# THE F-35 FIGHTER:
## A LOGICAL CF-18 REPLACEMENT

The NATO Association of Canada

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The F-35 Fighter: A Logical CF-18 Replacement


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# INTRODUCTION

Canadian military history in the latter half of the twentieth century has shown that no multi-billion dollar defence procurement project can be executed without political influence. Such influence is not always done in the best national interest. The classic example is the cancellation of a signed contract with Westland-Augusta by the Chretien Government in 1993. This contract, which would have delivered 47 EH-101 helicopters as ship-borne and search and rescue aircraft, was awarded after an exhaustive competitive bid process and one that secured jobs for Canadian aerospace workers. Indeed, Canadian aerospace companies and workers stood to benefit from the regional industrial benefits of the project as components of every EH-101 made would have been manufactured in Canada.

The contract was cancelled only a few days after Chretien took office costing the taxpayers almost a half a billion dollars in cancellation fees and lost jobs. It led to a subsequent contract for fifteen of the same aircraft in the Search and Rescue role five years later. All these aircraft were built overseas with no Canadian industrial benefit. A much delayed ship-borne helicopter contract was signed after another four years for aircraft that are only now coming into service fifteen years later.[1] The true total cost of the cancellation including the need to operate a dual fleet and the requirement to keep the old Sea King helicopters flying for another twenty plus years will likely never be calculated. But it is indicative of the damage that can be done when politicians interfere with the process that is supposed to be at arms length.

The Royal Canadian Air Force (RCAF) CF-18 Replacement Project has perhaps seen more political influence than any defence project in Canadian history. No doubt the cost magnitude of this project has driven partisan involvement to such a high level. However, this involvement has already significantly delayed the project and threatens its success by procuring an aircraft at great expense that may not meet Canada's defence needs in either the short-term or long-term.

Having successfully executed several previous sole-source aircraft procurements for Strategic Airlift, Tactical Airlift and Medium to Heavy Lift Helicopter, the Conservative Government announced on 16 July 2010 that it would procure up to sixty-five F-35 fighter aircraft without a competition. This procurement subsequently became an issue in the 2011 General Election. The Liberal Party of Canada stated that they would cancel any plans to buy the F-35 and would immediately enter into a competitive bid process to replace the CF-18s. Their argument was that the Conservative Government had neither explained why the aircraft was essential at that time nor secured any guarantee of industrial benefits.[2] In their platform for the same election, the Conservative Party defended the F-35 purchase noting that the previous Liberal Government had invested in the development of the aircraft and that it was the best option for Canada.[3]

Notwithstanding the Conservative win in that election, criticism against the government's decision and against the aircraft began to mount. A report from the Office of the Auditor General (OAG) was critical in terms of life-cycle cost estimates, which they felt were underestimated. It also found that there were significant weaknesses in the decision making process and the quality of briefings to senior decision makers including the Minister of National Defence (MND), and that Public Works and Government Services Canada (PWGSC) did not fully carry out its role as the government's procurement authority. It also found that although DND engaged Industry Canada early, which succeeded in securing early contract opportunities for Canadian companies, subsequent estimates for industrial benefits varied widely. It recommended that DND refine its estimates for complete life-cycle costs and supporting assumptions as soon as possible, noting that some costs would not be possible to estimate accurately given the thirty-year life span of the aircraft.[4]

In response specifically to the OAG report, on 03 April 2012, the Conservative Government stood up the National Fighter Procurement Secretariat (NFPS) to oversee the replacement of the CF-18. Operating within PWGSC, the mission of the NFPS is to ensure that the RCAF acquires the fighter aircraft it needs to complete the missions asked of it by the government. A seven-point process was established to address issues related to the replacement project. These points were: freezing the acquisition funding envelope; establishing the secretariat; the Department of National Defence (DND) will provide annual updates to Parliament and will evaluate options to sustain a fighter capability; Treasury Board Secretariat (TBS) will commission an independent review of costs and ensuring full compliance with procurement procedures; and Industry Canada will update Parliament on F-35 industrial participation benefits.[5] This process also included the appointment of an Independent Review Panel (IRP) who reported on the work of the NFPS in regards to rigor, impartiality, comprehensiveness and understandability.[6] The IRP was completely satisfied with the work of the NFPS as reported in February 2014. This work validated the costings and analyzed options including the possibility a mixed fleet all within a fixed budget. This work, which was independent of political influence, led the Conservative Party to continue to support the acquisition of the F-35 although it was not specifically mentioned in their 2015 election platform.

The primary criticism of the F-35 by the Liberal Party is whether or not we need a stealth capability. Their election platform described the F-35 as a 'First Strike' capability, one that is not needed for the defence of North America, which they see as the primary mission of our fighter capability.[7] However, the Cold War term 'First Strike' refers to a country's pre-emptive use of nuclear weapons to destroy another country's nuclear capability. Canada of course is not a nuclear power and has no aspirations as such. First Strike capabilities refer to submarine launched nuclear missiles and strategic bombers, not fighter aircraft.[8] The Liberal Party's use of this term to voice their opposition to the F-35 indicates both a lack of understanding of military terminology and the need for stealth in the future combat zone. Indeed, its use is somewhat inflammatory as it suggests to those unfamiliar with military terminology that Canada would someday become an aggressor nation. Part of the Liberal Party's criticism in the 2011 election was that the Conservative Government had not properly explained why Canada should buy the F-35. One could easily counter that in the 2015 election, the Liberal Party has not provided any legitimate reason why it should not be bought.

This paper will review the potential threat environment within which a future fighter will have to operate and how to deal with that threat. Specifically, it will define stealth capability and its importance to aircraft and pilot survivability in future combat. It will review the developmental history of the F-35 and Canada's involvement. Additional capabilities of the F-35 that will benefit the RCAF will be described as will the technical criticisms of the aircraft. This will lead to a comparison of the various fighter aircraft that are available to meet the threat over the next thirty years. A review of the financial criticism of the F-35 by both the Parliamentary Budget Officer (PBO) and the Auditor General will be reviewed. Finally, the current and potential industrial benefits of the F-35 to Canada will be discussed and the impact to the Canadian Aerospace industry of procuring an aircraft other than the F-35. This analysis will determine that the F-35 remains the best option for the CF-18 Replacement Project both qualitatively and quantitatively, has the best potential for industrial benefits and as such should be allowed to compete in the project.

## THREAT

Canada has deployed its fighter planes on four combat missions as part of United Nations sanctioned international coalitions. These were the Gulf War in 1991, Serbia in 1999, Libya in 2011 and Iraq and Syria in 2014-16. In each case the government of the day assessed both the specific threat and the national interest in making such a commitment. However, much longer term planning and analysis is necessary to determine the force structure and capabilities envisaged in the long-term. Thus, governments develop high level strategies, which identify future security environments. The Canadian Armed Forces (CAF) then conduct Capability Base Planning to be compliant with policy. It is important to get these processes right, as procurement of military equipment can take decades and involves billions of dollars.

In 2013 the Chief of Force Development (CFD) issued a document entitled "The Future Security Environment 2013-2140.[9] This document provided a detailed evaluation of the international situation in terms of geopolitical, socio-economic, environmental, technological and military trends. Canada's allies produce similar documents, which indicate significant consensus on these trends and their impact on security.[10] Globalization, migration, urbanization, climate, information and new miniature technologies usable for both military and civilian are overarching trends. More specifically the proliferation of advanced technologies, conventional and nuclear weapons as well as nuclear materials used in so-called dirty weapons are of increasing concern. Furthermore, State, non-state actors and non-state actors seeking to become state actors employing such technologies both in combined conventional and irregular conflict, referred to as hybrid warfare, will make the future security environment increasingly complex.[11] Thus, it would be naïve to think that the CAF will not be sent into harm's way again in the future, regardless of how a current government may think in the short-term.

In his report to the NFPS, the Chief of Defence Intelligence (CDI) suggests that over the next thirty years, the threat to Canada will increase as technological improvements made by potential adversaries also increase. Future hostile aircraft will have greater range, higher speed and will be able to carry larger payloads. High speed air and sea launched missiles, and hostile aircraft carriers operated by emerging nations will also pose a threat. Man Portable Air Defence Weapons Systems (MANPADS) will become more prevalent and will also pose a threat. Regional conflicts will likely be the norm, but these will have the potential to escalate particularly with states that wish to gain regional dominance. Non-state actors who pose a direct threat to Canada could gain access to sophisticated weapons as availability through proliferation expands.[12]

Specific tactical and operational level threats remain based upon a Western and non-Western divide. The Cold War may well be over but the vast majority of weapon systems that Western forces will face have their origin primarily in Russia and China. Aircraft, missiles and ships will become less detectable through the use of low-observable technologies, which will reduce the range at which a target can be detected by radar. Aircraft without low-observable technologies will be easier to detect both by radar and advanced electro-optical sensors, and as such will be less survivable.

Fighter aircraft will be characterized as 'Progressive' or 'New Designs'. Progressive designs are based on existing airframes with advanced radar, high-capacity data-links with advanced avionics and the ability to deploy current and future weapon systems. New designs will operate in a network centric environment with low-observable technologies, infra-red search and track sensors for both air-to-air and air-to ground weapons, advanced avionics and multi-sensor data fusion for vastly improved situational awareness while easing the pilot's workload. Other technologies common to new-design fighters include integrated electronic warfare system technology, integrated communications, navigation, advanced identification technology, thrust-vectoring and super cruise capabilities.[13]

While CDI has classified future fighters as either Progressive or New Designs, it has been commonplace to describe them in terms of their generation. Generation 4 fighters incorporate Pulse-Doppler radars, high maneuverability and look-down shoot-down missiles. The CF-18 is considered a Generation 4 fighter. Generation 4+ fighters feature high maneuverability (no more than generation 4 aircraft), sensor correlation and reduced signatures. The Eurofighter, Rafale and F/A-18E/F are examples of this generation. Generation 4++ fighters have Active Electronically Scanned Array (AESA) radars, reduced signatures using waveform cancelling and some supercruise. The Russian SU-35 is an example of a Generation 4++ aircraft. Generation 5 fighters include all aspects of Very Low Observable (VLO) stealth including internal weapons, extreme agility, full sensor fusion, integrated avionics, and operate at Mach 1.6 with an operational internal load of air-to-ground and air-to-air weapons. Both the F-22 and F-35 are considered Generation 5 aircraft.[14]

Data integration will also be a characteristic of future SAM systems as a result of digital upgrades and provide their command and control nets a much more accurate common operating picture. Similar improvements to MANPAD systems, Anti-Aircraft Artillery (AAA), Air to air Missiles (AAM), Ground Controlled Intercept and Airborne Early Warning will require future aircraft to be designed with low-observable technology in order to increase aircraft and pilot survivability and mission success.[15]

## REQUIREMENT

Many pundits have postulated that the era of the manned fighter was over and that the same job could be done with Unmanned Aerial Vehicles (UAVs) or drones. UAV technology has advanced in the recent past allowing them to operate either controlled from a ground station or to operate autonomously for specific tasks. However, the technology required to allow a drone to carry out all of the tasks of a manned fighter aircraft is still not available or affordable. Although much research and development is currently underway, a viable unmanned fighter replacement is still not on the horizon.[16] Even if they were available, the legal aspects of deploying an autonomous weapon system without a human in the firing decision loop could be deemed illegal. Much in the same way anti-personnel mines were banned in the 1990s due to their indiscriminate effects, an autonomous drone may also be deemed indiscriminate.

The predominant role for a CF-18 replacement will be domestic Defensive Counter Air (DCA) both to protect Canadian sovereignty and to meet Canada's treaty obligations under the North American Aerospace Defence treaty (NORAD). This is an air interdiction task in scenarios referred to as Sovereignty Pressured, Sovereignty Challenged and Sovereignty Attacked. The first is the most likely scenario where fighters are used to enforce sovereignty. The second scenario would require additional capability to be developed as a hedge against the potential emergence of a new sophisticated threat. The positioning of advanced fighters and next generation air-to-air weapons in the Arctic by the Russians is well understood and is a clear and present evolving threat. This last scenario would require a complete reassessment in Canadian and American defence planning. Nevertheless, the Sovereignty Pressured scenario is fundamental to Canada's non-discretionary sovereignty mission and no combination of other force elements can match that of a fighter interceptor. Furthermore, a less capable aircraft would impose significant risk on the mission.[17]

While the domestic mission remains non-discretionary, expeditionary operations are at the discretion of the government of the day. It must be assumed that whatever aircraft is acquired will be deployed on coalition operations in the future. When deployed with aerial tankers, they can deploy faster than any other asset, but will be at risk from the air to air and surface-to-air threats previously described. Such a deployment would be as part of a Coalition Contribution, a First Strike Contribution or a Peer State on State Warfighting Contribution. The first scenario is the most likely in which intervention in a failed or failing state occurs. The second represents offensive operations in the earliest stages of a coalition intervention, commonly referred to as surge operations. The last scenario represents a protracted conventional war against a state adversary with sophisticated, integrated, networked and replaceable air defence systems.[18]

In developing an options analysis for a complex project such as a new fighter aircraft, the project team must consider both qualitative and quantitative criteria. Quantitative criteria refer to the financial cost both for the acquisition of the aircraft, commonly referred to as the flyaway cost and the recurring costs for operations and maintenance. For the new fighter aircraft, a system of criteria called Measures of Capabilities (MoCs) has been established. Determining an effective and efficient balance of these MoCs in an aircraft involves a blend of both scientific modelling and judgment based upon professional experience. These MoCs are laid out as follows:

1. **Lethality**, which is the ability to detect, target, engage and destroy threats using precision and low yield weapons with minimal collateral damage;
2. **Survivability**, which is the ability to sustain operations in the operational area with regards to the ability to withstand opponent capability and environmental threats;
3. **Reach**, which is the ability to operate autonomously at a distance;
4. **Persistence**, which is the ability to remain airborne. Included in this MoC is the ability to be refueled while airborne;
5. **Responsiveness**, which is the ability to be effective when and where required and to change tasks and re-orient in mid-operation;
6. **Interoperability**, which is the ability to operate and share information with other CAF elements and headquarters, other governmental departments and allied forces. The last point is primarily with the United States in a NORAD context, but is also required in coalition operations; and
7. **Awareness**, which is the ability to gather, fuse and display information.[19]

It is important to note that when comparing options using the above MoCs, an option may well be marginally better than a CF-18 and much less expensive than other options. However, the final choice will likely not be operational for five years after a decision is made and will have to be in service for thirty to forty years. During this time Canada's aircraft will have to remain interoperable with our closest allies, ten of which have chosen the F-35. They will all receive the same updated software to maintain interoperability and will each pay their fair share of the associated costs. Canada's share will be for sixty-five aircraft out of upwards of four thousand if we accept the F-35. The selection of another aircraft will mean Canada's share of costs to remain interoperable will be much higher, as much as 100% depending on the aircraft. Thus, the final choice should also be selected based on longevity of effectiveness to avoid becoming prematurely obsolete.

## STEALTH

Since the end of the Nineteenth Century, military forces have taken steps to conceal themselves on the battlefield through camouflage and use of terrain. Air Forces have done the same with their aircraft with the intention of avoiding detection by enemy forces. The use of paints in disruptive patterns and low visibility have increased concealment in the visual range since the Second World War. However, the appearance of increasingly sensitive radars has decreased the ability of aircraft to avoid detection. The use of the term 'Stealth' became famous with the deployment of both the F-117 Nighthawk Fighter Bomber in 1983 and the B-2 Spirit Bomber in 1989. Both were shrouded in secrecy and as a result 'Stealth' became a somewhat exaggerated phrase, with many believing that the aircraft would be rendered virtually invisible. Thus, the NFPS has suggested that the term low-observable technology is a better phrase as it more accurately describes the effect. Regardless of how it is named, this technology, which has been under development for decades, provides an aircraft purposely built to avoid detection by radar. The same technologies are being used in the design of surface warships.

An aircraft's ability to avoid detection by radar is referred to in terms of its Radar Cross Section (RCS). RCS is defined as "the effective area intercepting an amount of incident power which, when scattered isotropically, produces a level of reflected power at the radar equal to that from the target." Determining the RCS of an object is a complex process and difficult to explain in layman's terms. The RCS of an object is given in square meters. However, it is not the same as the cross sectional area of the target. Rather it is the projected area of a metal sphere that, if substituted for the target, would scatter the same power back to the radar. It should also be noted that the orientation of the object or aircraft will also determine the RCS, which is not the same for all areas of the object. Thus, an aircraft might have a small RCS head on, but a larger RCS to the flanks, top or bottom of the aircraft.[20]

Older aircraft tend to have larger RCS. However, the concept was understood in the Second World War by the Horton brothers who designed a flying wing fighter plane for the Luftwaffe. Recent tests on a dimensional copy of the original showed that the aircraft would have been difficult to detect by early radar and if it had been built earlier could have had an impact on the outcomes of some air battles.[21] Low RCS is achieved through both use of wavelength absorbing materials and the geometry of the aircraft. (It is not possible to retrofit stealth into an older design because their geometry is fixed). The impact of such designs is to reduce the detection range from missile defences, resulting in reduced time to intercept the target. Targets with less than 0.1 square meter are difficult for Surface-to-Air Missile (SAM) fire-control radars to track. Thus, even if the SAM battery detects the target, it may not acquire sufficient lock on the target to complete the intercept. Furthermore, an aircraft with a low RCS will have a much greater chance of survival as will the pilot flying it. For the purposes of comparison using modern aircraft types, a B-52 bomber has an RCS of 100 square meters and a CF-18 has an RCS of one square meter. The F-22 Raptor has an RCS of about 0.0001 square meter and an F-35 has an RCS of about 0.005 square meter.[22]

## SENSOR FUSION

Survivability is also a matter of being able to make tactical decisions quickly and to engage the enemy first in a combat environment. In order to do this a pilot must have excellent situational awareness, which is the ability to identify, process and comprehend the critical elements of information about what is happening to the team with regards to the mission.[23] As sensors become more capable and numerous, more information is available to pilots and commanders to be able to more quickly assess how to engage. The risk with so many sensors and so much information is information overload, a situation where commanders, staff and pilots lose situational awareness and cede the advantage to the enemy.

Sensor fusion is the ability to analyze data from an aircraft's on-board sensors as well as off-board sensors from other fighter aircraft, drones and Airborne Warning and Control Systems (AWACS) aircraft to give a pilot a "God's-eye view of the battlespace". Sensor fusion will give a pilot a superior situational awareness over those piloting aircraft which lack this capability.[24] It will also share data with other platforms in order to provide for a Common Operating Picture (COP), in which every aircraft on the network will have the same understanding of the battle-space. This means that in order for an enemy to degrade the situational awareness provided by an integrated COP, they will not just have to degrade the sensors on one aircraft but multiple sensors on multiple aircraft.[25]

When stealth and sensor fusion are combined it will give an aircraft so designed an edge over older legacy fighters, particularly in beyond visual range engagements. Because they will be able to engage enemy aircraft at long-range without being detected, aircraft like the F-35 will be both more survivable and more lethal than older designs. Both Russia and China are developing aircraft with these capabilities, which will be fielded in the coming decade. Thus, older western designs which do not have these capabilities or which have only a limited capability of one or the other risk becoming outclassed early in their operational career.

## F-35 DEVELOPMENTAL HISTORY

The F-35 is a product of the Joint Strike Fighter (JSF) Program under the US Department of Defence (DoD). The JSF is itself an amalgamation of several other projects that were combined in 1994 in order to provide a single fighter plane to replace several others, such as the Navy F/A-18, the Marine AV8 Harrier and the Air Force F-16. The Joint Advanced Strike Technology (JAST) office was established in 1994 and began life as a technology development program. By 1996 a Statement of Requirement had been developed and a Request for Proposals (RFP) was tabled in March of that year. The RFP would select two contenders to proceed to the Concept Demonstration Phase where they would build test aircraft to demonstrate the capabilities of their designs. The two winning contractors were Boeing and Lockheed Martin. They would enter into a competition that would ultimately result in the selection of the winning design, the Boeing X-32 or the Lockheed Martin X-35. There were to be three versions of the aircraft. The A version was to be a Conventional Take Off and Landing (CTOL) version, primarily for the USAF. The B version was to be a Short Take Off and Vertical Landing (STOVL) version for the USMC. Finally, the C version was to be a Carrier Variant (CV) for the USN and USMC. All would share common or cousin components to provide economies of scale in production and 100% common avionics and sensors. [26]

The next phase in the program was the Concept Demonstration Phase (CDP). During this phase, potential export countries were invited to participate in the program. These partners would contribute funding to the development and depending on how large the contribution would have influence on the development. Furthermore, additional partners could result in more foreign sales, which would lower the unit cost of the final product. There were four levels of participation. Level 1 was a full collaborative partner of which the United Kingdom is the only partner. This is the only level that can influence the requirements. Level 2 is an Associate Partner of which Denmark, the Netherlands and Norway have committed. Canada and Italy began at

Level 3, which is an Informed Customer. Level 4 is a Major participant and includes Singapore, Turkey and Israel.[27]

The CDP was an intense four-year process during which both companies built and flew several prototypes and competed in a final fly-off competition. The Canadian government was offered the opportunity to directly participate in the evaluation of the Boeing and Lockheed Martin prototypes but declined. However, personnel from DND were assigned to the JSF Program Office and had full access to the competition results. This competition was a winner-take-all process, which ended in October 2001 when the JSF Program announced that Lockheed Martin's X-35 was the winner of the competition.[28] The CDP was then followed by the System Development and Demonstration (SDD) Phase, which involves the development of the X-35 into the F-35 production aircraft and includes further development of the winning design, testing of the complete weapon system and further development and refining of the manufacturing processes.

## INDUSTRIAL BENEFITS

In 1997 The Chretien Liberal Government joined the JSF as an informed partner with an initial investment of USD$10M and a promise to invest up to USD$150M. Notwithstanding the financial commitment to the development of the aircraft, it was made clear initially that this was not a commitment to buy the aircraft. However, they understood the value to the Canadian Aerospace Industry in becoming a partner in this project both in providing needed work and access to technology since only companies from partner countries would be able to bid on contracts. With a potential program value of over US$300B the potential benefit to Canadian industry was significant. Indeed, the primary role of the project Office was to sell Canadian Industry to the Prime Contractor. Both the Martin and Harper Governments continued the investment into the program with an additional investment of US$551M for the Production, sustainment and Follow-on Development Phase of the program. This funded Canada's fair share of the stand-up of the production facilities required to build Canada's aircraft, develop a global sustainment system for the fleet and prepare for follow-on development of future updates to the aircraft.

The relatively small investment in comparison to other partners resulted in a much larger return for Canada. By 2012 this investment resulted in 72 Canadian companies being awarded contracts valued at US$438M for work on aircraft delivered as of that date. So long as Canadian companies provide best value and remain competitive, the value just for these contracts could total more than US$7B. Additional opportunities for work in sustainment has the potential of dramatically increasing this amount, as maintaining aircraft is costlier over the forty-years of operation than the acquisition cost of the aircraft. An immediate technological advantage has also been realized by Canadian companies who were able to use their experience on the F-35 program to win similar contracts on work for other aircraft such as the Bombardier C-Series. This information was readily available in 2011 and yet the Liberal Party claimed in their election platform that there was no guarantee of industrial benefits. However, withdrawing from the program or not procuring the F-35will mean that Canadian companies will no longer be able to compete on contracts for the F-35 or benefit from technology sharing.

## CAPABILITY OF THE F-35

The F-35A CTOL variant is the version that the RCAF prefers to replace the CF-18. It is a multi-role 5th generation fighter with both very low-observable technology and sensor fusion. Its Electro-Optical Distributed Aperture System (DAS) provides pilots with situational awareness in a sphere around the aircraft for enhanced missile warning, aircraft warning, and day/night pilot vision. The F-35 is also equipped with an internally mounted Electro-Optical Targeting System (EOTS), which provides extended range detection and precision targeting against ground targets, plus long-range detection of air-to-air threats. Tactical data links provide the secure sharing of data among F-35 flight members as well as other airborne, surface and ground-based platforms required to perform assigned missions. These are the most important characteristics of the aircraft that will provide for much higher survivability and mission success in a threat environment. [29]

The F-35A is equipped with a prognostic health monitoring system that performs constant monitoring of aircraft systems to ensure operational readiness and to identify maintenance issues early. The fleet of F-35s is supported by an Autonomic Logistics Information System (ALIS), which will integrate current performance, operational parameters, current configuration, scheduled upgrades and maintenance, component history, predictive diagnostics and health management, operations scheduling, training, mission planning and service support for the global F-35 fleet. This capability combined with a high production rate which will lower spares costs and will reduce the overall cost of maintenance support.[30]

The F-35A has a maximum speed of Mach 1.6, with an operational load of air-to-ground and air-to-air weapons. This may seem less than that of some Generation 4+ aircraft, who claim higher top speeds, but without external stores and weapons. They are subsonic with an operational configuration of weapons and fuel. The F-35A has a range of 1,350 nautical miles and is capable of air-to-air refueling. It has a maximum payload of 18,000 pounds with weapons mounted both internally and externally. It also has an internally mounted 25mm cannon.[31]

The actual contents of the RCAF CF-18 replacement SOR are classified as are some aspects of the F-35. However, the RCAF determined that the F-35A was the best aircraft in both 2011 and in 2014. The last assessment was conducted under the auspices of the NFPS and was given a thumbs up by the IRP who reported on their work in regards to rigor, impartiality, comprehensiveness and understandability. Thus, qualified people within the RCAF have made a careful assessment, which has passed a careful review by equally qualified people. In addition to the United States Armed Forces, the United Kingdom, Australia, Italy, The Netherlands, Norway, South Korea, Israel, Turkey and Japan are procuring the F-35 as their next generation fighter.

## CRITICISM OF THE F-35

This aircraft is "too expensive, too slow, too clumsy and too complicated."[32] Shipments of the aircraft have been halted because of engine problems.[33] A fix is required to correct a design flaw that caused cracks in the plane's tail.[34] Such criticism and challenges with a new design are common as we have seen with the F-35. However, the preceding comments are criticisms and challenges related to the CF-18 when it was first introduced. Of course all these issues have indeed been resolved and the CF-18 has served Canada well. The F-35 is in its final stages of development, which will conclude in 2017, even though it is in initial production. There has been significant criticism of the aircraft because of production delays and software development, which further suggest that it may not be combat capable. However, as with the F/A-18, the aircraft upon which the CF-18 is based, there is no reason to believe the same will not be true of the F-35. The mainstream media in Canada has taken every opportunity to criticize this aircraft as well. Their sources tend to be political parties, politically motivated individuals and competitors of the F-35. What is lacking in their analysis is some true investigative reporting to prove or disprove the claims of such critics.

The F-35's software is one area of criticism, particularly because early production aircraft have been delivered without the software being fully developed.[35] However, this was planned from the outset. The aircraft is the first modern fighter to fly without a heads up display (HUD), which has been replaced by a Helmet Mounted Display (HMD), a revolutionary design that provides the pilot with primary flight references. This new capability as well as the flight characteristics, sensor and weapon integration require well over eight million lines of code. Thus, it was planned to break the development of software into blocks to allow production to proceed in parallel to software development. Block 0.1 software was the basic amount to allow the aircraft to fly. Block 1.0 had baseline air-to-air and air-to-ground capability, which would allow for the training of pilots and maintenance.[36]

Block 2 software provided an initial combat capability, which the USMC were able to declare Initial Operational Capability (IOC). Block 3 delivers the full operational capability envisaged when the development of the F-35 began. The USAF will declare IOC in late 2016 with Block 3 software which includes Suppression of Enemy Air Defence (SEAD) capabilities. Subsequent blocks of software allow for the integration of non-US weapons and other weapon systems as they are developed, which gives the aircraft significant growth potential.[37] These developmental blocks of software were planned in the early stages of the aircraft program to allow a strategic development of 8.6 million lines of code. Thus criticism of the software indicates a lack of knowledge of the planned development of the aircraft or how any major project approaches complex program management.

The question of the F-35's single engine has raised the ire of critics as well. The Centre for Policy Alternatives released a report in 2014 entitled "One Dead Pilot" that compares the F-35 to an older single engine aircraft, the CF-104. Its author, Michael Byers, a political science professor at UBC and a vocal opponent of the F-35, suggests that not much has changed between the F-35 and the CF-104. He notes that 110 CF-104s crashed with 39 pilots losing their lives and suggests that the F-35 would have a similar loss rate. This comparison is a bit like comparing apples to oranges. The F-104 was designed in the 1950's and the F-35 fifty years later. Byers describes the CF-104 as a tactical strike fighter which would fly fast at low-altitudes, exacerbating risk of incidents. [38] However, although Canada used the CF-104 as a low-level strike reconnaissance aircraft, it was at odds to what it was really designed for, as a high altitude interceptor. To quote an experienced CF-104 and CF-18 pilot "we were always low level, always high speed, always in shitty weather and in rolling terrain, with very limited aircraft systems - all ingredients that led to a higher accident rate. While not ideal, the aircraft did a very creditable job in all roles, and its speed profile at low level was a distinct asset."[39] Of the 110 aircraft losses, only 14 were related to engine losses.[40] A common cause of engine failure is bird strikes. However, the blades and components of an F135 engine are much more robust than the CF-104 engine so drawing a comparison between the two is not realistic.

Byers goes on to compare the incident rates of several legacy aircraft over time and admits that engine reliability has indeed increased. He cherry picks data without providing more than a cursory analysis. For example, he does not provide a breakdown of mission employment, conditions, whether in combat or not and so on. Furthermore, he does not provide any data for the F-35 or for later versions of the F-16 or the SAAB Gripen. He also uses incidents involving engine shut downs on civilian airliners as a comparison. Again, this is also a bit of comparing apples to oranges. Legacy airliner designs such as the Boeing 707 and Douglas DC-8 had four engines. Modern airliners such as the Boeing 777 and Airbus A330 have two engines. Much larger aircraft like the Boeing 747 and Airbus A380 have four engines because the aircraft are so large there are no engines that could provide the power needed if only two were used. Similarly, fighter aircraft designs that require two engines are for power requirements only as no fighter has ever been designed with two engines for redundancy. Redundancy is indeed built into the F135 engine including improved electronic engine controls which monitor critical operating conditions through sensors designed into the engine.

Recently, the Commander of the RCAF, LGen Michael Hood, made his opinion about single engine versus twin engine fighters quite clear. When questioned by the Standing Committee on National Defence he stated that when the CF-18 was selected as a replacement for earlier aircraft, two engines were not a mandatory requirement of the replacement. Notwithstanding Byers' claims, LGen Hood further stated that the U.S. military has not lost a single-engine fighter to an engine failure since 1991. Furthermore, he also stated that there are some advantages to having a single engine, one of which is maintenance costs, which are lower for a single engine fighter.[41]

One of Byers" arguments in favor of twin engine aircraft is that the USN only flies twin engine aircraft. However, the USN will be flying the F35C Carrier variant, and the USMC will fly the F-35B STOVL variant. Furthermore, the USAF will be replacing its F-15 Eagle twin engine aircraft with the F-35A in Alaska, that has the same challenges as Canada in the arctic. Norway will also be flying the F-35A in the same conditions.[42] Norway has also chosen the F-35A, which includes the provision of a drag chute for challenging landings on icy runways. Their analyses have shown the single engine in the F-35 will deliver equivalent or better reliability than current twin engine fighters.

Recent criticism of the ability of the F-35 to dogfight was published by David Axe, a military blogger, and was picked up by major Canadian media agencies. Axe writes "A test pilot has some very, very bad news about the F-35 Joint Strike Fighter. The pricey new stealth jet can't turn or climb fast enough to hit an enemy plane during a dogfight or to dodge the enemy's own gunfire".[43] This follows a test between an F-35 and an F-16 in January 2015. The F-16 was victorious, a report was leaked and Axe had his story. Sometime thereafter several articles were published shedding new light on the test, none of which were reported in the mainstream media. An article by Gareth Jennings a journalist with IHS Jane's provides some of the details missing from Axe's article. The F-35 in question was an early production aircraft, which lacked the mission systems software to use the sensors that allow the F-35 to see its enemy long before it knows the F-35 is in the area. It did not have the special stealth coating that operational F-35s have that make them undetectable to radar. And it was not equipped with the weapons or software that allow the F-35 pilot to aim a weapon with the helmet, and fire at an enemy without having to point the airplane at its target. Indeed the aircraft in question was designed for flight sciences (aircraft handling) testing and not weapons employment.[44]

The F-35 was designed to engage a target before visual range without the need to enter a dogfight, and the ad hoc test in question was not a fair determination of its ability in this regard.

A test has not yet been conducted with a fully functioning F-35 with all its advanced systems. Jennings does suggest it would have been able to defeat the adversary on its own medium to long range terms. The aircraft's sensors and missile technology does render the classic dogfight less likely. However, Jennings questions the ability of the F-35 at visual range and a perceived lack of close-in aerial combat capability. Jennings concludes that this concern will persist until the F-35 is able to prove otherwise, regardless of whether the aircraft was designed to dogfight or not.[45]

Both Axe and Jennings are of course journalists, and it would be better to get a view from pilots experienced in both legacy fighters and the F-35. A Norwegian F-35 pilot, Maj. Morten Hanche provides just such a point of view. He has 2200 hours flying the F-16 and is a US Navy Test Pilot School graduate and exchange instructor with the USAF. He provides a detailed rebuttal of Axe's article and concludes "this is an airplane that allows me to be more forward and aggressive than I could ever be in an F-16,"…"So how does the F-35 behave in a dogfight? ... To sum it up, my experience so far is that the F-35 makes it easier for me to maintain the offensive role, and it provides me more opportunities to effectively employ weapons at my opponent."[46] Hanche provides significant technical details to justify his position, which clearly refutes Axe's article. However, there is no coverage of it at all in the Canadian mainstream media.

The speed of the aircraft is also an area of criticism. Kyle Meema, a law professor at the Southern Alberta Institute of Technology is a vocal opponent of the F-35 and a proponent of the SAAB Gripen. Meema compares the top speed of the F-35 at Mach 1.6 with the Eurofighter Typhoon at Mach 2, the F/A-18E at Mach 1.8, the Rafale at Mach 1.8 and the Gripen at Mach 2.[47] However, these speeds are for clean aircraft flying at altitude and missing from his analysis is the issue of where the weapons are stored and their effect on speed. The maximum speed of an aircraft will depend upon the fuel load, weapons load, internal and external and the altitude. The F-35 has internal weapons stowage and can maintain Mach 1.6 fully laden, whereas the other aircraft have external stowage, which increases drag and limits the top speed. For example, the Eurofighter Typhoon can supercruise with a typical air to air weapons load at Mach 1.2[48] Figures for the other aircraft are not readily available but it can be assumed that any fighter with full external weapons and fuel tanks will not achieve supersonic flight, much less its maximum speed.

Perhaps the most contentious issue of the F-35 is the cost and how they have been presented. The OAG report released in 2012 was critical of both DND and Public Works PWGSC as described in the introduction. With regards to cost the OAG had suggested that DND established the budgets for the F-35 acquisition (CAN$9 billion) and sustainment (CAN$16 billion) in 2008 without the aid of complete cost and other information. Nevertheless, the report agreed that some of that necessary information would not be available until years from now.[49]

The issue with the OAG's point of view is that things like salaries, fuel, training weapons and infrastructure are already included in the defence budget. Thus, DND's calculations on the recurring costs did not include such items. When the OAG required them to be included, the costs became accounted for twice. As there is a one for one planned replacement of the CF-18 by a new aircraft, there are no new personnel or sustainment requirements. There were no new pilots or support personnel positions being created, fuel and infrastructure would be required regardless of what aircraft was procured and the same airfields and related infrastructure would be used. Furthermore, instead of budgeting for a period of twenty years the OAG changed the criteria and asked for projected costs over 42 years. The twenty-year estimate was done in accordance with the accepted planning process of the day. The OAG changed the rules. Hence, the projected costs jumped from $25B to $42B, not surprising since the time period assessed had more than doubled.[50]

The OAG did not audit the merits of the F-35 aircraft. Nevertheless, the mainstream media presented the total costs as being associated only with this aircraft. Furthermore, reporting tended to ignore the twenty versus forty-two-year difference in cost estimates, stating simply the total project costs. Not to be outdone, Michael Byers has suggested an astronomical figure of $126B over the life span of the aircraft. Professor Byers would seem to know more than the OAG, RCAF and the IRB who have all agreed to the $42B cost over forty-two years. His report is presented by the Rideau Institute and The Canadian Centre for Policy Alternatives, two left-leaning politically partisan organizations.[51] It is also interesting to note that David Pugliese, a journalist with the Ottawa Citizen has accepted their numbers unequivocally, which also suggests some biased political motivation.[52] This report was also mentioned by most other mainstream media outlets, without any appropriate analysis.

One of the key issues in Byers' report is that the US government has stated that the F-35 operating costs will be 10% higher than the legacy aircraft it is replacing, and that the DND costings are based on the operating costs of the CF-18. Byers refers to the 2013 report in his paper which is missing key information and is not as mature as the final report tabled in 2014[53] The NFPS 2014 report clearly states that sustainment costs and fuel consumption rates are provided by the F-35 program office. All other operating costs such as personnel infrastructure, ammunition usage, training regimes and base support costs are specific to the RCAF and would be estimated by the RCAF based on experience with a legacy aircraft.[54] Thus, it's not a black and white comparison as Byers has suggested.

Other issues Byers raises such as cost of future ammunition purchases, drag parachutes, modifications to air to air refueling requirements, have not been overlooked. Indeed, these issues as well as the fluctuation exchange rates have also been addressed by the NFPS and apply to whatever aircraft we buy to varying degrees. The drag parachute has already been adopted in production aircraft for the Norwegian Air Force so a cost for that capability is already available and incorporated into the 2014 cost estimates. The F-35A uses a boom refueling system, but the RCAF currently uses a Drogue and Probe system. Byers has allocated more than $600M in his budget for these two items.

Byers assumes the refueling aircraft will need to be modified to support the F-35 at a cost of about $400M. He suggests that other options including relying on the USAF or leasing tanking capability "can hardly be taken seriously." However, Byers does not mention that the current RCAF aerial tankers are not presently used in the Arctic on NORAD missions because their avionics are not suitable. Although RCAF CC-130 tankers have the required avionics and do operate in the arctic, the RCAF is also refueled by USAF aerial tankers in this mission. Furthermore, the RCAF tankers will need to be replaced by 2025 (about the time a new fighter would be fully operational) because they will be at the end of their service life. A replacement aircraft could be procured with the boom system at that time, which will give the RCAF the added flexibility of refueling their C-17s which also require a boom system.[55] Thus it would not be practical to spend any funds upgrading the present fleet, rather it would make more sense to procure replacement tankers compatible with the F-35, which would enter into service about the time the F-35 fleet become operational.

Moving now to the report of the Parliamentary Budget Officer, which was produced in 2011 and which also contributed to the need to establish the NFPS. The primary concern with this report is how costs were calculated. In fairness, there was a lack of cooperation and communications between PBO and DND which led to varying differences in numbers. In order to calculate the cost of ownership, the PBO used a theoretical estimation based on historical trends in cost per pound of previous fighter aircraft extrapolated to the projected date of delivery. This methodology produced a cost estimate of procurement and sustainment over a thirty-year period of US$29.3B, US$9.7B of which is capital. The report does state that the costs are based on historical evidence and that the F-35 costs may well be different. However, based on the modelling used by the PBO, a unit cost of US$148.5M is suggested.[56]

Since the PBOs report the cost per aircraft has begun to decline as forecasted by the JSF Program Office. Most recently the cost per aircraft has dropped to US$100M and is expected to drop to about $80M by 2019.[57] That number is well within the current capital cost estimate of the government of $9.533B, which includes development and acquisition. Sustainment and operating costs over 42 years are $35B or $833M/year.[58] Over twenty years that amounts to 16.7B, which is very close to the government's estimate of $16B. Thus, when all is said and done, the numbers presented by the government in 2010 are not that different from what was presented in 2014 and agreed to by the IRP. The only difference is that the OAG demanded a forty-two year cost estimate instead of a twenty-year estimate. The report by Michael Byers and other non-experts can be easily dismissed as political posturing.

## COMPARISON OF OTHER OPTIONS

When considering options for the replacement of the CF-18, there are limitations to sources of aircraft. Russian and Chinese aircraft are really not options as these countries are or could be partners with potential adversaries. Aircraft that are out of production or limited only to the manufacturing nation's own air force are not options. The Lockheed Martin F-22 Raptor falls into this category. This leaves only four other competitors to the F-35. These are the Boeing F/A-18E Super Hornet, the Dassault Rafale C, the Eurofighter Typhoon, and the SAAB Gripen E.

All four manufacturers, as well as Lockheed Martin with the F-35, were invited to take part in a detailed market analysis conducted by the NFPS. The aim was to assess rough and non-binding market price and availability. Four of the five manufacturers agreed to participate in the market analysis. The fifth, SAAB declined the invitation and the Gripen was not assessed in the analysis. A classified report with detailed results of the evaluation has been provided to the government to inform a decision on the path forward to replace Canada's CF-18 fighter fleet.[59] It is understood that the report is classified primarily for commercial-in-confidence reasons and that it confirms the previous recommendations of DND and PWGSC to the government that the logical choice for Canada remains the F-35.[60] In the absence of the content of the classified report, it is possible to extrapolate the contents based on unclassified information readily available from open sources.

The Boeing F/A-18E Super Hornet is a twin-engine Generation 4+ aircraft that was developed from the F/A-18 upon which the CF-18 based. It is a progressive design, with many similarities to its predecessor, although somewhat larger. Nevertheless, it is not a new aircraft. It was proposed as a replacement for the USN/USMC F/A-18s in 1991 and development began in 1992. The first prototype flew in 1996 and production began in 1997 with the first operational squadron in 1999.[61]

There are three version of the Super Hornet. The first is the F/A-18E, a single seat version of which 292 have been ordered by the USN. The second is the two seat F/A-18F of which 280 have been ordered for the USN and 24 for the Royal Australian Air Force (RAAF).[62] It should be noted here that the RAAF is not replacing its fleet of legacy F/A-18s with the F/A-18E. Rather it is replacing its fleet of F-111 bombers with them, and as a stopgap between the retirement of its oldest F/A-18s and the delivery of the first F-35s. Its F/A-18s are being replaced by 72 F-35As.[63] The third version of the Super Hornet is the F/A-18G Growler, which is an Electronic Warfare (EW) aircraft that will replace the EA-6B Prowler in the USN. The USN has ordered 114 of these aircraft and the RAAF is converting twelve of its F/A-18E.

This aircraft is also not problem-free. Most recently reports of hypoxia-related events with all versions of the aircraft have been on the rise. Pilots feeling dizzy, confused or 'a little strange' have been linked to on-board oxygen generation system failures, environmental control failures, human factors and other system failures. These problems have existed for some time but seem to have become more prevalent since 2010. The problem remains somewhat unresolved, notwithstanding some technical solutions applied recently.[64]

Boeing is nearing a decision point with the Super Hornet as it reaches the end of its production. With only two operators, the USN and RAAF, the aircraft has not had the same success as its predecessor. Just over 700 aircraft have been ordered, with potential foreign sales of no more than 200 more. Boeing has reduced the production rate from three to two aircraft per month and is considering building aircraft on speculation. However, recent cuts in its commercial aircraft workforce indicate that the company has limited flexibility in this regard. It is possible that Boeing may shut down its assembly line before a competitive bid process can be concluded.

Boeing has suggested that they can provide Super Hornets for $1.5B less than the F-35 based on the flyaway costs. However, their flyaway costs are likely to be between US$75M and US$85M when basic equipment such as external fuel tanks and sensor pods as well as the Foreign Military Sales (FMS) charge are all included.[65] Furthermore, the earliest any aircraft would be delivered based on the current government timetable is in the early 2020s. By that time, RCAF Super Hornets would be the last ones produced and will be for an almost thirty-year-old design. Furthermore, the USN aircraft would already be more than halfway through their lifespan. Thus, as Canadian Super Hornets entered the latter half of their lifespan, the USN will have retired theirs and the cost of operating a small orphaned fleet of Canadian, Australian and possible other small operators would increase due to the cost of production of small volumes of parts. Finally, any direct industrial benefits of acquiring an aircraft so late in the production schedule will be minimal.

The Dassault Rafale is a twin engine Generation 4+ aircraft produced in France. Development began in 1982 and its first flight took place in 1991. Production began in 1992 with the first production aircraft delivered in 1998. There are currently three versions with the French Armed Forces, the Rafale B, which is a two seat version, the Rafale C which is a single seat version and the Rafale M which is a carrier variant. A total of 286 are planned for the French Armed Forces, of which 135 had been delivered by 2015. Foreign orders consist of 24 aircraft for the Egyptian Armed Forces, 36 for the Indian Air Force and 24 for the Qatar Air Force.[66]

The per unit cost in 2013 for the Rafale B was US$101M and the Rafale C was US$94M.[67] Looking at a 2020 delivery date the unit cost for Rafale B would in the US$120M range and the Rafale C about US$110M. The cost of the aircraft has placed the deal with India in some jeopardy and a final deal is still not forthcoming. This situation has led India to consider buying the F/A-18E or an advanced version of the F-16.[68] Thus, it would seam that the Rafale is not that competitive. Furthermore, with such small numbers the potential industrial benefits to Canada in the event of a deal would also be minimal.

The Eurofighter Typhoon is a twin Engine Generation 4+ multi-role fighter produced in the Europe by a multinational consortium with work shared between the UK, Germany, Italy and Spain. All of these countries have ordered and taken delivery of Typhoons for their respective air forces. The Typhoon has been under development since the mid-1980s and the first prototype flew in 1994. The first production aircraft was not delivered until 2003. As of late 2012 a total of 559 firm orders had been placed, with options for another 148. Aircraft for Saudi Arabia and Austria are included in these numbers.[69] It is interesting to note that the Eurofighter has competed against the F-35 in several countries unsuccessfully. Japan, Norway, Turkey and South Korea have all opted for the F-35.[70]

The per unit cost is reported in 2015 at £87M or US$128M, much higher than the projected costs of the F-35 even with attempts by British Aerospace to slash costs by 20% over the past five years.[71] It has also had its share of production problems including cracks in stabilizers, holes in the fuselage and problems with external fuel tanks.[72] From an industrial benefits point of view, a Canadian order would come near the end of production, and with a multinational consortium already involved, economic benefits to Canada would be minimal.

The SAAB Gripen is a single engine Generation 4 Fighter aircraft, which is an almost a thirty-year-old design. Development began in 1982 with the first prototype flying in 1990 and the first production aircraft delivered in 1992. Less than 200 of these aircraft have been produced and only sixty more are on order. The version likely to be a contender in a Canadian competitive bid would likely be the Gripen NG (Next Generation), which is still in its final development stage.[73]

The SAAB Gripen NG is a progressive design based on the earlier Gripen C/D. It is visually similar to the earlier version and maintains an external weapon load. However, it has a more powerful engine as well as increased fuel capacity. SAAB does include sensor fusion in its description, as well as limited stealth.[74] The RCS of this aircraft is not readily available, but SAAB claims it is better than the Gripen C/D. Nevertheless, it is unlikely to be close to that of a true stealth aircraft. It has a top speed of Mach 2.0 and is capable of supercruise at Mach 1.25.

The per-unit cost of these aircraft varies from a low of $45M to a high of over $100M. The lower price is for sixty aircraft being converted from older C/D models to the NG model.[75] New aircraft will cost much more. SAAB plans to sell over three hundred Gripen NG over the next 20 years and has recently sold 36 aircraft to Brazil in a US$4.7B deal. As part of this contract, 29 aircraft will be built in Brazil.[76] The breakdown of the deal are not known, but a per aircraft cost of $130M is suggested, which would seem to be high. Nevertheless, the Swedish government has pegged the production costs at about US$105M in 2012. This number is much higher than the

SAAB's estimate as is the operating cost of US$21K per hour versus the company's claim of US$10K per hour.[77]

With less than 150 aircraft ordered to date and a forecast of only 300 over twenty years, this aircraft comes with the risk of high sustainment costs, regardless of the manufacturers claims. Furthermore, with such a low volume they cannot hope to reduce production costs through economies of scale or learning curves. It has also been suggested that this aircraft could be built under license in Canada. Based on experience with the CF-5, this could add 20% to the cost of the aircraft, which would make it much more expensive than the F-35 with limited industrial benefit not on the scale of the F-35. Finally, Swedish neutrality could place the supply chain at risk in the event of conflict or tension with Russia. If low volume parts had to be manufactured in Canada the costs would be significantly higher.

All of the options available have some capabilities that the F-35 has such as Active Electronically Scanned Array (AESA) radar, ability to use all modern NATO Weapons, varying degrees of sensor fusion, and state of the art avionics including the HMD. However, none of them have the small RCS of the F-35. Most are at or near the end of their production and it would seem that there is no real competition on price. Indeed, the Rafale and Eurofighter Typhoon are significantly more expensive than the F-35. All of the contenders have low production runs in comparison to the F-35 which increases the risk of cost over runs and increasing sustainment costs. The only aircraft whose price is coming down as planned is the F-35. The Liberal Government has stated it will reduce the funds available to the fighter program and buy a less expensive aircraft. This would now seem to be an unlikely scenario. If all the available aircraft are more expensive or at the same price, the only way to reduce expenditures would be to buy less aircraft.

## SUMMARY

Stealth will give our aircraft an edge over potential adversaries both in the air and the ground. With a minimal radar cross section compared to legacy fighter aircraft and current production aircraft, the F-35 will be able to engage or observe at long-range with a low risk of being detected from the air or ground. Stealth will make the F-35 much more survivable from air to air and ground to air missiles, meaning our pilots will have a greater chance of coming back alive from combat. Notwithstanding the suggestion that our fighters are there just for the defence of North America, it should be noted that the Liberals have committed fighters to overseas operations in the past, namely the Kosovo bombing campaign. If the political situation warrants it, they will be sent again. Indeed, stealth will also be an advantage in North American Defence.

Our government should be seeking to give the advantage to our own pilots rather than those of the enemy.

A review of the major points of criticism indicate that although there are areas of concern, similar to that of other aircraft in final development, most of the criticism is without warrant. Those with political objectives whose expertise is in areas other than aviation seem to oppose the F-35 simply because the former Conservative Government was in favor of it. Indeed, most criticisms are easily rebutted based on work by individuals whose expertise is in the field of aviation. It is unfortunate that the mainstream media essentially chose to accept the work of those with no aviation expertise over those who did. One would expect a truly unbiased media to table both sides of the story.

A review of the reports by both the OAG and the PBO would indicate that the numbers presented by the former Conservative Government were indeed low, but not by very much. After a four-year process of assessment, the projected capital costs are 9% more than projected and the twenty year costs are 4.3% more than that projected by the Conservative Government. One could question the need to estimate the costs over 42 years, particularly since it is quite impossible to accurately forecast the situation that far in advance. Thus, it would seem to be a nugatory exercise. Nevertheless, the media chose to rely on their ‘experts’ to provide an extremely pessimistic cost estimate.

This analysis has determined that the F-35 remains the best option for the CF-18 Replacement Project both qualitatively and quantitatively, has the best potential for industrial benefits and as such should be allowed to compete in the project. Should the government proceed with a competitive bid process that specifically excludes the F-35, they will be living up to a campaign promise that was based on ideology as opposed to strategic thought. This process will also place our pilots at greater risk in an aircraft that is potentially less survivable and with interoperability challenges with our main ally, the US. Indeed, the likely competition to the F-35 are more expensive, less capable and offer little in the way of long-term industrial benefit. Perhaps the government should take a more strategic approach, opening up the competition to all potential suppliers to ensure the maximum return to Canadian industry while ensuring the best aircraft is bought for the RCAF. The current Federal Liberal government has indicated that it will proceed with a competitive bid to replace the RCAF’s CF-18 fighter planes. However, it will preclude the F-35 from competing stating it will buy a cheaper aircraft. That will not be possible. Canada has invested in the Joint Strike Fighter Program over three successive governments and the current one may walk away from those investments based on an ill-conceived campaign promise.

[1] J.L. Granatstein, *Who Killed the Canadian Military?* (Toronto: Harper Collins, 2004), 164-5.

[2] Liberal Party of Canada, https://www.liberal.ca/files/2011/04/liberal_platform.pdf; p.85, Internet, accessed 15 December 2015.

[3] Conservative party of Canada, Here For Canada, http://www.scribd.com/doc/52594069/Conservative-Party-of-Canada-2011-Election-Platform#scribd; p.34, Internet, accessed 15 December 2015.

[4] Office of the Auditor General of Canada to the House of Commons, *Chapter 2 Replacing Canada's fighter Jets*. http://www.oag-bvg.gc.ca/internet/English/parl_oag_201204_02_e_36466.html; Internet, accessed 16 December 2015.

[5] Public Works and Government Services Canada, National Fighter Procurement Strategy, http://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/air/snac-nfps/index-eng.html; Internet, accessed 16 December 2015.

[6] Statement by the Independent Review Panel Regarding the Royal Canadian Air Force Report to Ministers on the Evaluation of Options to Sustain a Canadian Forces Fighter Capability, February 28, 2014. http://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/air/snac-nfps/sg-eng.html; Internet Accessed 17 December 2015.

[7] Liberal Party of Canada, "F-35" https://www.liberal.ca/realchange/f-35/; Internet, accessed 15 December 2015.

[8] Roger Hilsman, *From Nuclear Military Strategy to a World Without War: A History and a Proposal* (Westport: Praeger, 1999), 102.

[9] Department of National Defence, *The Future Security Environment 2013-30140*, (Ottawa: DND, 2013).

[10] Department of Defense, *The Joint Operating Environment 2010* (Suffolk: United States Joint Forces Command, 2010; available from http://fas.org/man/eprint/joe2010.pdf; Internet accessed 27 December 2015.

[11] DND, *The Future Security Environment, . . . , 14, 26, 48, 77, 96-99, 101,113.*

[12] Chief of Defence Intelligence, *Threat Capability Assessment for Canada's Fighter Aircraft Capability,* (Ottawa: DND, 2014), 3-6.

[13] *Ibid*, 6.

[14] John A. Tirpak, "The Sixth Generation Fighter", *Air Force Magazine*, 92 No. 10, (October, 2009):40; http://www.airforcemag.com/Magazine/Archive/Documents/2009/October%202009/1009fighter.pdf; Internet, accessed 15 January 2015. Note: **Supercruise** is sustained supersonic flight of a supersonic aircraft with a useful cargo, passenger, or weapons load performed efficiently, which typically precludes the use of highly inefficient afterburners. The F-22 is the only aircraft that can supercruise with an operational load of fuel and weapons. (Mach 1.6 with 6 air to air weapons) Many aircraft can supercruise at very low Mach without external weapons.

[15] *Op cit,* Chief of Defence Intelligence, *Threat Capability Assessment for Canada's Fighter Aircraft Capability,* 7-8.

[16] Vice chief of the Defence Staff, *Analysis of Options to Sustain a Canadian Forces Fighter Capability, Task 2: Chief of force Development Mission Needs Analysis*, p.15.

[17] *Ibid,* p. 18-20.

[18] *Ibid*, p. 21-22. Note. The use of the phrase First Strike to describe the intermediate expeditionary scenario is perhaps a poor choice of words. As shown in the introduction to this paper, the phrase refers to a pre-emptive nuclear strike against another nuclear power's nuclear capability so as to reduce the risk of a counter strike. None of the scenarios presented envisage a Canadian aircraft employing nuclear weapons.

[19] *Ibid,* p. 17.

[20] Radar Cross Section, http://www.globalsecurity.org/military/world/stealth-aircraft-rcs.htm; Internet, accessed 15 March 2016.

[21] Brian Handwerk, "Hitler's Stealth Fighter" Re-created, *National Geographic News,* http://news.nationalgeographic.com/news/2009/06/090625-hitlers-stealth-fighter-plane.html, Internet accessed 05 May 2016.

[22] Radar Cross Section, http://www.globalsecurity.org/military/world/stealth-aircraft-rcs.htm; Internet, accessed 15 March 2016. Note: These are estimates. The actual RCS is classified.

[23] Situational Awareness, https://www.uscg.mil/auxiliary/training/tct/chap5.pdf; Internet, accessed 21 April 2016.

[24] Dr. Malcolm Davis, Canada's Future Airpower after the F- 35 Joint Strike Fighter, *CDA Institute Blog: The Forum*, 28 October 2015, https://www.cdainstitute.ca/en/blog/entry/canada-s-future-airpower-after-the-f-35-joint-strike-fighter, Internet accessed 21 April 2016.

[25] Second Line of Defence, "The F-35 and Sensor Fusion" http://sldinfo.com/whitepapers/the-f-35-and-advanced-sensor-fusion/; Internet, accessed 22 April 2016.

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