AiMT Advances in Military Technology
Vol. 10, No. 2, December 2015

F-35 - Win or Loss for the USA and their Partners?

T. Schóber[1*] and P. Puliš[2]

[1] *Slovak Air Force HQ, J. Jiskru 10, 960 01 Zvolen, Slovak Republic*
[2] *Technical University of Košice, Faculty of Aeronautics, Rampová 7, 041 21 Košice, Slovak Republic*

The manuscript was received on 16 November 2015 and was accepted after revision for publication on 20 December 2015.

Abstract:

Joint Strike Fighter evolved into the world's largest and most expensive weapons program. The information flow from the media is keeping us informed about the achievements and mishaps of the program almost on week basis. The aim of this paper is, according to numerous articles and official reports, to evaluate and analyse current status of the program from the developmental and financial point of view, and to outline future trends, possible limitations and hidden risks for the projected customers. This article also compares the cost growth, factors contributing to cost growth, and operational and strategic risk of past joint and single-service programs.

Keywords:

F-35, Aircraft, Development, Design, Procurement, Capability.

1. Introduction

The F-35, also referred to as the Joint Strike Fighter (JSF), is touted as the most lethal and versatile aircraft of the modern era. It combines advanced stealth capabilities, radar-jamming abilities, supersonic speed, extreme agility and state-of-the-art sensor fusion technology [1]. The fifth-generation stealth fighter plane was originally conceived to upgrade the U.S. military's aging tactical fleet. In place of the specialized roles performed by older aircraft, the single-seat F-35 can conduct air-to-air combat, air-to-ground strikes, intelligence, surveillance and reconnaissance missions. It can penetrate enemy territory without being detected by radar; and its specialized helmet display gives pilots a 360-degree view of their surroundings [1]. All these statements are mainly official claims by the Lockheed Martin which is the primary contractor. Of course, the JSF is a true fifth-generation fighter aircraft, but... Its current price tag is roughly $400 billion - almost twice the initial estimate. According to the Government Accountability Office (GAO), to maintain and operate the JSF program over the course of its lifetime,

* *Corresponding author: Slovak Air Force HQ, J. Jiskru 10, 960 01 Zvolen, Slovak Republic, phone: +421 911 135 384, Fax: - , E-mail: tomas.schober@gmail.com*

the Pentagon will invest nearly $1 trillion. The aircraft suffers from so many children diseases that are, in combination with disappointing test results, raising doubts about its performance and future combat capabilities. And the list of critics of the program is really huge.

The JSF, just like its predecessor - the F-22, has adopted a buy-before-you-fly production approach. In this approach, fewer planes are produced and tested early in the development process. The production rate is then increased each year as the technology matures, however, these aircraft then require some retrofits after test-flight discoveries. Lockheed Martin highlighted that this approach allows them to deliver the planes to each military branch more quickly. On the other hand, one of the biggest critics of the program, Democratic California Rep. Jackie Speier (referring to the F-22) said "the result was a program we had to cancel after producing 555 fewer planes than the Air Force initially wanted. And similar trend is evident in the development of the F-35. The price of adding all the testing, retrofits and capabilities the program office has deferred will be higher than the entire cost of the F-22 program." She says that the F-35's logistics system is 80 % unreliable, its engine stability is "extremely poor" and electronics in the individually sculpted $400,000 pilot's helmet is currently unable to distinguish friend from foe. "At best, when the services declare 'initial operating capability', we will be launching an unstable plane that cannot perform many of its core missions for years. At worst, it'll hurt people or we'll ground it in the hangar and spend billions on a retrofit." Lockheed Martin spokesman Michael Rein, although defending the aircraft, admits that even declared operational in 2015 (Marine version), it still won't be available for combat use for at least another two years, with several branches not prepared to use it until even later. This is an example of almost every day and never ending disputes through the entire history of the program. If we want to analyse and highlight the pros and cons of the aircraft and the whole program, we have to proceed step by step and concentrate on key areas [1].

2. Background

Lockheed Martin F-35 was developed from the X-35, the winning design of the Joint Strike Fighter program. JSF is the final stage of the Common Affordable Lightweight Fighter (CALF) project dated back to 1993. The CALF program's aim was to develop the technologies and concepts to support the ASTOVL (Advanced Short Take-off / Vertical Landing) aircraft for the U.S. Marine Corps and Royal Navy (RN) and a highly-common conventional flight variant for the U.S. Air Force (USAF) [2]. In parallel to the CALF program, the USAF and the Navy initiated the Joint Advanced Strike Technology (JAST) Program in late 1993 as a result of the U.S. Department of Defence's (DoD) modernization plans. DoD, according to the assumption that the US should maintain the ability to fight and win two near simultaneous Major Regional Conflicts (MRCs), needed to develop next-generation aircraft to replace A-6, F-14, F-16 and F-111 as they reach the end of their service lives. By the end of 1994, the JAST program had absorbed the CALF program. As JAST was already considering STOVL variants, this merger was accommodated with comparatively little disruption. The findings of the Concept Exploration (CE) studies showed that a "tri-service family" of aircraft was the most affordable solution to the collective joint-service needs. The tri-service family would entail a single basic airframe design with three distinct variants:

- Conventional Take-Off and Landing (CTOL) for the USAF to complement the F-22 Raptor and to replace the aging F-16 Fighting Falcon and the A-10 Thunderbolt.
- Short Take-Off/Vertical Landing (STOVL) for the U.S. Marine Corps to replace both the AV-8B Harrier and the F/A-18 C/D Hornet; and
- Carrier variant (CV) for the U.S. Navy to complement the F/A-18 E/F Super Hornet.

With the continued interest by the U.K. Ministry of Defence (MoD) in the programme and multiple studies, two critical decisions were made - aircraft would be single-crew and single-engine. Although U.S. Navy has preferred to have two engines in case one is lost during flight, the choice of a single-crew aircraft was accepted. Later, in the spring of 1995, all three of the contractor teams (Lockheed, McDonnell Douglas and Boeing) selected derivatives of the Pratt & Whitney (P&W) F119 engine to power their aircraft. In 1996, after the final proposals were issued to the contractors, the JAST program name had changed to Joint Strike Fighter (JSF) [3].

3. Joint Aircraft vs Single-Service Aircraft

Joint aircraft program is an aircraft program in which two or more services are significantly involved in all stages of the acquisition and operational phases - that is, in the design, development, procurement, and operations and support (O&S) of the aircraft. Joint aircraft programs are thought to save significant Life Cycle Cost (LCC) by eliminating duplicate efforts and realizing economies of scale. But the need to accommodate different service requirements in a single design or common design family leads to greater program complexity, increased technical risk, or increased weight beyond that needed for some variants, potentially leading to higher overall cost, despite the efficiencies.

RAND Corporation[*], on the USAF demand, executed analysis of the numerous joint aircraft programs the DoD has launched or attempted to launch in the past 50 years. Comparing the cost growth of joint and single-service programs, their findings are unambiguous - historical joint aircraft programs have experienced higher rates of acquisition cost growth than single-service aircraft programs and have not saved overall LCC. Although the JSF program was structured to overcome some of the problems encountered by past joint fighter programs, it faced the challenge of accommodating three substantially different sets of service requirements (along with international partner requirements) and ambitious technical and performance objectives (such as supersonic low observable STOVL capability) into a single core aircraft design, with an 80-percent commonality goal among service variants [4].

4. Factors Contributing to Cost Growth

An important factor contributing to the joint aircraft acquisition program cost-growth increase is the tension between the need to attain maximum design and system commonality, which is the basis of potential joint cost savings, and service-specific requirements, which tend to reduce commonality. Historically, the services have entered

[*] RAND Corporation is the USAF's federally funded research and development centre for studies and analyses.

joint aircraft programs with unique requirements that arise from differences in operating environments, missions, doctrine, and operational concepts.

Past joint fighter programs have typically evolved toward distinct service variants with significantly reduced commonality. For example, the congressionally mandated joint Air Combat Fighter program in the early 1970s evolved from an original goal of 100 percent commonality into two distinct platforms with zero commonality: the Air Force F-16A/B and the Navy F/A-18A/B. In other cases, necessary design compromises left the services unsatisfied and sometimes resulted in one or more partners withdrawing from the program, as in the case of the Air Force/Navy F-111 program and numerous others. The following figure illustrates the tensions between commonality and service optimization in four historical joint fighter programs from the 1960s and 1970s, each of which began with the goal of 100-percent commonality but diverged into unique service variants (Fig. 1).

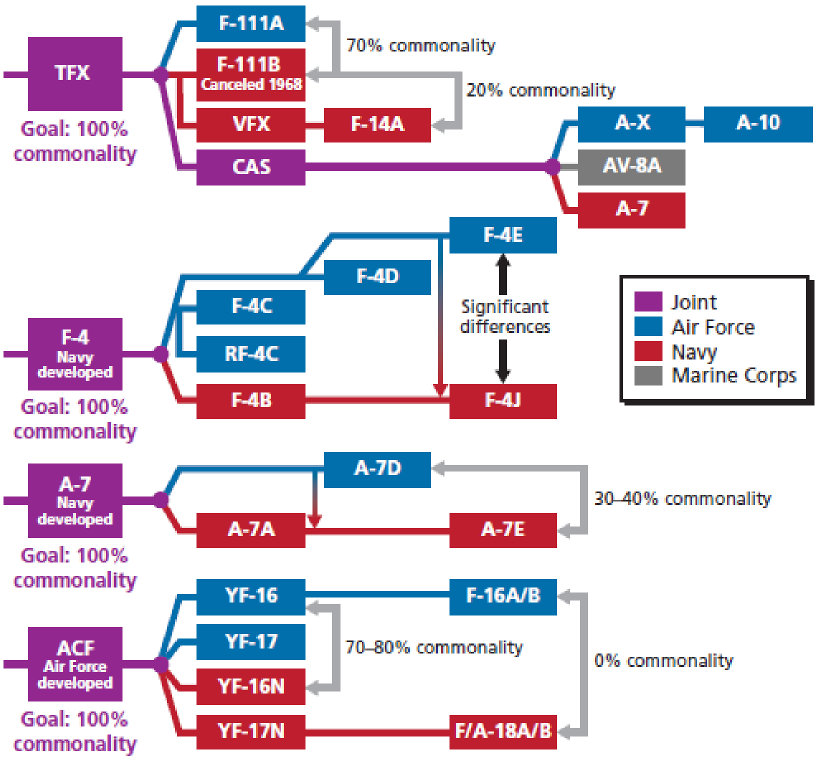

Fig. 1 Comparison of four historical joint fighter programs from the 1960s and 1970s which began with the goal of 100-percent commonality but diverged into unique service variants [4]

The JSF program was initially envisioned as an affordable program costing $175 billion (fiscal year [FY] 2002) for procurement of 2.852 joint fighters with the full-rate production starting in 2012. For comparison, estimates from December 2014 grew to $391 billion for procurement of only 2.457 aircraft with the full-rate production expected to start in 2019. The final number of the JSF O&S cost growth is hard to predict, however, the latest estimate of O&S cost growth is undoubtedly greater than that of the F-22 or any other recent single-service aircraft.

Moreover, two additional issues bear consideration for future military aircraft acquisition planning.

4.1. Industrial base

At the beginning of the JSF program in the early 1990s, there were eight major prime contractors that were credible combat aircraft developers (Fig. 2).

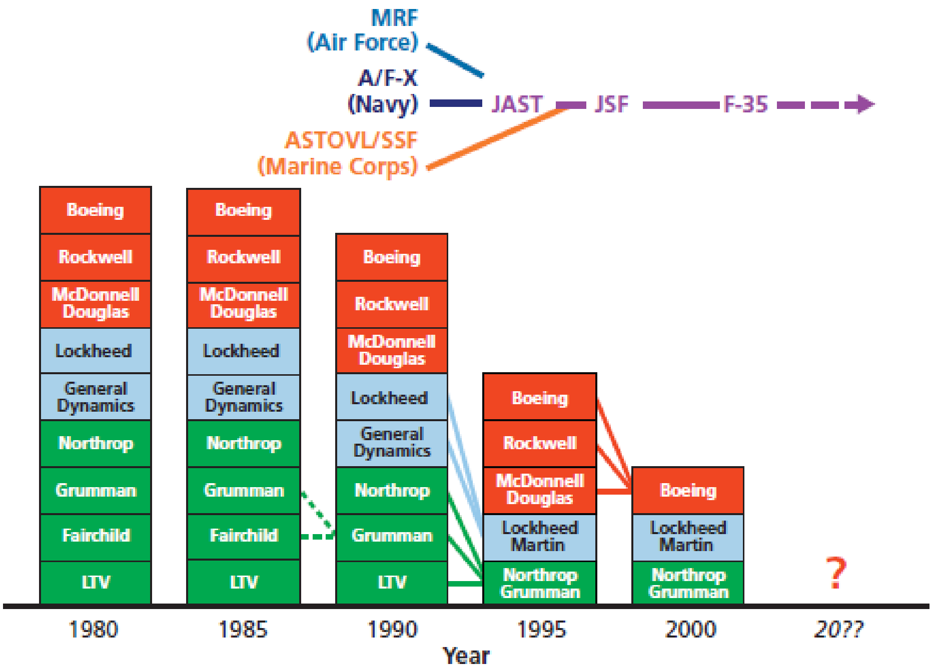

Fig. 2 Consolidation of fighter prime contractors with JSF development [5]

As of 1990, three major programs (for USAF, Navy and Marine Corps) for new fighters were in the very early stages of development. Between three and six prime contractors had been developing three entirely separate new fighters, thus maintaining skills and fostering competition and innovation. Later, as the F-22 and the F/A-18E/F matured and went into production, JSF became the only remaining new fighter/attack aircraft program for any of the services for the foreseeable future. At the beginning, three prime contractors (McDonnell Douglas, Boeing, and Lockheed Martin) competed for that program (in the meantime McDonnell Douglas was purchased by Boeing). Selecting Lockheed Martin's X-35 design made Boeing left without any future manned fighter/attack program after its current F/A-18E/F and F-15 fighter programs wound down. Thus, Lockheed Martin is now the only prime contractor actively leading a fifth-generation manned fighter/attack aircraft development and production program. Such a situation reduces the potential for future competition, as well as it may discourage innovation, which makes costs more difficult to control. In the future, DoD will have to address the challenges of a smaller, less competitive industrial base. European aircraft industry is facing similar situation, too.

4.2. Operational and Strategic Risk

Depending on a single weapon-system type or platform across all the services to carry out an entire mission area poses the operational and strategic risks. Joint programs could potentially increase the operational and strategic risk to war fighters by increasing the chances of simultaneous fleet-wide stand-downs of all aircraft in a major mission area and reducing the capability options available to meet unforeseen enemy capabilities and other challenges.

In contrary, having a variety of designs and capabilities in the fighter inventory provides a range of options for war fighters and industry to rapidly and successfully respond to an unanticipated and superior enemy capability. Besides that, having multiple fighter types radically reduces the probability that all fighters will have to stand down at the same time, reducing operational risk and increasing deterrence [4].

5. F-35 – Variants Description

The F-35 is being procured in three distinct versions tailored to the needs of each military service. Differences among the aircraft include the manner of take-off and landing, fuel capacity, ordnance, and carrier suitability, among others.

5.1. F-35A - Air Force CTOL Version

F-35As are to replace Air Force F-16 fighters and A-10 attack aircraft, and possibly F-15 fighters. The F-35A is intended to be a more affordable complement to the Air Force's new F-22 Raptor air superiority fighter [6]. The F-35A is neither as stealthy, nor as capable in air-to-air combat as the F-22, but it is more capable in air-to-ground combat than the F-22. The Air Force states that "The F-22A and F-35 each possesses unique, complementary, and essential capabilities that together provide the synergistic effects required to maintain that margin of superiority across the spectrum of conflict." The F-35A variant was first flown on December 15, 2006.

5.2. F-35B - Marine Corps STOVL Version

F-35Bs are to replace Marine Corps AV-8B Harrier vertical/short take-off and landing attack aircraft and Marine Corps F/A-18A/B/C/D strike fighters, which are CTOL aircraft. The Marine Corps decided not to procure the newer F/A-18E/F strike fighter and instead to wait for the F-35B in part because the F/A-18E/F [7] is a CTOL aircraft, and the Marine Corps prefer aircraft capable of vertical operations. The F-35B variant was first flown on June 11, 2008.

5.3. F-35C - Navy Carrier-Suitable Version

The Navy is procuring the F-35C, a carrier-suitable CTOL version of the aircraft. The Navy plans in the future to operate carrier air wings featuring a combination of F/A-18E/Fs (which the Navy has been procuring since FY1997) and F-35Cs. The F-35C is to be the Navy's first aircraft designed for stealth, a contrast with the Air Force, which has operated stealthy bombers and fighters for decades. The F-35C variant was first flown on June 6, 2010 [5].

6. Procurement Numbers

Tab. 1 Planned quantities (by DoD) for F-35 program over the years [8, 9]

Year	Total plan (incl. foreign customers)	USAF	NAVY	Marine Corps
1996	2.978 + 60 for UK	2.036	300	642
1997	2.852	1.763	480	609
2003	2.443	1.763	680	
2015	2.443	1.763	260	80 (C) + 340 (B)

The F-35 program continues efforts to make the F-35 cost-competitive with previous-generation aircraft. U.S. Air Force Lieutenant General Christopher Bogdan, the Pentagon’s manager of the program, told reporters in Canberra today: “The cost of an F-35A in 2019 will be somewhere between $80 and $85 million, with an engine, with profit, with inflation“ [10]. The GAO, a congressional watchdog agency, remains sceptical about those efforts, noting that the A-model (the simplest model) jets procured in 2013 cost $124.8 million each, about $41 million above the Pentagon's target for 2019 [11]. Despite permanently growing and higher-than-predicted costs, DoD officially expects an average prize for F-35s much lower (as stated in following table).

Tab. 2 F-35 Projected Unit Cost (in millions FY 2012$) [12]

	F-35A	F-35B	F-35C
Airframe	66.0	76.8	78.2
Engine	11.7	28.7	11.5
Total	77.7	105.5	89.7

The degree of concurrency in the F-35 program, in which aircraft are being produced while the design is still being revised through testing, appears to make upgrades to early-production aircraft inevitable. The cost of those upgrades may vary, depending on what revisions are made during the testing process. However, the cost of such upgrades is not included in any negotiated price. The first F-35As, for example, were loaded with a basic software release (Block 1B) that provides basic aircraft control, but does not have the degree of sensor fusion or weapons integration expected in later blocks. The initial estimate for modifying early-production F-35As from a basic configuration to a capable warfighting level is $6 million per jet, plus other associated expenses [13].

According to the 2013 baseline and flight test schedule, DoD will procure 289 aircraft for $57.8 billion (then-year dollars) before the end of developmental flight testing [14]. That represents $200 million per aircraft. In other words, roughly 12 % of all produced (predicted) aircraft would be dedicated only for testing, with limited combat capability.

7. International Participation

International participation in the F-35 program is divided into three levels, according to the amount of money a country contributes to the program - the higher the amount, the greater the nation's voice with respect to aircraft requirements, design, and access to technologies gained during development.

Level I Partner (United Kingdom) status requires approximately 10 % contribution to aircraft development and allows for fully integrated office staff and a national deputy at director level.

Level II partners consist of Italy and the Netherlands, contributing $1 billion and $800 million, respectively. On June 24, 2002, Italy became the senior Level II partner. Italy wanted to have its own F-35 final assembly line, which would be in addition to a potential F-35 maintenance and upgrade facility. The Netherlands signed on to the F-35 program on June 17, 2002, after it had conducted a 30-month analysis of potential alternatives.

Australia, Denmark, Norway, Canada, and Turkey joined the F-35 program as Level III partners, with contributions ranging from $125 million to $175 million (Tab. 3) [15].

The cost of F-35s for the customers depends in part on the total quantity of F-35s produced. As the program has proceeded, some new potential customers have emerged, other countries have considered increasing their purchases, while some have deferred previous plans to buy F-35s. In July 2010, Lockheed and the Italian firm Alenia Aeronautica reached an agreement to establish an F-35 final assembly and checkout facility (FACO) at Cameri Air base, Italy, to deliver aircraft for Italy, Netherlands and Norway beginning in 2014. The facility opened in July, 2013 [16].

8. Current Program Status

Mission systems are developed, tested, and fielded in incremental blocks of capability.

Block 1. The program designated Block 1 for initial training capability and allocated two increments: Block 1A for Lot 2 (12 aircraft) and Block 1B for Lot 3 aircraft (17 aircraft). No combat capability is available in either Block 1 increment. All Lot 2 aircraft have been converted to Block 1B; the U.S. Services currently have 26 Block 1B aircraft (13 F-35A in the Air Force and 13 F-35B in the Marine Corps). Additionally, two F-35B Block 1B aircraft have been accepted by the United Kingdom and one F-35A Block 1B aircraft by the Netherlands; these aircraft are currently assigned to the training centre at Eglin AFB.

Block 2A. The program designated Block 2A for advanced training capability and delivered aircraft in production Lots 4 and 5 in this configuration. No combat capability is available in Block 2A. The U.S. Services have 62 aircraft in the Block 2A configuration (32 F-35A in the Air Force, 19 F-35B in the Marine Corps, and 11 F-35C in the Navy). Additionally, one F-35B and one F-35A have been accepted by the United Kingdom and the Netherlands, respectively; both aircraft are assigned to the training centre.

Tab. 3 Partnership countries and their planned orders (as of mid-2015 [5, 15, 17]

Country	Planned orders (initial / current)	Version	Confir-med orders	Already received (mid 2015)	Notes
Australia	100 72 (14+58)	A	2	2	2 F-35 at Luke AFB for training 1st F-35 for AUS in 2018
Canada	80 65 (2008)	A			Reopened fighter competition
Denmark	48 (later 30)	A			Reopened fighter competition
Israel	100	A	19 + 14		1 F-35A for trials & tests, will not enter operational service; option for 17 more
Italy	131 90 (2012)	A & B	3 + 3	1	Plans for Air Force (60 F-35A & 15 F-35), 15 F-35B for Navy
Japan	42	A	4		38 will be assembled in Japan
Nether-lands	85 37 (2013)	A	2 + 8	2	2 F-35 at Edwards AFB for OT&E 35 F-35A (deliveries to start in 2019)
Norway	52	A	22		4 F-35 will stay in USA for training (2016), rest delive-ries to start in 2017
South Korea	60 40 (2014)	A			Scheduled deliveries from 2018
Turkey	100	A	2 + 4		Orders postponed due to increased costs and developmental delays
United Kingdom	150 (2005) 138 (2007) 48 (recent)	B (A?)	8	3	4 for OT&E at Edwards (Eglin) AFB as „reserve squadron“ 14 (in 2016) as training squadron in Beaufort MCAS, later (2018) to RAF Marham

Block 2B. The program designated Block 2B for initial, limited combat capability for selected internal weapons (AIM-120C, GBU-32/31, and GBU-12). This block is not associated with the delivery of any production aircraft. Block 2B software has been in flight test since February 2013. Once complete with flight test and certification, Block 2B software may be retrofitted onto aircraft from production Lots 2 through 5, provided the necessary hardware modifications have been completed as well. Block 2B is planned to be the Marine Corps IOC configuration.

Block 3i. The program designated Block 3i for delivery of aircraft in production Lots 6 through 8, as these aircraft will be built with a set of upgraded integrated core processors (referred to as Technical Refresh 2, or TR2). The capabilities associated with Block 3i software will vary based on the production lot. Lot 6 aircraft are expected to be delivered with capabilities equivalent to Block 2A in Lot 5, aircraft in Lots 7 and 8 are planned to be delivered with capabilities equivalent to Block 2B. Block 3i software began flight testing in May 2014. The program delivered the first Block 3i aircraft, an F-35A, to Luke AFB, Arizona, in late October. Four more F-35A aircraft were delivered to Luke AFB and one F-35B to Marine Corps Air Station (MCAS) Beaufort, South Carolina, by the end of November 2014.

Block 3F. The program designated Block 3F as the full SDD capability for production Lot 9 and later. Although under development, flight testing with Block 3F software on the F-35 test aircraft has not started. The program plans to begin flight testing in early CY15. Aircraft from production Lots 2 through 5 will need to be modified, including the installation of TR2 processors, to have Block 3F capabilities [18].

9. Development Problems

As mentioned before, the program's troubled approach built on buy-before-you-fly basis brings a permanently rising spiralling costs. Following an engine fire during tests last year, the 131 F-35 jets are in the process of being refitted with new engines with pricey improvised modifications. A GAO report said their reliability remains *"very poor (less than half of what it should be)."* The jet's self-diagnosing and targeting software was also deemed inadequate earlier this year, requiring what are likely to be years of upgrades.

Despite the development lapses, delayed production and lame performance, the JSF program is just too big to cancel. Another claim is that the project has simply eaten too much money to be cancelled. Well known problems with flawed software that hinders the ability of the plane to employ weapons, to communicate information, and to detect threats; maintenance, engine and helmet problems are increasing costs and risks to the program. Rather than slow down production to focus resources on fixing these critical problems, U.S. Congress decided to speed up production – 34 in FY2015 and 57 in FY2016. However, whole present production both for U.S. and partner countries is dedicated to testing and systems evaluation.

According to official report from Defence Department's Director of Operational Test and Evaluation (DOT&E) the F-35 has reached a stage where it is now obvious that the never-ending stream of partial fixes, software patches, and ad hoc workarounds are inadequate to deliver combat-worthy, survivable, and readily employable aircraft. DOT&E report pointed out on some key issues:

- "Recent improvements in F-35 reliability figures are due to changes in the way failures are counted and processed, but do not reflect any actual improvement," writes Giovanni de Briganti when summarizing the DOT&E report. Instead, massaging the numbers helps Lockheed Martin meet its contract specifications. It does not, however, decrease the user's maintenance burden or help the plane fly more often [19].

- The F-35 has a high level of vulnerability to catastrophic fire from both combat and weather hazards. Live-fire test and evaluation confirmed that the fuel tank system that fills the wings and surrounds the engine is at significant risk of catastrophic fire and explosion in combat. This means that if an F-35 is hit by gun or missile projectiles - even fragments - in any of the multiple fuel tanks throughout the plane, there's a likelihood of catastrophic failure. The F-35 design attempts to mitigate these problems by reducing the amount of fire-sustaining oxygen in the fuel tanks' explosive vapour spaces, but the On-Board Inert Gas Generation System (OBIGGS) remains unable to eliminate enough oxygen during dives, and may require additional post-production modification, even after its recent redesign. The 270 volt electrical system in the F-35 - unprecedented in a fighter aircraft - also elevates fire risk because such high voltages increase the likelihood of strong sparks from wires damaged by maintenance mistakes or even minor combat hits. While on the ground, the F-35 Lightning's electrical and fuel tank systems are also inadequately protected against lightning strikes due to the OBIGGS's inability to maintain "residual inerting", which is to remove enough oxygen from the tanks' explosive vapour spaces to be safe for at least 12 hours after flight. Lightning tolerance qualification testing is ongoing, but the plane continues to be restricted from flying within 25 miles of thunderstorms.
- 2014 DOT&E reported that every F-35 variant struggled with uncommanded "wing drop" when manoeuvring hard at high subsonic and transonic speeds. This year's report notes that all three variants needed "modifications of the control laws to control the effects of transonic flight [wing drop] and buffet manoeuvring." However, add-on spoilers, such as those added to the F-18E/F to address a similar problem, will almost certainly decrease all-around stealth, as well as they will increase weight and drag, thereby further decreasing manoeuvrability, acceleration, and range.
- A major engine failure - caused by excessive engine flexing, induced hard rubbing, and then catastrophic failure of fan blades - started a fire that destroyed the rear fuselage and tail of an F-35A in June 2014. All F-35s have been severely restricted in speed (under .9 Mach for production aircraft and 1.6 for test planes), turning g (3.0g and 3.2-g respectively), and manoeuvre limits (less than half-stick roll rate and 18 degrees angle of attack) as a result. These restrictions have made it impossible to fully test weapons loads, buffeting during manoeuvres, manoeuvre limits, and wing drop limits for the various F-35 versions. The restrictions have also stopped testing on the ground collision avoidance system - which warns pilots when to pull up to avoid crashing. Some of these restrictions may remain in place for a considerable time because no long-term fix for the engine's excessive flexibility has been found.
- The F-35's helmet-mounted display system (HMDS) projects onto the pilot's visor threat information, flight instrument readout, and almost 360-degree video and infrared images of the world around the pilot. Supposedly this provides the pilot with "unprecedented situational awareness and tactical capability." The almost 360-degree video and infrared imagery comes from the six cameras and complex processing software of the Distributed Aperture System. DOT&E has found, however, that even after a major redesign and software upgrade the Distributed Aperture System "continues to exhibit high false-alarm rates and false

target tracks, and poor stability performance.” Testing of the redesigned helmet system “discovered deficiencies, particularly in the stability of the new display management computer for the helmet. All of these problems mean that the pilot cannot rely on the helmet display to provide adequate situational awareness in combat. This is particularly a concern for rear hemisphere threats, since the unusually wide fuselage and solid bulkhead directly behind the pilot’s head means he cannot see below or behind him if his helmet fails [18, 20].

10. Conclusion

The F-35’s cutting-edge capabilities are accompanied by significant costs. Some analysts have suggested that upgrading existing aircraft might offer sufficient capability at a lower cost, and that such an approach makes more sense in a budget-constrained environment. Others have produced or endorsed studies proposing a mix of F-35s and upgraded older platforms; yet others have called for terminating the F-35 program entirely.

To save some money, the Pentagon is now annually buying less aircraft than anticipated few years ago. However, of the money saved by buying fewer jets, several billions are being paid for continued development and testing. The F-35 program is designed so that there is no requirement to prove its combat capability before approving an annual production rate of 57 aircraft, a rate unprecedented for any fighter with so little operational testing accomplished and so many unresolved problems. But these problems are being ignored to continue funding a politically driven acquisition program. Although there are visible qualitative leaps month by month, the F-35 is still years away from being ready for initial operational capability. The program’s attempts to save money now by reducing test points and deferring crucial combat capabilities will result in costly retrofits and fixes later down the line, creating a future unaffordable bow wave.

The F-35 is a complicated aircraft, though, and may prove to have been just too ambitious. Its software includes over 30 million lines of code, which is six times more than that of the F-18E/F Super Hornet. There are plenty of bugs in the software and the aircraft’s other systems that will take years to work through. Due to the compromises necessary to get the STOVL version to fly, the gun of the F-35 STOVL version is carried externally in a pod (reducing the stealth capability). It will hold 180 rounds of 25 mm ammunition weighing about 200 pounds. So the STOVL F-35 is an expensive way of carrying 200 lb of ordnance into battle. It carries two 1.000-lb bombs instead of the 2.000 lb bombs on the Air Force version, once again due to weight limitations. The software to enable the STOVL F-35 to drop the latest Small Diameter Bomb II (short enough to fit the bomb bay) won’t be uploaded until 2022 [21].

JSF is a “living“ proof, that attempts to make an advanced single aircraft capable of stealth air-to-air combat, close air support, vertical take offs and carrier landings is just too ambitious and won’t be worth the funds needed.

Biggest challenge now lies with countries projecting to operate the F-35s as the only type of aircraft (e.g. Norway, Denmark and Netherlands). Despite the advanced equipment, weaponry and on board systems, the aircraft would not be suitable to perform all intended and required missions. Compared with its predecessors planned to replace (mostly F-16 variants), the F-35 will be inferior in many key areas (manoeuvrability - dogfight, maintenance and total numbers). Especially during first years of service we can expect plenty of groundings due to technical and operational problems. It is possible that with low number of procured aircraft (due to astronomical price) several countries will lose some of the long and hard-built capabilities. They simply will not have enough aircraft (however superior in certain areas) to ensure training, QRA missions, international exercises and (overseas) combat deployment. Another possible unwanted outcome could be that with such a small numbers of extremely expensive aircraft procured, the (NATO) countries will not be willing to risk and send their assets to warzones and conflict areas. These countries would then need to invest more millions to buy other types of aircraft to fill the capability gap left by small fleets of JSF. However, the first idea was to produce cheap and affordable light multirole fighter for the USA and their partners...

References

[1] COHEN, Z. „The F-35: Is the world's most expensive weapons program worth it?“, *CNN Politics*, 16.7.2015. Available at: http://edition.cnn.com/2015/07/16/politics/f-35-jsf-operational-costs/.

[2] *DARPA / Navy Common Affordable Lightweight Fighter (CALF) 1993-1994*. Available at: http://www.globalsecurity.org/military/systems/aircraft/calf.htm.

[3] *Joint Advanced Strike Technology (JAST).* Available at: http://www.globalsecurity.org/military/systems/aircraft/jast.htm.

[4] LORELL, M. A., KENNEDY, M., LEONARD, R. S., MUNSON, K., ABRAMZON, S., AN, D. L., GUFREY, R. A., *Do Joint Fighter Programs Save Money?* RAND Project Air Force, Santa Monica, CA, 2013. Available at: http://www.rand.org/pubs/monographs/MG1225.html.

[5] GERTLER, J., *F-35 Joint Strike Fighter (JSF) Program*, CRS Report RL30563, Washington, DC: Congressional Research Service April 29, 2014.

[6] CRS Report RL31673, *Air Force F-22 Fighter Program*.

[7] CRS Report RL30624, *Navy F/A-18E/F and EA-18G Aircraft Program*.

[8] BOLCOM, CH. and O'ROURKE, R., CRS Report RS21488, *Navy Marine Corps Tactical Air Integration Plan: Background and Issues for Congress*.

[9] *IHS Jane's Defence Insight Report "Air Platforms"* June 2013.

[10] SCOTT, J., *F-35s to Sell for as Low as $80 Million in 2019, Pentagon Say*. Bloomberg.com, March 11, 2014.

[11] SHALAL, A., *U.S. focuses on cheaper, more reliable F-35 jet: Air Force official*, Reuters.com, April 1, 2014.

[12] Office of the Secretary of Defence, *Selected Acquisition Report (SAR): F-35 Joint Strike Fighter Aircraft (F-35)*, December 31, 2013.

[13] STAROSTA, G., *Block Upgrades For Earliest F-35s To Cost $6M Per Aircraft*. InsideDefense.com, March 26, 2014.

[14] GAO, F-35 Joint Strike Fighter: *Current Outlook Is Improved, but Long-Term Affordability Is a Major Concern*. GAO-13-309. Washington, D.C.: March 11, 2013.

[15] Australia, Belgium Enter Joint Strike Fighter Program as EMD Partners, *Inside the Air Force*, April 21, 2000.

[16] BUTLER, A., Deal for Italian JSF Assembly Facility Finally Set. *Aerospace Daily*, July 20, 2010.

[17] SIEGEL, M. and SHALAL, A., *Australia orders 58 F-35 Lockheed Martin stealth fighters.* Reuters.com, April 22, 2014.

[18] *F-35 Joint Strike Fighter*, *FY 14 DoD Programs*, p. 39-72. Available at: http://www.dote.osd.mil/pub/reports/FY2014/pdf/dod/2014f35jsf.pdf.

[19] BRIGANTI, de G., F-35 *Program Massages Flight Test Results*, Defense-Aerospace.com, published Jan 19, 2015. Available at: http://www.defense-aerospace.com/article-view/release/160298/f_35-program-massages-flight-test-results.html.

[20] Not Ready for Prime Time. *DOT&E Report: The F-35 Is Not Ready for IOC and Won't Be Any Time Soon*, 12.3.2015. Available at: http://www.pogo.org/our-work/straus-military-reform-project/weapons/2015/not-ready-for-prime-time.html#cooking_the_numbers.

[21] ARCHIBALD, D., The Disappointment That Is the F-35. *American Thinker*, 21.3.2015. Available at: http://www.americanthinker.com/articles/2015/03/the_disappointment_that_is_the_f35.html.