operational-level commanders the ability to achieve air superiority in the time and space of their choosing.

BACKGROUND

The term "fighter gap" refers to the predicted shortfall in fixed-wing combat aviation assets and has been the subject of study by the U.S. Air Force (USAF) for over 20 years. These studies predict the fighter deficit to peak at around negative 400 USAF combat aircraft between 2024 and 2028 (Figure 1).[2] The gap in combat capability is the result of a continuous reduction in airpower capability and a lack of fighter aircraft procurement since the end of the air campaign in Iraq in 1991 (Figure 2). At the time of the Gulf War, the USAF fighter fleet consisted of roughly 3,500 aircraft, which included nine distinct airframes, encompassing 134 fighter squadrons.[3] However, as a result of the military drawdowns following the end of the Cold War, the USAF retracted to its present size of approximately 1,900 fighter and attack aircraft, which equates to 55 combat squadrons, with the majority of those labeled as legacy 4th generation (4^{th}-gen) fighters.[4] This number falls well short of the stated goal of 2,200 fighter aircraft, as evidenced by Senator John McCain's recent whitepaper, which states the USAF "may require closer to 60 combat squadrons to be competitive against near-peer threats like Russia and China."[5] Moreover, the past 27 years of continuous combat operations, force reductions, and ineffective fighter acquisition programs have left the USAF the oldest, smallest, and least-ready it has been in its 70-year history.[6] As a result, the U.S. military is on track to lose the capability to achieve air superiority against near-peer adversaries in the next 5-10 years, if not sooner.

While the total number of fighter aircraft available (mass of firepower) is an important factor in achieving air dominance, the capability of those aircraft is equally significant due to the ever-increasing capability of anti-access and area-denial weapon systems (A2/AD). America's potential adversaries have taken note of the DoD's reliance on

airpower to achieve military objectives and have subsequently taken active measures to mitigate that asymmetric advantage.[7] Near-peer competitors, such as China and Russia, have invested heavily in weapon systems capable of denying freedom of movement to 4th-gen aircraft, which at present makes up the majority of the USAF's fighter fleet. At the time of this writing, 85% of the USAF's fighter inventory consists of 4th-gen F-15C/D/Es, F-16C/Ds, and A-10s, with the remainder being F-22A Raptors and F-35A Lightning IIs.[8] Further complicating the fighter gap issue is the fact that the F-22 production line was shuttered in 2010 due to political and economic pressure, leaving the Air Force with only 177 of the originally planned 680 Raptors.[9] The end result is an outdated fighter fleet that is incapable of air operations in regions defended by advanced integrated air defense systems, similar to the Russian systems employed by President Bashar al-Assad in the western half of Syria or by Chinese forces in the Taiwanese Straits.

Figure 1. Congressional Budget Office (CBO) Report Depiction of Fighter Gap[10]

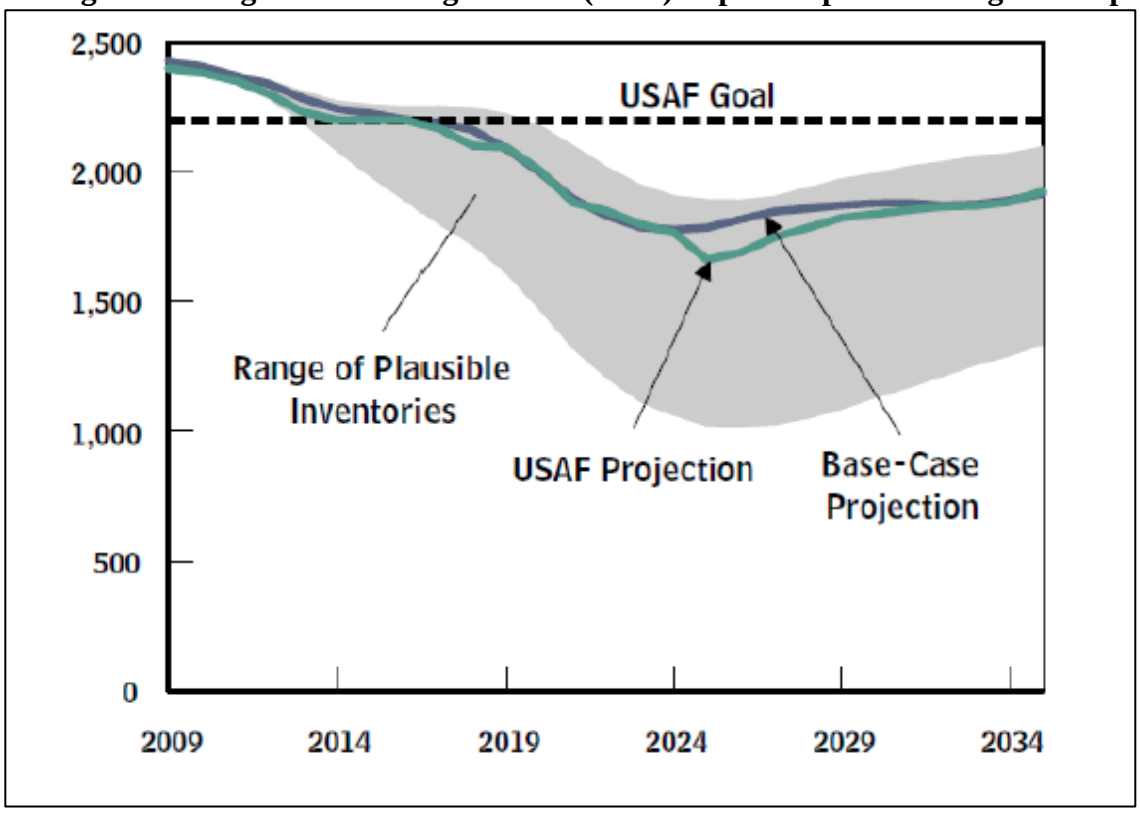
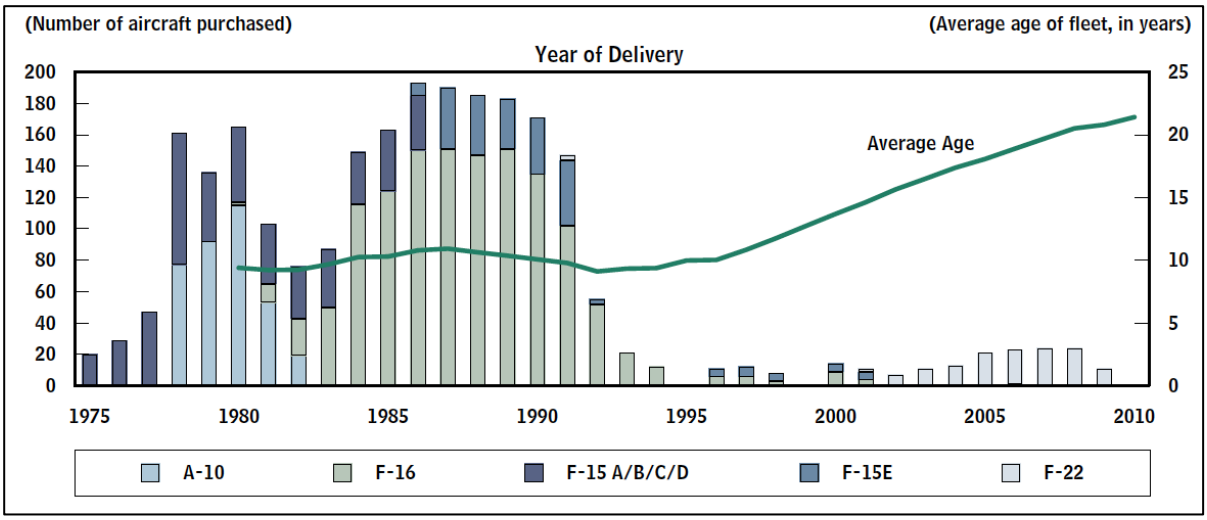


Figure 2. CBO Report Depiction of Numbers of Aircraft Purchased & Average Age[11]



Supporting the operational commander in this problem set is a slow and complicated procurement process, and more problematic than just choosing the best aircraft and purchasing the required number of jets to meet national defense requirements. Fighter jets take time to build, and they can be prohibitively expensive. Currently, the F-35 is the only active 5th generation (5th-gen) production line among friendly nations, and Lockheed Martin (LM) can only produce about 90 new F-35As a year, with a total maximum production rate of 160 JSFs by 2023.[12] In addition to LM's production limitations, there are also budgetary concerns with modernization, although some of the trepidation associated with sequestration has been eased with the recent 2018 omnibus defense-spending bill. That being said, airplanes are still expensive. At present, the cost of a low rate initial production (LRIP) JSF is $94.3 million per jet[13], which is a substantial price jump when considering the original per unit cost of the F-16C/D was approximately $18.8 million.[14]

The combined effects of an aging fighter fleet approaching the end of its lifespan, a battlespace that is becoming more and more contested, and budgetary restraints has created a paradox for operational commanders. Filling the fighter gap will have significant and lasting

implications on the USAF's ability to win militarily for the next half-century, and must be taken with great care to balance mission requirements while accounting for the risk associated with the gap in capability during aircraft production. In an effort to enumerate the consequences of these decisions, this paper will outline the pros and cons of the "continuation" option and the "reduction" option through the lens of the Joint Functions of *protection*, *fires*, and *sustainment*. This analysis will serve to highlight the survivability, lethality, and operating cost associated with the decision to modernize the USAF's fighter fleet with the right mix of 4th- and 5th-gen fighter aircraft capability.

F-35 Protection Benefits

Protection has been a fundamental aspect of airpower since pilots first flew canvas biplanes over the battlefields of Europe during World War 1. Early airpower pioneers, such as Frank Luke Jr., defended themselves in the skies with handheld pistols well before the first Vickers machine guns were mounted on Sopwith Camels. During World War 2, *protection* evolved to include heavily armed and armored bombers, like the B-17 Super Fortress, and the employment of pursuit fighter screens carried out by P-38s and P-51s. Vietnam saw the dawn of the missile-age and the heroic *protection* efforts of Wild Weasel aircrews in the Suppression of Enemy Air Defense (SEAD) role. The F-105 Thud aircrews utilize high-tech avionics equipment and the High-speed Anti-Radiation Missiles (HARM) to detect, deny, and destroy SAM systems, like the Vietnam-era SA-2, in an effort to protect strike aircraft. Finally, during Operation DESERT STORM, airpower *protection* methods progressed to include the first-ever use of Low Observable (LO) stealth technology (F-117 Night Hawk) to defeat the SAM batteries defending Baghdad, Iraq. The first 100 years of U.S combat aviation reflect a remarkable evolution in airpower *protection* technology and tactics;

however, potential enemy 5th-gen fighters and advanced long-range SAMs are rapidly outpacing American Airmen on the 21st-century battlefield.

This battlefield of tomorrow is actually the battlefield of today. Russia and China are investing heavily in air defense technology that negates America's airpower advantage. Systems such as the Russian built S-400 (SA-21) and the Chinese built HQ-9 boast an engagement range out to 150 nautical miles (NM) with the capability to intercept low-altitude cruise missile size targets.[15] Additionally, potential competitors are also fielding operational 5th-gen aircraft with capabilities similar to the F-22A. The Russian made Su-57 PAKFA and Chinese built J-20 Black Eagle are both prime examples of potentially unfriendly 5th-gen fighters. Both of these aircraft incorporate LO technology and advanced avionics to include cutting-edge active electronically scanned array (AESA) radars. The above facts and figures are prime examples of how America's near-peer competitors are taking steps to negate the advantages of airpower by denying access to significant portions of contested airspace. More to the point, the above Russian systems are operational in Syria, along with a multitude of other advanced SAM systems, including the SA-17, SA-19, SA-21 and SA-26.[16] These types of missile systems are commonly referred to as "double-digit" SAMs, and, due to their speed, range, and lethality, make the employment of 4th-gen aircraft all but impossible.

In contrast, 5th-gen aircraft incorporate organic *protection* capabilities, which allow them to operate in contested regions, similar to western Syria or the Taiwanese Straits. This is due in part to the unique design of 5th-gen aircraft, which feature LO radar cross-section (RCS) stealth technology. While the myth of stealth aircraft being invisible to radar is just that, a myth, the reduced RCS of the F-35 will permit flight operations in heavily defended

regions, which are otherwise inaccessible to legacy fighters. In addition to being LO, 5th-gen airframes also incorporate advanced avionics and sensor suits, which present near-perfect situational awareness (SA) to the pilot. For example, the advanced avionics of the F-35 utilize "fusion" technology, which can blend a multitude of sensor data, both internal and external to the JSF, into one seamless picture of the battlespace. Also of note, 5th-gen platforms can employ electronic attack (EA) as a *protection* capability, which further denies and degrades adversary air defenses. The synergistic effect of airframe RCS technology and advanced avionics inherent to the JSF negate the capabilities of anti-access weapon systems and restores the asymmetric airpower advantage of theater-level commanders.

The Syria scenario offers a unique litmus test for the need to modernize the USAF fighter fleet with F-35As. A key reason for this is because Syria is not considered a near-peer adversary, but due to their employment of Russian built double-digit SAMs, the western half of the country is all but off-limits to U.S. 4th-gen aircraft. Evidence of this fact can be seen in the lack of military action taken by President Barak Obama in the wake of al-Assad's use of chemical weapons in 2013, and again with the more recent use of military force by the Trump Administration in April of 2017 and 2018. While the strategic-level decision to use military force against the Assad regime factored in more than just the *protection* capabilities of the USAF fighter force, it no-doubt played a significant role. It should also be noted that during the most recent coalition airstrikes against Syria's chemical weapons facilities that there was no concerted effort to establish air superiority in the form of a no-fly zone over the western half of the country. The uncomfortable reality is that the U.S. fighter fleet cannot achieve air superiority over Syria due to its advanced air defense systems, at least not without significant loss of aircraft and aircrew.

The threat from surface-to-air fires is the primary obstacle to achieving air superiority, as evidenced by the fact that since 1965 air defense artillery and SAMs have claimed over 1,500 USAF aircraft.[17] In order for America to recapture the asymmetric advantage of airpower, it needs to modernize its fighter force with the *protection* capabilities resident to the JSF. Only then will theater-level commanders have the ability to achieve freedom of movement across the air domain, and subsequently hold at risk enemy centers of gravity while simultaneously defending and supporting friendly forces. Replacing the USAF's aging 4th-gen fighters with the *protection* capabilities of the F-35 will guarantee geographic combatant commanders have the ability to achieve air superiority at the time and place of their choosing.

F-35 Fires Benefits

The employment of *fires* from military aircraft has also evolved significantly over the past 100 years. Early airpower pioneers were limited to hand-delivered bombs during World War 1, and quickly evolved to larger unguided gravity munitions delivered by multi-engine aircraft equipped with bombsight by the late 1930s. The missile-age brought forth the first employment of guided munitions with the use of laser-guided bombs aided by targeting pods (TGP), and radar frequency (RF) and infrared (IR) guided missiles. In recent years the age of "smart-weapons" has seen the advent of global positioning system (GPS) aided weapons, as well as the most recent development of multi-spectral guided missiles, which blend data from multiple sensors to aid in terminal guidance. Throughout the improvements of airborne *fires*, one thing is clear, both aircraft and weapons are becoming more accurate and increasingly lethal, and the F-35 is no exception.

The JSF has unique *fires* capabilities that differentiate it from legacy 4th-gen fighters when it comes to providing battlefield effects for the theater-level commander. Within the DoD, most air-to-air (A/A) and air-to-ground (A/G) weapons are interchangeable on all aircraft; however, the F-35 can carry these weapons, along with its full complement of fuel, internally, which preserves its stealth RCS signature. This allows the F-35 to retain the above *protections* measures while still providing offensive *fires* in heavily defended regions similar to those found in Syria or the Taiwanese Straits. Internal weapons carriage is unique because legacy fighters must carry weapons and surplus fuel externally, which increases their RCS signature (and the likelihood of being targeted by surface-to-air fires) and reduces their maneuverability. For example, the F-16, which is regarded as one of the most maneuverable fighters in the world, must carry bombs, missiles, and fuel tanks externally to be combat effective. In doing so, it loses its impressive maneuverability while simultaneously becoming a larger target for radar guided SAMs. In contrast, the F-35A can carry four A/A missiles, up to eight A/G bombs, and 18,200 pounds of jet fuel, all without giving up its stealth signature or maneuverability (Figure 3).[18] The F-35's complementary effects of *protection* and *fires* bring a unique battlefield capability to operational commanders that are not resident in 4th-gen fighter aircraft.

In addition to carrying weapons internally, the F-35 is also equipped with an advanced fire control system, which utilizes sensor fusion technology to find, fix, track, target, engage, and assess (F2T2EA) enemy targets.[19] The JSF fire control system utilizes onboard computer systems to fuse information from multiple RF and IR sensors, both active and passive, to provide the pilot with supremely accurate SA on A/A and A/G targets, simultaneously. Lt. Col. Ethan Sabin, an F-35 Operational Test Pilot, described this

capability as, "playing the game *Battleship* while looking at your opponent's side of the game board."[20] The enhanced SA provided by the F-35's sensor fused fire control system allows pilots to rapidly complete the F2T2EA kill-chain in contested regions, while simultaneously denying adversaries the same opportunity.

In discussing the *fires* capabilities of the F-35, it is important to acknowledge the supporting role the USAF plays in the joint fight, which typically equates to Close Air Support (CAS). Joint Publication 3-09.3 defines CAS as, "Air action by fixed-wing and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and requires detailed integration of each air mission with the fire and movement of those forces."[21] In recent years, the F-35 has received some negative publicity regarding the aircraft's ability to effectively execute the CAS mission. Specifically, critics of the JSF are quick to point out the inferiority of the F-35 when compared to the A-10. Which is true, the A-10 is a better CAS fighter than the JSF; however, it is important to recognize that no fighter or attack aircraft ever built, in the history of time, has ever been as good at CAS as the A-10. That being said, the F-35 can effectively conduct CAS missions, and in some scenarios more successfully than the A-10. Considering the Syria scenario described previously, an F-35 can conduct CAS missions in regions defended by advanced air defense systems, which would be otherwise non-permissive to legacy 4th-gen fighters, to include the A-10. Moreover, the F-35 recently started Initial Operational Test and Evaluation (IOT&E) trials, which required a CAS "fly-off" between the A-10 and JSF. Lt. Col. Nicholas Ihde, a Test Pilot with the Joint Operational Test Team, stated in reference to the CAS phase of IOT&E that, "During the High-Threat CAS scenario, I was able to locate and kill the factor SA-11 SAM within about three minutes of test initiation."[22] Again, this is not to say that the

F-35 will ever be better at CAS than the A-10, but rather that, due to its unique *protection* and *fires* capabilities, the JSF can achieve battlefield effects in regions inaccessible by legacy fighter aircraft.

Lastly, the F-35 offers *fires* versatility that legacy fighters cannot duplicate. As previously mentioned, the F-35 has the ability to carry weapons and fuel internally, which preserves the LO RCS signature of the aircraft. In the LO configuration, the F-35 can carry 4,000 pounds of A/G munitions, equal to the full bomb load of a B-17, and is also capable of carrying external weapons if the threat environment allows. A scenario of this nature would typically arise several days into an air campaign after the majority of enemy air defenses have been neutralized, and air superiority is achieved. With external carriage, the F-35 can triple its A/G munitions load with up to six 2,000-pound guided bombs, which eclipses the A/G capability of legacy fighters, both in combat radius and total payload (Figure 3).[23] This capability gives theater-level commanders the ability to adjust F-35 armament options based on threat and mission requirements, which represents another capability not resident to 4th-gen fighter aircraft.

Figure 3. Air-to-Ground Weapons Carriage and Combat Radius

Max A/G Weapons	**F-35A**	**F-16E**	**F-15SA**	**F-22**
250 lbs. Munitions	8/24[1]	16	28	8/8[1]
2,000 lbs. Munitions	2/6[1]	4	5	0
Combat Radius[2]				
400NM	2/6[1]	2	5	0
500NM	2/6[1]	0	5	0
600NM	2/6[1]	0	5	0
700NM	2/4[1]	0	2	0

1) Stealth capacity / total capacity (Stealth capacity indicates that weapons and fuel are carried in internal bays. Total capacity indicates that weapons and fuel are carried both in internal bays and on external racks.)
2) Air-to-Ground Weapons capacity for 2,000 lbs. munitions, out to a specified Mission Radius
Adapted from Congressional Budget Office Report, Alternative for Modernizing U.S. Fighter Forces (Washington DC: Government Printing Office, 2009) Page 17.

F-35 Sustainment Benefits

Sustainment of military aircraft, as a Joint Function, is typically expressed in terms of program acquisition unit cost (PAUC) and operations and sustainment (O/S) cost. Both of these metrics can be used as a comparison tool to highlight the financial burden associated with the acquisition and operation of new and existing combat aircraft. It should be acknowledged up front that buying, operating, and maintaining fighter aircraft is expensive, and the F-35 is no exception. Moreover, the topic of cost, as it pertains to modernizing America's fighter fleet, is of particular concern due to the negative reputation of the F-35 as the most expensive DoD acquisitions program to date, which is valid. The total F-35 program is estimated to cost the American Taxpayers approximately $379 billion (non-inflationary adjusted dollars), which includes the full DoD purchase of 2,456 aircraft and $54.4 billion in research and development.[24] While the acquisition and operational cost associated with fighter aircraft does not directly translate to operational capability, it does speak to the strategic level decisions that eventually result in combat capability at the theater level.

The JSF is the most expensive DoD acquisitions program in history; however, when looking at the total acquisition cost in inflationary dollars and excluding the research and development cost of the aircraft, the PAUC of the F-35 is $94.3 million per jet, and falling as more and more jets are built.[25] Regardless, the JSF still has a considerably higher PAUC than other legacy fighters, specifically the F-16. The F-16 fleet makes up approximately 50% of the USAF's fighter inventory, and since the F-35A is scheduled to replace it on a one-for-one basis, comparing the per unit cost of the two platforms seems appropriate. The Air Force advertised PAUC for the F-16C/D is $18.8 million, in fiscal year 1998 dollars.[26]

These figures are based on the original F-16 acquisitions program, with the majority of the aircraft being delivered in the late 80s and early 90s (Figure 2).[27] However, if the newer and more advanced F-16E (Block-60) were to be purchased today, the Air Force estimates the PAUC would be roughly $60 million per jet.[28] While the F-35A is still 36% more expensive than the F-16E, the stigma of being the most expense DoD weapons program is brought into focus when contrasted with the combat capability afforded by the 5th-gen technology resident within the JSF.

Even more noteworthy is the "Cost per Capability" concept developed by the RAND Corporation, which states, "it may be impossible to estimate cost per capability across disparate aircraft when those aircraft provide different sets of capabilities."[29] As such, comparing the F-35 to legacy 4th-gen fighters is a bit like comparing apples to oranges based on the unique *protection* and *fires* capabilities of 5th-gen aircraft. Therefore, a more appropriate capabilities-based comparison would be to contrast the F-35 PAUC with that of its 5th-gen counterpart, the F-22, which originally cost $185.7 million per aircraft (non-inflationary adjusted dollars).[30] While these figures are not justification for the extremely high cost of fighter aviation, they begin to paint a more favorable picture of the F-35 as an economical 5th-gen fighter aircraft, and not as the "most expensive DoD acquisitions program to date."

Another methodology to evaluate the financial aspect of *sustainment* is to compare the O/S cost of analogous aircraft. The RAND Corporation states that comparing O/S cost from different aircraft "could inform acquisition choices or decisions about retaining existing fleets and shaping force structure."[31] To do this, it will be important to look at the Cost Per Flying Hour (CPFH) metric, which is a well-known method of evaluating a platform's O/S

cost as an individual flying hour expense. In doing so, each aircraft's O/S cost will need to be normalized to account for fuel expenses, inflation indexes, and added mission system hardware not organic to the base-model aircraft (TGPs, EA Pods, HARM Targeting System, etc…).[32] The calculation for CPFH is the *Normalized O/S Cost* divided by *Total Flying Hours*.[33] The resultant numbers can then be used to evaluate the cost per operating hour of each aircraft's relative combat capability (Figure 4).

Figure 4. Cost by Airframe with PAUC and CPFH

Airframe	F-15C/D	F-15E	F-16C/D	F-22	F-35	F-15SA	F-16E
2018 Inventory	246	217	963	177	180	-	-
Fleet Age (Years)	34.7	26.4	28.1	11	3.7	N/A	N/A
PAUC (Millions)	$29.9	$31.1	$18.8	$185.7	$94.3	$90.0	$55-60
O/S Cost (CPFH)	$38,846	$27,203	$25,541	$59,166	$32,554	Not Available	Not Available

Adapted From: United States Air Force. *USAF Fact Sheets. 2018*
F-35 Cost Per Unit from: Jeremiah Gertler *Air Force F-35 Joint Strike Fighter (JSF) Program* (Washington DC: Congressional Research Service, 2014)
F-22 Cost Per Unit from: Jeremiah Gertler *Air Force F-22 Fighter Program* (Washington DC: Congressional Research Service, 2013)
F-16E Cost Per Unit Estimated by; Congressional Budget Office, Alternative for Modernizing U.S. Fighter Forces (Washington DC: Government Printing Office, 2009)
F-15SA Cost Per Unit Estimated from: Government Accountability Office, Tactical Aircraft: Air Force Fighter Reports (Washington DC: Government Printing Office, 2011)

Based on the above calculation method, the F-35A has a CPFH of $32,554.[34] In contrast, the F-16C/D and F-22A have a CPFH of $25,541 and $59,166 respectively.[35] These numbers reveal the same conclusion as the previous PAUC sections; however, in this example, the JSF is only 21% more expensive to operate than the legacy F-16C, and 44.9% cheaper to operate per hour than the F-22A. Furthermore, as the F-35 fleet continues to mature it is anticipated that the O/S cost will continue to drop, with the USAF's end goal to match that of the F-16C/D. General Dave Goldfein, Air Force Chief of Staff, stated, "Our initial target is to get [the F-35] down to the equivalent or very close to what we're currently

spending to sustain 4th-gen fighters."[36] Ultimately, the F-35 is going to be expensive to buy and operate, no different than any other fighter aircraft, but the gains from modernization the USAF's aging fighter fleet with 5th-gen capabilities will prove invaluable to theater level commanders and their ability to gain and maintain air superiority.

Reduction Option – The Advanced Legacy Fighter

Some might argue that modernizing the USAF's fighter fleet with new advanced legacy fighters, like the F-16E, is a better option due to cost, production time, and near-equivalent capabilities. Due to several negative aspects surrounding the JSF acquisition program, there have been growing calls to limit the originally agreed upon procurement numbers, or even cancel the program entirely. Chief among these concerns are the seemingly endless delays with the F-35 IOT&E process. According to the CBO, the USAF should have reached initial operational capability (IOC) in 2011;[37] but, due to delays in development and testing, IOC was not reached until August of 2016. The five-year setback in reaching IOC has delayed LM's ability to produce the JSF at full rate, which is further amplifying the fighter gap problem.

As an alternative to the JSF, the USAF could choose to limit F-35A acquisitions in favor of purchasing an advanced version of the F-16. The LM F-16E production lines are already up and running, and the development and testing processes is largely out of the way, which mitigates the fielding timeline normally associated with new aircraft acquisitions. Further, because the USAF already operates a significant number of F-16s, the absorption of these new aircraft would represent minimal friction to the existing force structure. Existing legacy F-16 squadrons could receive new advanced aircraft, and older jets could be phased out over time based on age and mission requirements. This would allow the USAF to fill the

fighter gap on a more rapid timeline, and thus reduce, if not eliminate, the risk involved with waiting for the F-35 production line to swing into full gear. Additionally, the pilot training time and cost associated with upgrading to a new aircraft would be non-existent, as the transfer of flying qualifications and tactics to a newer version of the F-16 would be nearly identical.

The "reduction" option (advanced legacy fighter) also offers significant financial benefits over the current plan to purchase 1,764 JSFs for the Air Force. Should the USAF choose to limit F-35A production to less than 300 aircraft, and instead fill the fighter gap with F-16Es, the CBO estimates a savings of $31 billion through 2035.[38] This option would leave the USAF with an 80/20 split of 4th-gen and 5th-gen capable aircraft, and free up defense spending to pursue other airpower initiatives, such as a light-weight attack aircraft to replace the A-10 and/or a deep penetration strike weapons to solve the A2/AD problem.

Further, the capabilities of advanced 4th-gen fighters, like the F-16E, are nearly equivalent to 5th-gen platforms. The F-16E has approximately all the same avionic capabilities as a JSF, like an AESA radar and advances EA hardware. The AESA radar in the advanced version of the F-16 allows it to achieve near-parody with the F-35 with it comes to completing the A/A F2T2EA kill-chain. Additionally, while the F-16E will never be a LO stealth capable aircraft, the EA functions built into the new jet will mitigate some of the risk associated with advanced air defense system. The F-16Es can use EA to degrade and disrupt double-digit SAMs, which offers operational commanders some capability to achieve airpower effects in contested regions, similar to the Syria and Taiwan operating areas, more effectively than existing USAF legacy fighters.

The option of limiting F-35 production in favor of modernizing the USAF's fighter force with new advanced F-16Es offers a multitude of cascading benefits. This option offers a quicker solution to filling the fighter gap and mitigates the time-risk component of waiting for F-35s to roll off the assembly line over the next 17 years. In addition to providing combat airpower on a faster timeline, the F-16E also saves money in acquisition cost. The DoD budget is already stretched wire tight, and the option of cutting airpower acquisitions provides an array of options for the USAF to fill current operational needs while freeing up funding for other combat and logistical upgrades. Lastly, the difference in combat capabilities between the F-16E and the F-35A is negligible to the point of immeasurability. Therefore, significant considerations should be given to limiting the procurement of JSFs in favor of pursuing the more economical and effective F-16E.

Conclusion

The choice to modernize the U.S. fighter fleets is a very complex decision with lasting ramifications. Both options offer a pathway to solving the fighter gap problem, and each carry their own risk for the operational commander. Choosing the advanced legacy fighter options offers a quicker modernization route, but also assumes risk in capability. Moreover, it is very unlikely that a fighter force comprised primarily of 4^{th}-gen aircraft could establish air superiority in regions defended by advanced surface defenses. However, at the same time, continuing on the present course with the full JSF purchase is both extremely expensive and carries additional risk in fighter capacity due to LM's developmental delays.

Ultimately, it is incumbent on each service to make a choice in fighter acquisition that best meets the needs of their primary mission and domain focus. The USAF, as the primary arbiter of the air-domain, must ensure that theater commanders have the right capacity and

capability to achieve air superiority. The benefits gained from a fighter force comprised predominantly of 5th-gen aircraft far exceed the increased cost and delay in JSF procurement. The USAF must stay on course with the current programmed purchase of 1,763 F-35As in order to guarantee that American airpower remains an assumed fact of military life. JSF critics are quick to point out maneuverability, CAS capabilities, and aircraft cost as a reason to terminate the program, but these critiques quickly evaporate when air superiority becomes unachievable in places like Syria or the Taiwanese Straits. Regardless of how the JSF acquisition program plays out over the coming years, one thing is certain… air superiority is an asymmetric advantage that must be maintained at all cost.

END NOTES

[1] Congressional Budget Office, *"Alternatives for Modernizing U.S. Forces"* (Washington DC: Government Printing Officer, 2009), xix.
[2] Ibid, 10.
[3] Stephen Losey, *"Air Force Wants to Grow From 55 to 60 Fighter Squadron,"* (February 1, 2017) https://www.airforcetimes.com/news/your-air-force/2017/02/01/air-force-wants-to-grow-from-55-to-60-fighter-squadrons/ (accessed April 30, 2018)
[4] ibid
[5] John Mccain, "*Restoring American Power"* April 5, 2018, https://www..senate.gov/ mccain public/ cache/files/25bff0ec-481e-466a-843f-68ba5619e6d8/restoring-american-power-7.pdf (accessed April 24, 2018), 12.
[6] ibid., 13.
[7] Andrew T. Slawson, *"Air Power's First Among Equals: Why Air Superiority Still Matters," Joint Advanced Warfighting School* (Joint Forces Staff College: National Defense University, 2008) 56.
[8] U.S. Air Force, *"U.S. Air Force Fact Sheets,"* http://www.af.mil/About-Us/Fact-Sheets/Search/F-16/?Sort=Rank (accessed April 30, 2018)
[9] Jeremiah Gertler, "*Air Force F-22 Fighter Program*," (Washington DC: Congressional Research Service, 2013) 5.
[10] Congressional Budget Office, *"Alternatives for Modernizing U.S. Forces"* (Washington DC: Government Printing Officer, 2009), xii.
[11] ibid., 9.
[12] Gillian Rich, *"Pentagon's No. 2 Has This Confusing Mindset On Lockheed's F-35,"* Investor's Business Daily, (December 21, 2017), https://www.investors.com/news/lockheeds-f-35-full-rate-production-no-2-pentagon-official/ (accessed April 30, 2018)
[13] Lockheed Martin, *"How Much Does The F-35 Cost?"* Lockheed Martin, https://www.f35.com/about/cost (accessed April 23, 2018)
[14] U.S. Air Force, *"U.S. Air Force Fact Sheet – F-16 Fighting Falcon,"* September 23, 2015, http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104505/f-16-fighting-falcon/ (accessed April 22, 2018)
[15] Sean O'Connor, *"Intel Briefing: The S-300P and S-400: Russia's Strategic Defenders,"* April 16, 2018, http://www.janes.com/article/79146/intel-briefing-the-s-300p-and-s-400-russia-s-strategic-defenders (accessed April 24, 2018)
[16] Sean O'Conner, *"Access Denial – Syria's Air Defense Networks,"* http://www.janes360.com/images/assets/570/36570/Access_Denial.pdf (accessed April 26, 2018)
[17] Mark D. Kelly, *"The Fog and Friction of Victory: Congruent Training for Combat Capable Airpower"* Air Command and Staff College (Maxwell AFB Al: Air University, 2001) V.
[18] Congressional Budget Office, *"Alternatives for Modernizing U.S. Forces"* (Washington DC: Government Printing Officer, 2009), 17.

[19] U.S. Joint Chiefs of Staff, *"Joint Targeting, Joint Publication 3-60"* (Washington, DC: US Joint Chiefs of Staff, January 2014) I-8.
[20] Ethan Sabin (Air Force F-35 Test Pilot) in interview with the author, April 2018
[21] U.S. Joint Chiefs of Staff, *"Close Air Support, Joint Publication 3-09.3"* (Washington, DC: US Joint Chiefs of Staff, November 2014) xi.
[22] Nicholas Ihde (Air Force F-35 Test Pilot) in interview with the author April 2018
[23] Congressional Budget Office, *"Alternatives for Modernizing U.S. Forces"* (Washington DC: Government Printing Officer, 2009), 17.
[24] Jeremiah Gertler, *"F-35 Joint Strike Fighter (JSF) Program,"* (Washington DC: Congressional Research Service, 2012) 12.
[25] Lockheed Martin, *"How Much Does The F-35 Cost?"* Lockheed Martin, https://www.f35.com/about/cost (accessed April 23, 2018)
[26] U.S. Air Force, *"U.S. Air Force Fact Sheet – F-16 Fighting Falcon,"* September 23, 2015, http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104505/f-16-fighting-falcon/ (accessed April 22, 2018)
[27] Congressional Budget Office, *"Alternatives for Modernizing U.S. Forces"* (Washington DC: Government Printing Officer, 2009), 9.
[28] *"Tactical Aircraft: Air Force Fighter Reports,"* (Washington DC: Government Accountability Office, February 2011) 9.
[29] Michael Boito, Edward G. Keating, John Wallace, Bradley Deblois, Ilana Blum, *"Metrics to Compare Aircraft Operating and Support Cost in the Department of Defense,"* (Santa Monica, CA: RAND Corporation, 2015) 31.
[30] Jeremiah Gertler, "*Air Force F-22 Fighter Program*," (Washington DC: Congressional Research Service, 2013) 9.
[31] Michael Boito, Edward G. Keating, John Wallace, Bradley Deblois, Ilana Blum, *"Metrics to Compare Aircraft Operating and Support Cost in the Department of Defense,"* (Santa Monica, CA: RAND Corporation, 2015) 1.
[32] ibid., 20.
[33] ibid., 1.
[34] ibid., 20.
[35] ibid
[36] Valerie Insinna, *"U.S. Air Force Aims to Lower F-35 sustainment cost to that of an F-16,"* March 29, 2018 https://www.defensenews.com/air/2018/03/29/air-force-aiming-to-lower-f-35-sustainment-costs-to-that-of-an-f-16/ (accessed April 22, 2018)
[37] Congressional Budget Office, *"Alternatives for Modernizing U.S. Fighter Forces"* (Washington DC: Government Printing Officer, 2009), 6.
[38] ibid., 31.

Abbreviations

A/A – Air-to-Air
AESA – Active Electronically Scanned Array
A/G – Air-to-Ground
A2/AD – Anti-access and Area-Denial
CAS – Close Air Support
CBO – Congressional Budget Office
CPFH – Cost Per Flying Hour
DoD – Department of Defense
DoN – Department of the Navy
EA – Electronic Attack
F2T2EA – Find, Fix, Track, Target, Engage, and Assess
GPS – Global Positioning System
HARM – High-speed Anti-Radiation Missile
IOC – Initial Operational Capability
IOT&E – Initial Operational Test and Evaluation
IR - Infrared
JSF – Joint Strike Fighter
LM – Lockheed Martin
LRIP – Low Rate Initial Production
LO – Low Observable
NM – Nautical Miles
O/S – Operations and Sustainment
PAUC – Program Acquisition Unit Cost
RCS – Radar Cross-Section
RF – Radar Frequency
SA – Situational Awareness
SAM – Surface-to-Air Missile
SEAD – Suppression of Enemy Air Defense
TGP – Targeting Pod
USAF – U.S. Air Force

Bibliography

"Alternatives for Modernizing U.S. Fighter Forces," Congressional Budget Office, Washington DC: Government Printing Officer, 2009

Boito, Michael, and Edward G. Keating, John Wallace, Bradley Deblois, and Ilana Blum, *"Metrics to Compare Aircraft Operating and Support Cost in the Department of Defense,"* Santa Monica, CA: RAND Corporation, 2015

Boyne, Walter J. "Beyond the Wild Blue: A History of the United States Air Force, 1947-2007" New York: St Martin's Press, 2007.

Gertler, Jeremiah. "Air Force F-22 Fighter Program," Congressional Research Service Report for Congress, Washington DC: Government Printing Office, July 2013

Gertler, Jeremiah. "Air Force F-35 Joint Strike Fighter (JSF) Program," Congressional Research Service Report for Congress, Washington DC: Government Printing Office, April 2014

Insinna, Valerie. "U.S. Air Force Aims to Lower F-35 sustainment cost to that of an F-16," Defense News, March 29, 2018 (Accessed April 22, 2018) https://www.defensenews.com/air/2018/03/29/air-force-aiming-to-lower-f-35-sustainment-costs-to-that-of-an-f-16/

Joint Chiefs of Staff. Joint Publication 3-09.3, "Close Air Support," Washington DC: Joint Chiefs of Staff, 2014

Joint Chiefs of Staff. Joint Publication 3-60, "Joint Targeting," Washington DC: Joint Chiefs of Staff, 2014

Kelly, Mark D. "The Fog and Friction of Victory: Congruent Training for Combat Capable Airpower," Air Command and Staff College, Maxwell AFB: Air University Press, 2001

Lockheed Martin "How Much Does the F-35 Cost?" (Accessed April 23, 2018) https://www.f35.com/about/cost

Losey, Stephen, "Air Force Wants to Grow From 55 to 60 Fighter Squadron," Air Force Times (Accessed April 30, 2018) https://www.airforcetimes.com/news/your-air-force/2017/02/01/air-force-wants-to-grow-from-55-to-60-fighter-squadrons/

Mccain, John. "Restoring American Power" Whitepaper, (April 5, 2018),

(Accessed 24 April, 2018)
https://www..senate.gov/ mccain public/ cache/files/25bff0ec-481e-466a-843f-68ba5619e6d8/restoring-american-power-7.pdf

O'Connor, Sean. "Intel Briefing: The S-300P and S-400: Russia's Strategic Defenders," Janes 360, (Accessed April 24, 2018)
http://www.janes.com/article/79146/intel-briefing-the-s-300p-and-s-400-russia-s-strategic-defenders

O'Connor, Sean. "Access Denial – Syria's Air Defense Networks," Janes 360, (Accessed April 26, 2018)
http://www.janes360.com/images/assets/570/36570/Access_Denial.pdf

Rich, Gillian. "Pentagon's No. 2 Has This Confusing Mindset On Lockheed's F-35," Investor's Business Daily, (December 21, 2017),
https://www.investors.com/news/lockheeds-f-35-full-rate-production-no-2-pentagon-official/ (accessed April 30, 2018)

Slawson, Andrew T. "Air Power's First Among Equals: Why Air Superiority Still Matters," Joint Advanced Warfighting School, Joint Forces Staff College: National Defense University Press, 2008

"Tactical Aircraft: Air Force Fighter Reports," Washington DC: Government Accountability Office, February 2011

United States Air Force, "U.S. Air Force Fact Sheet F-16 Fighting Falcon," (Washington DC: United States Air Force, September 2015) (Accessed 22 April 2018)
http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104505/f-16-fighting-falcon/