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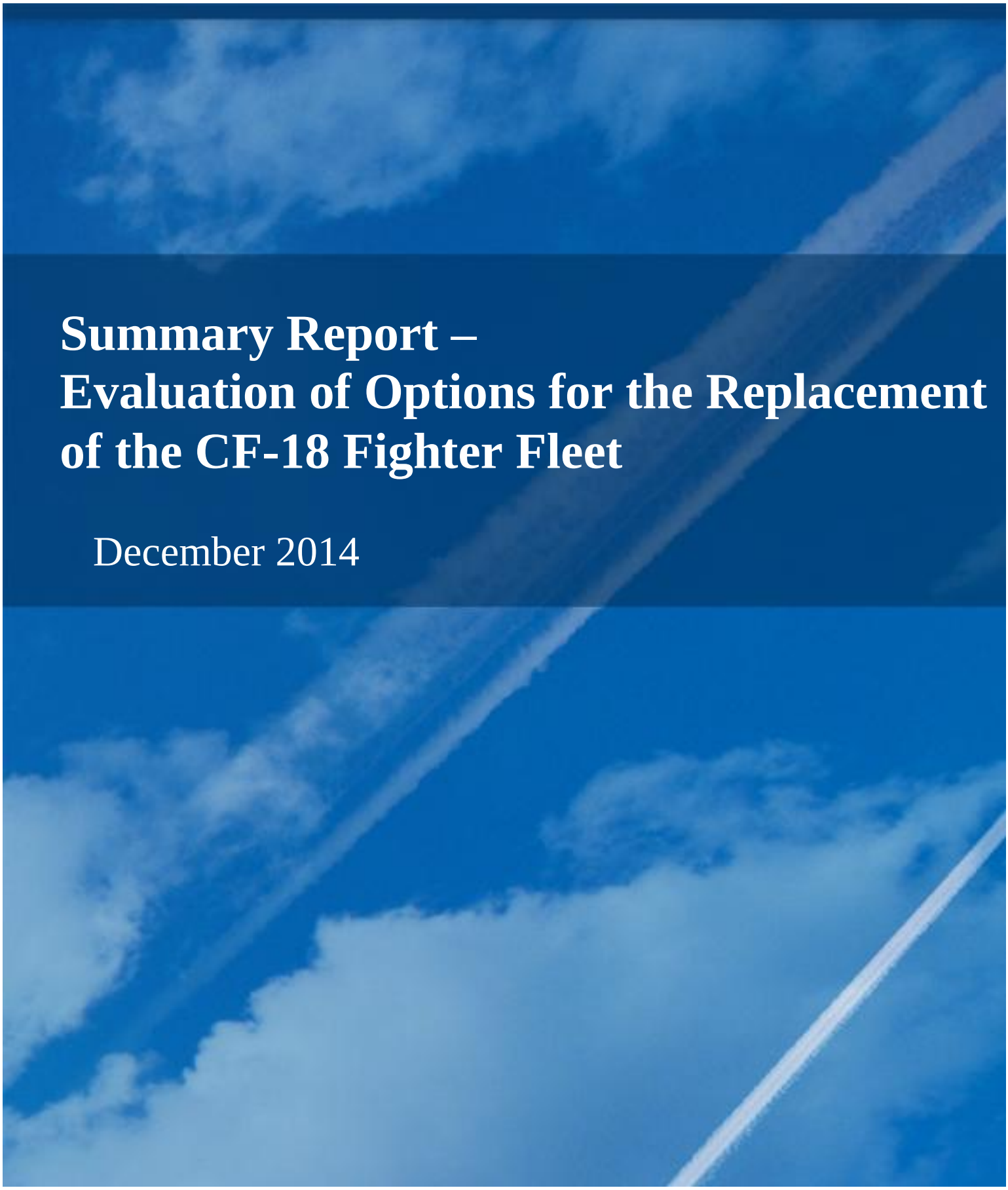

Summary Report – Evaluation of Options for the Replacement of the CF-18 Fighter Fleet

December 2014

Canada

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1. Introduction

The Seven-Point Plan and the Evaluation of Options

As part of the Government's Seven-Point Plan, the Department of National Defence and the Canadian Armed Forces conducted an evaluation of options to sustain a Canadian Forces fighter capability well into the 21st century. This evaluation assessed fighter aircraft from companies that agreed to participate in the market analysis against the roles and missions outlined in the *Canada First* Defence Strategy. The outcome was a risk-based assessment of each aircraft's ability to successfully complete *Canada First* Defence Strategy missions.

This report is being released in accordance with the terms of reference for the evaluation of options. It is intended to provide the unclassified findings of the assessment, respecting applicable non-disclosure agreements with other governments and industry. It provides a high-level description of the key findings with respect to the capabilities of fighter aircraft participating in the evaluation since, to respect commercial sensitivities, aircraft cannot be explicitly identified. A classified report that contains more detailed findings for each fighter aircraft has been provided to Ministers to inform a decision on the path forward.

Roles, Responsibilities and Oversight

The Royal Canadian Air Force was responsible for the overall leadership and coordination of the evaluation of options. It followed a methodology that produced a risk-based assessment of four available fighter aircraft.

An Independent Review Panel was established to oversee the evaluation process, and to participate at key milestones in the work. The mandate of the Panel was to ensure that the work performed was both rigorous and impartial and that the findings were comprehensive and understandable.

The Panel members were:

- Keith Coulter, a former fighter pilot and Deputy Minister;
- Philippe Lagassé, Associate Professor researching Canadian national defence at the University of Ottawa;
- James Mitchell, founding partner of Sussex Circle, an Ottawa consulting firm, and a former senior federal official; and
- Rod Monette, Fellow Chartered Accountant and former Comptroller General of Canada.

The Independent Review Panel met with representatives from the Royal Canadian Air Force and the Department of National Defence on a regular basis over a period of 14 months to assess the methodology used and the analysis performed.

Description of Work

The evaluation of options was implemented through a work plan based on six tasks. Three tasks were carried out under the direction of the Commander of the Royal Canadian Air Force and the remainder by organizations independent of the Royal Canadian Air Force. Task 1 was led by the Chief of Defence Intelligence, Task 2 by the Chief of Force Development and Task 4 by the Director General of Aerospace Equipment and Program Management.

The six tasks were as follows:

Task 1 - Threat Analysis
A comprehensive threat analysis was conducted to examine the broad strategic environment. This strategic environment included emerging challenges to Canada's defence and security and specific technological threats over two time horizons—that is, 2020-2030 and beyond 2030.

Task 2 - Mission Needs Analysis
A mission needs analysis determined what tasks the Royal Canadian Air Force would need a fighter capability to perform. A method called capability-based planning was used, which helped to forecast the capability that would be needed to meet the threats identified in the threat analysis.

Task 3 - Examination of Fighter Capabilities
Each fighter aircraft was assessed in terms of its technical capabilities and risks to the accomplishment of missions outlined in the *Canada First* Defence Strategy.

Task 4 - Review and Update on the Estimated Life Expectancy of the CF-18 Fleet
An update analysis of the Estimated Life Expectancy of the CF-18 fleet was conducted. It included an assessment of the CF-18's capability to contribute to operations beyond 2020 and an analysis of the cost of upgrades needed to maintain safe and effective operations.

Task 5 - Market Analysis
A market analysis was undertaken to obtain information directly from industry on the capability, production and supportability of four modern fighter aircraft from European and American manufacturers. This information was supplemented by open source as well as government-to-government information. The National Fighter Procurement Secretariat also gathered information through the market analysis on price and industrial benefits. Cost information is presented in section 9 of this report. Information on industrial benefits was assessed by Industry Canada and is presented in a separate public report.

Task 6 - Mission Risk Assessment
Based on the work done in the previous tasks, an assessment of risks was conducted for each aircraft against the missions identified in the *Canada First* Defence Strategy.

The following classified analytical background reports on each of the tasks informed this public summary report:

- Task 1 - Chief of Defence Intelligence - Threat Assessment
- Task 2 - Chief of Force Development - Mission Needs Analysis
- Task 3 - Fighter Aircraft Capability Assessment
- Task 4 - CF-18 Estimated Life Expectancy Analysis
- Task 5C2 - Critical Enablers Risk Assessment
- Task 5D2 - Operational Risk Assessment
- Task 6 - Integrated Risk Assessment Report
- Mixed Fleet Analysis

2. Security and Operating Environment

Canada First Defence Strategy: A Policy Foundation

The *Canada First* Defence Strategy, announced in May 2008, articulates the Government's defence policy and direction to the Canadian Armed Forces. It provides a detailed road map for the creation of a first-class, modern military that is well trained, well equipped and ready to take on the challenges of the 21st century. The Strategy also outlines the roles and missions that the Canadian military must fulfil in order to respond effectively to Canada's current and future security challenges. The Strategy therefore represents the policy foundation for the roles and missions expected of a replacement fighter fleet.

Three Roles of the Canadian Armed Forces

The Canadian Armed Forces have three primary roles in dealing with security challenges:

- *Defending Canada:* According to the *Canada First* Defence Strategy, ensuring the security of Canadians and helping to exercise Canadian sovereignty are the primary tasks of the Canadian Armed Forces. The document points out that the Canadian Armed Forces must be able to help Canadians in times of domestic crises. They must also monitor the country's territory and its air and maritime approaches, including the Arctic. They must be able to address quickly and effectively any identified threats. The military must also assist other government departments in dealing with such security concerns as overfishing, organized crime, the smuggling of drugs and people, and environmental degradation;

- *Defending North America*: The Strategy describes defence of Canada as integral to the effective defence of North America, alongside the United States. In this sense, the Strategy affirms a close defence partnership with the United States as a key element of Canada's own strategic interest. This partnership is exercised mainly through the North American Aerospace Defence Command (NORAD). In addition, Canada's Joint Operations Command shares objectives and works closely with the United States Northern Command. Joint training and personnel exchange, as well as ensuring compatibility in equipment and doctrine, are among the measures through which the forces of the two countries remain interoperable (i.e. able to work together coherently, effectively and efficiently in pursuit of shared objectives); and

- *Contributing to international peace and security*: As a member of the international community, and especially as a trading nation in a highly globalized world, Canada is affected by instability abroad. Among other things, the Strategy calls for these threats to be addressed at their source to prevent them from reaching Canadian shores. The *Canada First* Defence Strategy emphasizes that, in the pursuit of international peace and security, Canada cannot lead by words alone. Canada must be prepared to deploy military assets in support of national interests and international objectives.

The Six Core Missions

Responding to the challenges described above requires a flexible Canadian military. The *Canada First* Defence Strategy outlines six core missions that the Canadian military must be able to undertake at home, in North America, and globally, potentially at the same time:

- Conduct daily domestic and continental operations, including in the Arctic and through NORAD;
- Support a major international event in Canada, such as the 2010 Olympics;
- Respond to a major terrorist attack;
- Support civilian authorities during a crisis in Canada such as a natural disaster;

- Lead and/or conduct a major international operation for an extended period; and
- Deploy forces in response to crises elsewhere in the world for shorter periods.

Challenges to Canadian Defence and Security

The main challenges facing Canada's defence and security now and in the future cover a wide range of issues - from climate change to failed and failing states, to international terrorism and the proliferation of advanced technology into dangerous hands.

Together, these domestic and international challenges require the Canadian Armed Forces to operate across the entire spectrum of conflict, from humanitarian operations and disaster relief up to combat operations. Flexibility is therefore an important consideration in equipping the Forces. A fighter is one of the capabilities that can be used to fulfil the roles and missions outlined in the Strategy in the current and future security environment.

After the Cold War
The end of the Cold War initially gave rise to hopes of a new era of international peace and security. However, as the *Canada First* Defence Strategy states, it is clear that the peace dividend that resulted from the end of the Cold War was relatively short-lived. The 1990s saw the rapid emergence of diverse security challenges, including failed and failing states, civil wars and global terrorism. These challenges persisted in the 2000s, with global terrorism becoming the focus of international security efforts following the 9/11 attacks in the United States.

Power Rebalancing Within the Global System
The rebalancing of global power now underway is largely a result of higher economic growth rates in Asia and other parts of the world relative to Europe and North America. The United States National Intelligence Council predicts that, by 2030, Asia will have surpassed North America and Europe in Gross Domestic Product (GDP), population size, military spending, and technological investments. As a consequence of this rebalancing, emerging powers will likely play a greater political and military role in world affairs.

Access to the Global Commons
The global commons (air, sea, space and cyberspace domains outside any country's sovereign control) will increasingly be contested by state as well as non-state adversaries. Networks of transportation and communications will continue to be both means of legitimate commerce and interaction, as well as conveyors of potential threats. Secure lines of communications and a rules-based international system, including the means to police it, remain fundamental to Canada's security and prosperity.

Regional Conflicts and Ungoverned Spaces
Regional conflicts in parts of the world such as Africa, the Middle East or Asia could have an impact on Canada's national interests, security and prosperity. In addition, ungoverned spaces (for example, large parts of the Sahel in Africa) are often sources of humanitarian crises with potential implications for international stability. Moreover, they could cause larger security concerns by becoming both safe havens and breeding grounds for terrorists and transnational criminal organizations.

Increasing Influence of Non-State Actors
A wide range of non-state actors from terrorist networks and criminal organizations will be able to exploit new technologies and means of communication to increase their influence. International terrorism and other asymmetric challenges (i.e. threats of warfare between groups of significantly different levels of power and capacity) will therefore remain concerns. These threats will involve a

mix of regional groups, small cells and even individuals. Canada and its allies will need to pay attention to violent extremists, who are expected to retain the ability to strike Western targets and destabilize weaker states.

Threats to Critical Space Assets and Cyber Security
With the increasing importance to modern society of the safe use of space comes the increased potential for threats to critical space assets – whether commercial or military. Similarly, cyber security will remain a top national security priority for Canada and its allies. The increasing frequency and sophistication of cyber threats are likely to have a major impact on the future security environment.

Climate Change and Implications for Canadian Sovereignty
Changing weather patterns are already having an impact on ecological systems worldwide. These changes could lead to increased social and economic pressures and greater instability in some regions. For Canada, these changing patterns have special significance in the Arctic. Greater resource exploitation, increased commercial activity and changes in transportation and communication systems will increase the need for the exercise of Canadian sovereignty in the North.

Proliferation of Advanced Military Technology and Weapons of Mass Destruction
Technological advances in unmanned vehicles, robotics, sensors, signal processing, power generation and conversion, and propulsion are all likely to increase and expand military capabilities. These capabilities can fall into the hands of states or non-state actors that are hostile to Canada and its allies. The same is true with regard to the possible proliferation of various forms of weapons of mass destruction.

Future Technological Trends

The threat from foreign military weapons to Canada or its deployed forces will grow in direct correlation with technological improvements made by potential adversaries, both state and non-state. Future aircraft will have the ability to fly further, faster and higher than current aircraft as well as having an increased weapons payload potential and weapons capabilities. Missiles will be more capable of higher speeds and more capable of being launched from land, air and maritime platforms.

Fighter Aircraft
It is expected that as increased processing power becomes available, most future fighter aircraft will incorporate sophisticated data fusion engines to process a plethora of information, thereby providing not only the pilot but other air and ground-based platforms and command and control systems with real time intelligence grade information through high-bandwidth data transfer.

Surface-to-Air Missiles (SAM)
States will continue to improve current analog air defence systems with digital upgrades resulting in significant capability enhancements. Digital technology will also make it easier to link the various systems together and merge the data at the national level to provide command and control nets with an accurate common operating picture. Digital enhancements will also ease the transfer of targeting information to other digitally enhanced systems. Recent trends in SAM development that are expected to continue include increased mobility, longer engagement ranges and the use of “fire-and-forget” (i.e. self-guided) technologies.

Man-Portable Air Defence Systems (MANPADS)
MANPADS will continue to proliferate to both state and non-state actors. The trend in the employment of MANPADS includes a focus on improved counter-countermeasure performance and improved ease of use, along with a variety of other enhancements.

Anti-Aircraft Artillery (AAA)
AAA guns are widely used throughout the world as part of ground-based air defence systems. These AAA systems are often the same as those mounted on naval vessels, and modified versions of the same cannons equip many fighter aircraft. The trend is for greater integration of AAA systems with their associated fire-control systems and early warning networks into more fully integrated air defence systems.

Air-to-Air Missiles (AAM)
Current AAM technology enhancements translate into longer ranges, faster turn rates and more responsive manoeuvres. More aerodynamic control and better sensors will increase the ability and lethality of air-to-air missiles.

Early Warning Radars
The future of early warning radar systems will likely see the continued employment of digital technologies combined with advanced software algorithms to improve the capability of high-frequency, very high frequency and ultra high frequency radars. These systems will have improved system reliability, low-altitude detection performance, and target recognition. Increasingly these systems, through improved data extraction, will be seamlessly integrated into a country's integrated air defence system to automatically disseminate target track data to the command and control network in order to be able to vector fighters in a ground-controlled intercept mode.

Two Time Horizons: 2020-2030 and Beyond 2030

Canada's next fighter is expected to be in operation for at least 40 years. As a result, the evaluation of options analysis included a threat assessment covering two time horizons: 2020 to 2030 and beyond 2030.

Current Threat Technologies (2020-2030)
The 2020-2030 time horizon captures the operating environment for the estimated introduction of a replacement fighter against current threat technologies. These could include advanced next-generation fighter aircraft, bombers with supersonic cruise missiles, advanced anti-aircraft and surface-to-air missiles, as well as early warning radar systems.

Emerging Threat Technologies (Beyond 2030)
The beyond 2030 time horizon is characterized by the proliferation of existing as well as emerging technologies. The sophistication and proliferation of the threats identified in the 2020-2030 timeframe is expected to increase in the beyond 2030 timeframe.

3. Canada's Defence and Security Requirements

Determining Mission Needs: A Systems-Based Approach

The previous section examined the new and enduring challenges facing Canadian defence and security, as well as the military roles and missions needed to meet those challenges. This section examines the overall mission needs that the CF-18 replacement must be able to fulfil in order to meet these challenges.

In order to determine Canada's mission needs in terms of a fighter aircraft, the Canadian Armed Forces employed a methodology known as capability-based planning. This methodology, which is described in the next section, was used to determine the mission needs of the Canadian Armed Forces five to 30 years into the future, to assess the ability of the Armed Forces to meet those needs at the present time, and to forecast the capabilities required to meet them in the future relative to a range of evolving threats.

A Systems-Based Approach
As important as any aerospace system might be, it generally cannot achieve its military objectives in isolation. Military planning and operations must therefore adopt a "system of systems" approach. In this sense, a capability is the combined effort of multiple weapons systems. For example, a capability might be derived from the combination of a tank, a fighter, and an air-to-air refueller, among other assets. To understand the power of the "system of systems" approach, one should think of the way these individual platforms support each other since it is the synergies among them that determine the overall level of capability. In other words, the whole is greater than a sum of the parts.

Canada's Mission Needs

The Need for a Manned Fighter
The analysis conducted by the Department of National Defence - Chief of Force Development, and derived from capability-based planning, indicates that a future Canadian Armed Forces fighter aircraft will be used often and, when used, will likely contribute capabilities critical to mission success.

There is no indication that unmanned aircraft technology could be a viable replacement for the CF-18 either in the near or the medium term. Unmanned Aerial Vehicle (UAV) technology has advanced in recent years and UAVs have demonstrated their value in a variety of operations. They have been used by Canada, for example, to conduct Intelligence, Surveillance and Reconnaissance missions both domestically and internationally and our Allies have deployed UAVs to carry out precision strikes against ground targets in a limited range of tactical environments. UAV technology is such that they can be controlled remotely or be programmed to carry out specific tasks.

For the foreseeable future, however, UAVs do not have all of the capabilities required to replace a manned fighter aircraft and are not a viable solution to replace the CF-18. A UAV cannot, for example, operate in an air-to-air combat situation. Even though it can be remotely controlled, it lacks the speed, range, agility and defensive systems to be effective in air-to-air combat. In most military environments, UAVs are limited in the ability to attack specific targets. Their software systems are not sufficiently reliable to accurately identify a target, decide whether to engage a target, assess the situation following an attack, or make tactical decisions in combat environments. Technology cannot substitute a pilot's real-time on-board ability to be aware of rapidly evolving situations and respond appropriately.

It is assessed that the CF-18 replacement must be manned to meet the critical demands of domestic sovereignty and continental defence obligations and to provide an adaptable expeditionary air power contribution. At issue therefore, is not the need for a Canadian fighter capability replacement, but rather ensuring that the fighter replacement maintains or exceeds the current CF-18 capabilities baseline relative to evolving threats over the next several decades.

Domestic Missions

Domestic missions involve the protection of Canada's sovereignty and the fulfilment of the country's bi-national obligations under NORAD. Since Canada and the United States retain a close continental defence and security partnership, the Canadian Armed Forces must therefore be interoperable with US armed forces. These Canadian Armed Forces NORAD commitments and the Forces' search-and-rescue operations are both mandatory requirements for the Government. Historically, domestic and continental operations have accounted for at least 90% of the use of the Canadian fighter fleet.

Moreover, 80% of the missions flown by the fleet have related to the ability to protect Canadian air space from intrusion. This function is projected to continue to be the most important role of the Canadian fighter capability. The role of an airborne interceptor is one that only a fighter capability can accomplish. No other Canadian Armed Forces assets can perform that role, either alone or in combination.

Expeditionary Missions

Expeditionary missions would be conducted in the context of Canada's North Atlantic Treaty Organization (NATO) and United Nations (UN) obligations or through ad hoc coalition arrangements. It should be remembered that, in order to contribute to NATO's air defence commitments during the Cold War, between 1951 and 1993 Canada deployed squadrons of fighter aircraft to France, and then to permanent bases in West Germany. Shortly after the end of the Cold War these squadrons were returned to Canada but the tempo of Canadian fighter operations continued apace as a consequence of Canada's decision to contribute to coalition or allied operations abroad in response to military aggression and regional instability.

The mission needs analysis undertaken as part of the evaluation of options makes clear that Canadian engagement in future state-on-state conflicts will be highly unlikely. Far more likely, according to the mission needs analysis, are military engagements that are not clearly defined state-on-state warfare or explicitly humanitarian assistance missions but rather, as in the case of Libya or Kosovo, something in between.

Expeditionary missions are conducted on a case-by-case basis in two senses. Firstly, unlike missions involving the protection of Canadian air space, the Government is not obliged to undertake such a mission. For example, Canada declined to participate in the 2003 Iraq War, but was actively involved in Afghanistan. The Government also decided to participate in the 2011 air campaign in Libya, but to date has been poised to provide only political but not military support to potential action in Syria.

Secondly, the Government has choices regarding the type, degree and duration of Canada's involvement in, and contribution to, an expeditionary mission. The Government can decide whether, and to what extent, it would participate through aircraft, naval assets, or troops on the ground. In an expeditionary situation, while Canadian fighter aircraft could often be useful, they would sometimes not be essential for the purposes of the mission. In ungoverned spaces, for instance, Canada and its allies would have few airborne threats with which to contend. Given that a coalition force would establish air superiority in such situations, the focus of the fighter aircraft would largely shift to delivering the desired effects on surface targets. In these cases, and where the situation allows for ground forces to be deployed, the coalition would have access to other

systems, such as artillery, that could also be able to conduct these missions. The capability-based planning process for the Canadian Armed Forces uses these considerations when deciding what type of capability, if any, is required.

4. Current Fighter Capability: CF-18 Hornet

Canada's present fighter aircraft capability consists of the CF-18 Hornet fleet – currently 77 aircraft. As part of the evaluation of options to replace the CF-18 Fleet, the Royal Canadian Air Force was tasked to conduct an analysis of the fleet's estimated life expectancy.

The analysis included an assessment of the fleet's capability to contribute to operations for timeframes beyond 2020. It also addressed the cost of necessary upgrades to maintain safe and effective operations for specific periods after 2020.

This analysis was conducted by experts from the Director General Aerospace Equipment and Program Management office in the Materiel group at National Defence with operational input from the Royal Canadian Air Force.

Historical Background

The CF-18, a multi-role high-performance twin-engine combat aircraft also called the CF-18 Hornet, entered into Canadian service in 1982. It replaced three fleets—the CF-5 Freedom Fighter, the CF-101 Voodoo and the CF-104 Starfighter.

For nearly three decades, the fleet of CF-18 aircraft has been the backbone of Canada's air defence forces. It has been a fundamental part of the defence of Canada and its contribution to the defence of North America.

Canada's CF-18 fleet is a tangible example of the Government's commitment to the defence of the continent. Since 1958, Canadian Armed Forces aircraft have participated in the collective aerospace defence of North America through the North American Aerospace Defense (NORAD) Command agreement. As the only Canadian aircraft assigned to that role, CF-18s are on continuous alert to respond to potential aerial threats to the safety of Canadians and the security of Canada and the continent.

Together with the United States Air Force, Canada's CF-18s have been ready, on a daily and hourly basis, to undertake any missions to respond to potential threats to North America. In response to the 9/11 attacks, CF-18s conducted 24/7 airborne combat air patrol over vital Canadian points for a significant amount of time. Under NORAD, the Canadian fighter force conducts approximately 200 missions against potential threats each year. CF-18s have been deployed numerous times in response to activities by unwanted or unidentified aircraft approaching Canada's far north.

As Canada's primary air combat capability, the fleet has been a valuable component of Canadian support to international missions, an integral part of Canadian Armed Forces operations around the world.

In the early 1990s, the fleet participated in operations Desert Shield and Desert Storm in the Middle East, flying over 5,700 hours in approximately 2,700 sorties. The CF-18s were deployed twice in response to ongoing violence in the former Yugoslavia between 1997 and 2000. The fleet conducted air patrols in support of NATO peacekeepers in Bosnia-Herzegovina and participated in the 1999 air campaign over Kosovo. The CF-18s conducted 10% of the NATO missions during this campaign. They did so despite being a much smaller percentage of the total force.

Most recently, CF-18s were deployed in 2011 to southern Italy to participate in Operation Mobile / Operation Unified Protector, a multinational response to the crisis in Libya. The CF-18 was the only Canadian Armed Forces asset able to help enforce the no-fly zone over Libya to protect civilians.

Canada's CF-18 Fleet Extension Requirements

Estimated life expectancy identifies the latest date on which a fleet is expected to be able to continue flying. During a pre-defined period prior to that date, the fleet will be progressively reduced in numbers as individual aircraft are retired to a point (estimated life expectancy) where fleet operations cease. This is often called a ramp-down or transition window, and is the period when the retiring fleet is progressively replaced by a new one and during which time every effort must be made to sustain as much fighter capability as possible. A fleet's estimated life expectancy plan defines a transition window by taking into account replacement aircraft, spares, and support equipment delivery schedules as well as the fleet's personnel training capacity.

Unless otherwise specified, estimated life expectancy is based on the calendar year. An estimated life expectancy of 2003 assumes that the operations of the fleet will cease no later than December 31, 2003. Similarly, an estimated life expectancy of 2020 would mean that operations cease on December 31, 2020.

The original estimated life expectancy of the CF-18 was 2003. When the manufacturer initially set the estimated life expectancy of the CF-18 fleet at 2003, this estimate represented a service life of 20 years or a structural fatigue safe life of 6,000 hours. These calculations were based on anticipated usage by the original users, the United States Navy and the United States Marine Corps.

Proactive fatigue management and structural repair programs have extended the estimated life expectancy of the CF-18 to 2020. Similarly, a comprehensive program to modernize the avionics—the aircraft's electronic systems and devices—and its components has ensured that the aircraft will retain the ability to survive expected enemy threats. These steps enabled the aircraft to remain operationally relevant throughout this extended lifetime.

There are four important aspects to the estimated life expectancy of an aircraft. The first is that, as the term suggests, estimated life expectancy is an estimate. An individual aircraft may last a shorter or longer period of time than indicated by an initial or a subsequent estimate.

The second point is that an estimated life expectancy is calculated on the basis of a number of management assumptions. There are options that the Commander of the Royal Canadian Air Force, can initiate, mandate and/or leverage that can have an impact on the longevity of the aircraft. Reducing yearly flying rates, addressed later in this section, and increasingly using simulations, instead of actual aircraft, for training are two examples of this use of managerial flexibility.

Thirdly, estimated life expectancy is similar to the business concept of "useful life." Useful life is more than the physical or even the economic life of an asset. It refers to the period of time that an asset is expected to be usable for the purpose for which it was acquired. A fighter fleet that is physically in mint condition but can no longer fulfill its operational roles and missions has, for all practical purposes, come to the end of its useful life.

The fourth point is that the CF-18 aircraft's remaining safe life is measured by what is called its Fatigue Life Expenditure Index. Like a fleet of motor vehicles, an aircraft fleet's expected usefulness is impacted by the severity of usage as well as the duration. With more severe usage, structural elements of the aircraft wear out faster or "fatigue".

A series of actions, starting only a few years after Canada's CF-18 went into service, led to the extension of the CF-18 Hornet's estimated life expectancy to 2020. That new estimated life expectancy represented a service life of 38 years, almost twice the initial estimate.

That significant extension of the estimated life expectancy can be explained by the following five factors:

- *Comprehensive management*: In 1988, early in the life of the CF-18 fleet, there were concerns that certain structural problems would lead to limitations in the airworthiness of the aircraft. These concerns led to the implementation of a structural Fatigue Life Management Program;
- *Testing and re-certification*: The Royal Canadian Air Force and the Royal Australian Air Force undertook a full-scale structural fatigue test on a CF-18 aircraft. This test was based on Canadian and Australian flying and maintenance practices and circumstances. This new collaborative effort, known as the International Follow-on Structural Test Program (IFOSTP), was completed in 2006. IFOSTP re-certified the design life of the CF-18 to measure the fatigue life of the platform, and in this way replaced the use of flight hours as a measure of fatigue life. This new monitoring method extended the allowable and safe useful life of the platform.
- *Life Extension Program*: Data generated by IFOSTP formed the basis for the development of the CF-18 Hornet's Life Extension Program (LEP). The LEP was a structural refurbishment effort conducted in three stages. Refurbishments included the replacement of a key section of the centre fuselage of the aircraft (centre barrel replacement) where the wing attachment points are located since this area is prone to cracking in its original configuration. The third stage is currently being conducted on selected CF-18 aircraft.
- *Changes in the way the aircraft are flown*: In 1997, the CF-18 was certified to use precision-guided munitions, which are typically employed from higher altitudes. As a result, low-level flying and low-level flight training were no longer considered necessary. That type of flying, historically done by Canadian ground-attack fighter aircraft, demanded intense manoeuvring, frequently in turbulent conditions, which increased the strain on aircraft loaded with weapons. Not surprisingly, the cessation of low-level flying reduced the fatigue usage on the aircraft, thereby saving structural life of the fleet; and
- *Changed management assumptions*: The 2004 Estimated Life Expectancy report, which extended the CF-18 estimated life expectancy to 2020, was based on known facts, some of which have been outlined above. However, the extension was also based on variations to a number of key assumptions. These included a lower projected yearly flying rate, which is the total number of hours flown each year by the aircraft in a fleet. This measurement is important in relation to overall cost, but also in terms of overall usage and total fatigue consumption. Other variations to the 2004 assumptions are related to fatigue rates, structural modification requirements, continued US Navy support, the cost-benefit implications of proceeding with an extensive avionics modification effort, and the timelines associated with the projected introduction of a replacement fleet.

Options for Extending Estimated Life Expectancy

The evaluation of options process required a consideration of whether the CF-18 estimated life expectancy, having already been extended to 2020, could and should be extended even further. The analysis included an assessment of the capability of the fleet to contribute to operations for time frames beyond 2020. It also included calculations of the cost of upgrades that would be needed to maintain safe and efficient operations beyond 2020.

Two options for further extension in the fleet's Estimated Life Expectancy were considered as part of this analysis.

The 2020 - 2025 Time Frame
Extending the estimated life expectancy of the CF-18 to 2025 was assessed as a low-risk option in terms of cost, schedule and technical factors and as moderate risk in terms of operational factors. An estimated life expectancy of 2025, based on a five-year transition window would mean that the first aircraft in the fleet would be retired no earlier than January 1, 2021, and the last aircraft would retire on December 31, 2025. Such a change in estimated life expectancy would require an additional incremental investment to ensure the airworthiness of the CF-18 and to address issues of out-of-date and ineffective parts and avionics.

The 2025 - 2030 Time Frame
A CF-18 estimated life expectancy extension to 2030 would cost more and would be technically challenging. An extension of this magnitude has never been done before by any F-18 user nation. Therefore Canada would have to conduct and fund on its own the non-recurring structural engineering for the designs and implementation of this type of modernization program. The technical and schedule risks of this option are assessed to be high, and in turn, would drive up the cost risks. An estimated life expectancy of 2030, again based on a five-year transition window, would mean the first aircraft would be retired no earlier than January 1, 2026 and the last aircraft would retire on December 31, 2030. A change in estimated life expectancy to 2030 would require an additional incremental investment.

Key Considerations and Sensitivity Analysis

Any estimated life expectancy extension is based on three variables: technical feasibility; operational relevance; and cost-effectiveness.

Technical Feasibility
Currently known major system upgrades, refurbishments and replenishments that would likely be required to extend the estimated life expectancy of the CF-18 fleet have been identified by aerospace equipment and program management experts of the Department of National Defence. An estimated life expectancy extension past 2020 is assessed as technically feasible. However, the further the estimated life expectancy is extended into the future, the greater the technical, schedule and cost risk.

Operational Relevance
The CF-18 will remain operationally relevant until an estimated life expectancy of 2025, with risks due to obsolescence being managed by the Commander of the Royal Canadian Air Force. Beyond 2025, however, the operational relevance of the CF-18 will decline quite rapidly. The three elements of operational relevance are survivability, effectiveness and interoperability.

Survivability
The CF-18 lacks physical low-observability characteristics. It would, therefore, increasingly depend on electronic protection measures or be forced to consider staying out of enemy territory owing to advances in air and ground-based radar technology as well as air-defence capabilities. This shortcoming would make the CF-18 increasingly deficient on *Canada First* Defence Strategy missions.

Effectiveness
The level of information required by the platform and the pilot during domestic and expeditionary operations is expected to increase. In this complex information-heavy future operating environment, the operational effectiveness of the CF-18 would decrease in both domestic and expeditionary scenarios.

Interoperability
Beyond 2025, an increasing number of weapon system modifications would be required to maintain a minimum level of interoperability with the US and other present or potential coalition partners. After 2020 and even prior to 2025, a number of hardware and software upgrades would be needed to maintain interoperability such as in terms of communications (voice and data) with US forces if the current fleet were to continue flying. These upgrades would be needed to meet new regulatory requirements for air traffic control established by the International Civil Aviation Organization and the US Federal Aviation Administration as well as upcoming changes to US/NATO encryption requirements to ensure continued secure communications.

Sensitivity Analysis
The analysis for the CF-18 Hornet estimated life expectancy report is based on a number of technical assumptions. For example, the analysis assumes that the current concepts of operations and training for the CF-18 fleet will remain unchanged; the rates of attrition (i.e. loss of aircraft) will remain the same; and all aircraft reaching their end of life will be stripped for spare parts. It also assumes that the US Navy and some other F/A 18 fleet partners will continue operating the Hornet aircraft until at least 2025, thus ensuring availability of spare parts and key components for Canada's fleet of CF-18s.

There are also a number of operational assumptions. These include the requirement of a fleet size of 65 aircraft and a maximum yearly flying rate of 15,300 flying hours.

These assumptions were all sound, based on information available at the time the assessment was carried out. However, one or more of the assumptions could change. An analysis, known as a sensitivity analysis, was therefore conducted to determine how the estimated life expectancy calculation would change if there were changes in the yearly flying rates, fatigue consumption rates or attrition.

The analysis showed that changes to the yearly flying rate would have the greatest impact, and changes to attrition rates would have the least. Taken as a whole, the analysis showed that there is a limited ability to manage a procurement timeline slippage of one to two years by reducing the yearly flying and fatigue consumption rates. There would, however, be some impacts on operations.

Estimated Life Expectancy Incremental Cost Considerations

Aging considerations were also factored into the estimated life expectancy extension assessment. Experience has shown that, as is the case with an automobile, aging aircraft fleets become increasingly expensive to maintain. The maintenance burden of the aircraft is likely to increase, and the reliability of their key systems and components to decrease, as the aircraft age. This aging process increases the demand for spare parts, and so drives up sustainment costs. Moreover, serviceability rates generally decline, unless there is an increase in maintenance personnel and funding resources.

Flying the CF-18 past the current estimated life expectancy of 2020 will impose additional costs on the Department. Total rough order of magnitude incremental costs (costs over and above planned investments to continue operating the CF-18 fleet until 2020) associated with an estimated ife Expectancy extension decision amount to approximately $400 million for an Estimated Life Expectancy of 2025. Rough order of magnitude incremental costs for an Estimated Life Expectancy of 2030 are just over $1.5 billion and are primarily due to the requirement for a new structural life extension program needed to enable the CF-18 to be flown beyond its current safe life.

Some cost avoidance could be realized for structural upgrade costs by decreasing the yearly flying rate. However these savings are dependent on the number of hours flown and the actual fatigue life consumed. The only costs that are potentially avoidable are some avionics upgrade costs and associated development costs. Even in these cases, however, there would be some limited impact on operational capabilities if these upgrades were not pursued.

Operational Impact of Estimated Life Expectancy Extension

The steps in the transition to a new fleet will not all occur at the same time. The old fleet will gradually be drawn down as new aircraft are received. This is currently planned to occur over a period of five years. As a result, by the end of the Estimated Life Expectancy period, all CF-18s will have been retired from service.

During the five-year transition period, the CF-18 will experience a gradually decreasing level of operational availability until the transition to the new fleet is well underway and the new fleet has achieved an adequate measure of operational capability. Depending on the option selected, there could be four to nine years of reduction in the operational capability of the Royal Canadian Air Force's fighter force.

Summary of CF-18 Estimated Life Expectancy Findings

An Estimated Life Expectancy of 2025 represents low to medium technical and operational risk. On the other hand, an Estimated Life Expectancy target beyond 2025 would require unique structural investments to maintain the fleet's airworthiness. A 2025 extension mirrors the US Navy and Marine Corps' planned withdrawal date for their F/A-18 fleet. That fleet comprises approximately 630 aircraft, almost ten times the size of the Canadian Hornet fleet and almost two-thirds of all the original model F/A-18s still in use around the world. Once the US drawdown begins in earnest, Canada's sustainment of its fleet will become more difficult and costly with less access to repair and overhaul facilities or to US-produced spare parts for purchase.

An estimated life expectancy of 2030 is technically feasible. However, it represents a far more risky endeavour. This option would require the entire fleet to undergo significant structural refurbishment investments and procurement of wings and flight controls. This option is a high-risk one. There would also be increasing uncertainty from a cost perspective. From an operational point of view, the fleet would be exposed to a more lethal threat environment, leading to decreasing operational effectiveness and survivability. In addition, there would be decreased interoperability with newer aircraft flown by Canada's allies.

5. Bridging and Mixed Fleet Analysis

In order to assess all available options to sustain a Canadian fighter capability, a bridging/mixed fleet analysis was conducted. This analysis evaluated the implications of either (a) acquiring a temporary or interim fleet of aircraft or (b) a long-term acquisition of more than one type of aircraft to accomplish the missions outlined in the *Canada First* Defence Strategy.

Terminology

Bridging and mixed fleet options are two distinct concepts. A bridging option is a short-term solution to ensure that there is no gap in fighter capability as Canada makes the transition from the CF-18 fighter fleet to the replacement fleet.

A mixed fleet option, on the other hand, is concerned with the acquisition, operation and support of two new fleets of aircraft, one more capable than the other, to replace the CF-18 before the CF-18 reaches its estimated life expectancy.

Bridging to a Replacement Fighter: The CF-18

In April 2012, when the Government announced the Seven-Point Plan, it was anticipated that after 2020, the CF-18 would no longer be able to fulfil the tasks assigned by the Government of Canada. Further, it was assumed that a replacement fighter would not be in place until 2025. A possible result would be a capability gap and, consequently, the need for an interim capability to bridge that gap. However, as the Commander of the Air Force indicated to the Standing Senate Committee on National Security and Defence on March 25, 2013, the Royal Canadian Air Force determined that it was possible to fly the CF-18 through 2020 with upgrades already in place and using management tools at the commander's disposal. In this context, there was no need to pursue a bridging option. In addition, as noted in the previous section, the work done on CF-18 estimated life expectancy has shown that it is possible, with certain investments, to fly the CF-18 to 2025 and even beyond.

Mixed Fleet Analysis

The idea of a mixed fleet is not new to Canada. Prior to the introduction of the current CF-18 fleet, the Royal Canadian Air Force operated three separate fighter aircraft: the McDonnell Douglas CF-101 Voodoo, the Canadair CF-104 Starfighter, and the Canadair CF-5 Freedom Fighter. With the introduction of multi-role fighters like the CF-18, nations such as Canada have moved away from the operation of mixed fleets towards the operation of a single multi-purpose fleet, capable of fulfilling a number of fighter aircraft functions at a reduced cost associated with training and maintenance support.

That said, there are still countries that operate mixed fleets of fighter aircraft by choice. In particular, some countries with large air forces have chosen to employ a "high-low" mix that include a larger number of cheaper, less capable aircraft along with a smaller number of more expensive, more capable aircraft. The US Air Force, for example, has long employed this model with the McDonnell Douglas F-15 Eagle and the General Dynamics F-16 Falcon.

Australia initially acquired its F/A-18 Super Hornets as a "bridge" between the retirement of its F-111 Aardvarks and the planned procurement of up to 100 F-35 Lightning-II Joint Strike Fighters. It has since decided to operate a mixed fleet of 24 F/A-18 Super Hornets and 12 E/A-18 Growlers (specialized for electronic warfare) alongside its F-35s.

Methodology
The viability of a mixed fleet was assessed through the use of the Air Force Structure Analysis (ASTRA) model. The ASTRA model was used to calculate the resources, in both aircraft and pilots, needed to meet the *Canada First* Defence Strategy commitments for a fighter aircraft, using the single fleet and the mixed fleet options respectively. The ASTRA model did not take into account additional concerns, such as the technological risks involved in implementing one solution or the other.

The calculations were based on real-world figures supplied during consultations with the fighter community. Domestic requirements were completed on the basis of the NORAD agreement. Requirements for expeditionary missions were calculated on the basis of Canadian Armed Forces commitments to NATO.

The analysis did not assess every combination of available fighter options. Instead, the analysis was based on an assessment of a generic combination of two fighters capable of fulfilling NORAD

and NATO commitments and in keeping with the roles and missions identified by the *Canada First* Defence Strategy.

The analysis was based on a number of assumptions, including:

- A minimum of 65 fighter aircraft is needed to meet the mission requirements that are outlined in the *Canada First* Defence Strategy.
- Of the two aircraft types in a mixed fleet, one would be a lower-capability, lower-cost aircraft that could complete NORAD missions but not all NATO missions. The other platform would be of a higher-capability, most likely a higher-cost fleet, capable of completing all NORAD and NATO missions.

Summary of Bridging and Mixed Fleet Analysis Findings

The analysis found that a mixed fleet of higher capability aircraft able to fulfil the most challenging NATO missions and lower capability aircraft able to fulfil Canada's NORAD obligations totalling more than 65 aircraft could not provide the same overall capability as the single fleet of 65 higher capability aircraft. Moreover, there was strong evidence that unless the purchase cost of the fleet of lower-capability aircraft was half the purchase cost of the fleet of higher-capability aircraft, a mixed fleet would provide less capability at a higher cost.

6. Fighter Capabilities Available on the Market

Market Analysis: Objective

A key element of the evaluation of options was a market analysis. A market analysis is a standard tool to assess rough and non-binding market price and availability. The activities conducted during a market analysis are considered an initial step in any procurement process. Such an analysis surveys companies, both through formal consultations and using open-source information, to determine what these companies are able to provide and how much the procurement may cost. Information received from a market analysis is considered preliminary, since that information cannot be fully verified or validated and is not subject to a contractual agreement.

The market analysis was undertaken to obtain the most comprehensive and up-to-date information on each available aircraft. It was driven by the principles of fairness, openness and transparency to ensure that companies were given the opportunity to present the best available information on their respective fighter aircraft.

The Royal Canadian Air Force used the information provided by the participating aircraft manufacturers in the market analysis for its assessment of each fighter aircraft against each of the missions outlined in the *Canada First* Defence Strategy over a full life period expected to be at about 40 years. This information was augmented with open source and government-to-government information.

Industry Engagement

Ongoing engagement with the aircraft manufacturing industry through the National Fighter Procurement Secretariat was a key aspect of the Seven-Point Plan's principle of transparency.

A major part of the market analysis was three questionnaires referred to as Industry Engagement Requests (IERs). The first pertained to platform capability and to the manufacturer's production and supportability of the aircraft. This information was used in the Royal Canadian Air Force's evaluation of options. The second Industry Engagement Request asked questions pertaining to pricing. The third dealt with benefits to Canadian industry. All the questionnaires as well as other information related to industry engagement were made available publicly on the National Fighter Procurement Secretariat's website.

Companies were given the opportunity to help shape the information-gathering methodology. They were invited to provide comments on draft questionnaires and briefed on the methodology that would be used to assess the company's inputs. On the basis of the comments and questions they posed, the questionnaires were revised before being sent out in final form.

The Secretariat submitted requests for additional information to clarify industry inputs and to ensure a consistent level of information from companies. The companies were assured that they would be briefed at the end of the process on the assessment of their respective aircraft. They were also assured that information of a commercially sensitive or a classified nature would not be released publicly.

Capability, Production and Supportability

Capability

Companies were requested to provide detailed information on the technical capabilities of their fighter aircraft and associated support elements to sustain the fleet throughout its lifespan. They were asked to describe the capability of their weapons systems in the 2020-2030 and beyond 2030 time horizons and in the context of the indicative threats included in each horizon. In responding to the questionnaire, each company was asked to provide basic aircraft configurations, including weapons, for air-to-air, air-to-ground and anti-surface warfare missions.

The companies were informed of the aerospace capabilities that would be used to evaluate their respective aircraft. These capabilities were derived from Canadian aerospace doctrine and the mission needs analysis discussed previously in the Canada's Defence and Security Requirements section of this report.

The fighter aircraft systems about which companies were asked to provide details included weapons, sensors, communications, engine and mainframe, range and endurance, and radar/electronic signature.

Production and Supportability

Companies were also asked to provide information on their respective aircraft with regard to production and supportability. Production refers to issues related to the acquisition of the aircraft within the timeframes provided in the questionnaire. Supportability refers to the maintenance and logistics support to the aircraft over the lifespan of the fleet.

Questions on production and supportability covered the following six areas:

- *Procurement*: oriented towards understanding a) when Canada would be able to procure aircraft, b) possible buy profiles (aircraft per year), and c) any risks to on-time delivery of aircraft with the needed capabilities.
- *Supportability and connectivity*: oriented towards understanding the potential issues that Canada would need to assess regarding the long-term sustainability of the aircraft, management of the fleet, and the associated personnel (especially pilots and maintainers); assurance of continued operational capability; and interoperability within the Canadian Armed Forces and with allies.

- *Additional supportability issues*: related to product support of the fighter aircraft.
- *Growth potential*: oriented towards understanding the potential of the aircraft to accommodate future unforecasted technological developments and/or capability enhancements.
- *Global systems integration*: related to the aircraft's interoperability with other systems, such as communications networks and air-to-air refuellers, within the portfolio of the Canadian Armed Forces and/or allied forces for global deployability, employability, and supportability.
- *Safety*: regarding details that contribute to the operational safety of the pilot and the weapons system.

Participating Fighters

Companies with fighter aircraft currently in production, or scheduled to be in production, were invited to participate in the market analysis. Fighters that were not compatible with weapons systems used by Canadian allies, principally the United States and other NATO countries, were not considered suitable for consideration in the market analysis.

On December 27, 2012, on the basis of the foregoing criteria, an introductory letter was sent to five companies.

Four companies agreed to participate in the market analysis and provided responses to the Industry Engagement Requests:

- The Boeing Company – with the F/A-18 Super Hornet;
- Dassault Aviation – with the Rafale;
- Eurofighter – with the Typhoon; and
- Lockheed Martin – with the F-35 Lightning II Joint Strike Fighter.

The fifth company, SAAB, made a business decision not to participate in the market analysis and as a result of that decision, information on the SAAB Gripen did not form part of the assessment.

7. Methodology

The assessment methodology was designed to articulate the risks associated with various options for replacing Canada's CF-18 aircraft in their ability to successfully execute the missions outlined in the *Canada First* Defence Strategy.

To ensure that the outcome would be credible, the assessment of options used a process designed to be as fair as possible to all industrial respondents. For example, industry was consulted on the Capability, Production and Supportability Questionnaire and companies were briefed on the methodology in advance of the assessment.

The following characteristics were deemed essential to the methodology and guided the choices made during its development:

- *Impartial*: The methodology used would not favour any of the aircraft. It would be neutral in its application and consistently applied to all aircraft considered.

- *Comprehensive*: The methodology needed to consider all aspects of fighter use along with the factors that enable the fighter operations. A comprehensive methodology would provide less opportunity for bias in the overall assessment of the fighter replacement options.
- *Understandable:* By being understandable both in its structure and in its application, the methodology would allow its findings to be easily traced back to the appropriate evidence, including points where professional military judgements were used. Defensibility of its conclusions additionally would provide credibility to the methodology being used.
- *Robust*: A robust methodology would allow it to be applied without failure under a wide range of conditions. It is important that it do so without sacrificing analytical rigor. In the context of this methodology, robustness included the ability to use proprietary or classified information as part of the evaluation process. The methodology would also be replicable so that its conclusions remained consistent even if the assessors had changed or if the assessment process were to be carried out a second time.

Evaluation Framework

A foundational element for the methodology was the mission needs analysis. This analysis was based on previous Department of National Defence analyses of overall Canadian Armed Forces capability, and resulted in fighter mission scenarios, aerospace capabilities, and Measures of Effectiveness that are consistent with existing Department of National Defence guidance and documentation.

The methodology was applied to fighter operations occurring in two timeframes. The first is 2020-2030, the period during which the Royal Canadian Air Force will transition its fighter force from the CF-18 to its new aircraft. The second is beyond 2030, when it is expected that there will be increased proliferation of existing threats in addition to the introduction of new and upgraded threats. Both sets of threats make operating within this latter period more challenging. The feasibility and expected costs of safely operating the CF-18 beyond 2020 were carefully analyzed as part of the overall assessment.

Operational Capabilities Assessment
The starting point for the operational capabilities assessment was a tactical-level assessment, which evaluated each aircraft on the basis of its technical capabilities, relative to the leading edge technology in existence and irrespective of any mission context (Measures of Performance). Following this, each aircraft was assessed in terms of the contribution its technical capabilities make to specific aerospace capabilities expected of a fighter aircraft (Measures of Effectiveness).

At the operational level of the assessment, the aircraft were placed into fighter mission scenarios representative of the six *Canada First* Defence Strategy missions. This component of the evaluation assumed that the conditions required to use the fighter in its operational role are in place (such as availability of training, infrastructure and support). The output was a risk assessment describing each aircraft's ability to execute the *Canada First* Defence Strategy missions in both timeframes, mitigated using any means at the Royal Canadian Air Force's disposal. These mitigations needed to be reasonable in their application; for example, risks could not be removed simply by upgrading aircraft systems at significant additional cost. Regardless, the mitigations proved to be extremely important because they allowed for a more commonsense application of fighter assets to the mission scenarios.

Critical Enabling Factors Assessment
The critical enabling factors assessment built off the operational-level assessment by examining all the conditions which need to be in place for the fighter to perform its functions.

Risks were identified relative to four critical enabling factors:

- *Aircraft acquisition*: manufacturer's planned aircraft production periods and delivery dates; completion of any additional developmental work specific to Canadian requirements before an aircraft is ready for acceptance.
- *Supportability and force management*: long term availability of spare parts, equipment and engineering need for aircraft maintenance; infrastructure; commonality of parts, equipment and weapons with allies; software reprogramming to correct deficiencies and adapt to changing threats and operational environments.
- *Integration*: ability to connect with other Canadian Armed Forces/Government of Canada networks for communications, air-to-air refuelling assets within the Canadian Armed Forces or allied portfolios, and common ground/spares systems with allies.
- *Growth potential*: ability and feasibility of implementing system upgrades to preserve the aircraft's operational relevance in view of future advances in threat technologies and capabilities.

These four factors emerged during the evaluation of options as critical in assessing the risk to mission success over the longer term, because they affect the ability to acquire the aircraft in a timely fashion and maintain its operational relevance throughout its service life. For example, without access to spare parts and technological upgrades, the operational effectiveness of the aircraft would diminish, thereby affecting the ability to employ the aircraft to complete *Canada First* Defence Strategy missions. Once again, assessors applied measures to mitigate risks when deemed to be within the control of the Royal Canadian Air Force and/or Department of National Defence.

Integrated Assessment
The integrated assessment combined the operational and critical enabling factors into an overall mission risk assessment for each individual aircraft in each timeframe against each of the six missions. It is important to note that, since some risks had a greater or lesser effect on a particular mission and/or timeframe, the combined risks in each case did not necessarily reflect an average or mean of the operational and critical enabling factors risk assessment.

Subject-Matter Expertise

In the absence of being able to fly the aircraft under the conditions specified in the fighter-mission scenarios, the expert judgment of subject-matter experts was a critical component of the assessment process. Breaking down *Canada First* Defence Strategy missions into components helped ensure that appropriate subject-matter experts could be identified and that these experts were never asked to evaluate anything outside of their area of specialty. Multiple assessment teams were also used whenever feasible. This added a variety of opinions and helped reduce the possibility of groupthink. Also, subject-matter experts were required to provide substantiation to validate each of their assessments and their findings were scrutinized by the Independent Review Panel.

For a more detailed description of the methodology, please see the National Fighter Procurement Secretariat website at: http://www.tpsgc-pwgsc.gc.ca/app-acq/stamgp-lamsmp/snac-nfps-eng.html.

8. Capabilities of Available Fighter Jets

The purpose of this section is to provide a high-level description of the Royal Canadian Air Force assessment findings while respecting applicable non-disclosure agreements with other governments and industry. As previously stated, in order to respect commercial sensitivities, the assessment findings are presented as a general range and aircraft are not identified.

The findings are organized following the three parts of the assessment, first an operational level assessment, followed by a critical enabling factors assessment, and finally an integrated mission risk assessment.

For the purposes of the assessment, *Canada First* Defence Strategy mission four (assistance to civil authorities in Canada) was not included as it would not be expected to entail a requirement for fighter aircraft. *Canada First* Defence Strategy mission five (lead and/or conduct an international operation for an extended period) was divided into two types of missions: a peace enforcement mission and a state-on-state war fighting mission. Peace enforcement operations were understood to be comparable to the type of missions that Royal Canadian Air Force fighter aircraft undertook in Libya in 2011. State-on-state war fighting, on the other hand, would involve Canadian fighter aircraft taking part in coalition combat operations against a near-peer competitor, such as might hypothetically occur on the Korean peninsula.

The purpose of the assessment was to evaluate the risk associated with each fighter's ability to complete the missions outlined in the *Canada First* Defence Strategy. The assessment began at the operational level where each aircraft's performance was assessed against six representative *Canada First* Defence Strategy mission scenarios over two time periods (2020-2030; and beyond 2030). This was followed by a critical enabling factors assessment that looked at measures necessary to maintain the operational relevance of each aircraft over its life cycle. The integrated mission risk assessment combined these two risks to produce an overall level of risk for each aircraft for each mission across the two time periods. While the differences between aircraft were relatively modest in the first timeframe, these differences grew in the second timeframe mainly due to the cumulative impact of the critical enabling factors.

Operational Capabilities Assessment

During the first part of this process the assessment team of senior Royal Canadian Air Force officers focused on assessing risk for each of the four aircraft in relation to the roles expected of a Royal Canadian Air Force fighter aircraft, as identified in the *Canada First* Defence Strategy mission scenarios.

Each fighter was assessed in the areas of:

- *Awareness*: The ability to gather, assimilate and display, to the pilot, real-time information from onboard sensors. Awareness is largely dependent on the fidelity of the information and the capability of the sensors. In addition, the capability to automatically combine and display comprehensive information, derived from separate inputs, produced from multiple sensors, is beneficial.

- *Survivability*: The ability to operate within the operational battle space by denying or countering the enemy's application of force. Survivability can be increased by detecting, classifying, and locating threats and subsequently evading them or negating their effectiveness. Once alerted to a threat (by the use of onboard detection and warning systems), the pilot can counter threats by a variety of active or passive means. "Active"

includes but is not limited to the use of electronic attack measures, jammers and decoys. “Passive” includes but is not limited to the employment of aircraft signature reduction measures, aircraft manoeuvre, and the use of chaff/flares.

- *Reach and Persistence*: The distance and duration across which a fighter aircraft can successfully conduct the mission. Factors such as speed, endurance, range, and the ability to carry additional fuel (external fuel tanks and/or the ability to refuel in the air) also contribute to reach and persistence.

- *Responsiveness*: The timely application of air power, including the ability to shift from one target to another while prosecuting multiple targets within the same mission; the ability to seamlessly change from one mission to another; and the ability to conduct more than one function simultaneously. For example, while conducting a Defensive Counter Air mission, can a given aircraft also contribute to the intelligence, surveillance and reconnaissance situational awareness of participants within the overall mission? Also, the speed at which an aircraft can re-target, re-role, and re-position within the area of operations should be considered.

- *Lethality*: The ability to negate/prosecute a target or threat via a variety of kinetic (the use of weapons) or non-kinetic (the use of electronic warfare systems) means. This may include the support and use of other onboard sensors and systems. This area includes the assessment of aircraft sensor and weapons capabilities.

- *Interoperability*: The ability to operate with and exchange information with friendly forces in order to contribute to mission success. Interoperability with national and coalition ground, sea and air assets is critical. As an example, this interaction can include, but is not limited to, the use of secure, jam resistant data and voice communications system.

Each aircraft’s capabilities were assessed over the two timeframes, 2020-2030 and beyond 2030. The assessment used both current and planned capabilities of the aircraft and assumed that planned technological improvements would be in place as outlined by the manufacturers. The risk ratings took into consideration potential mitigation measures, such as changing the way in which a particular aircraft is employed during the course of the mission. Where risk mitigation was within the control of the Royal Canadian Air Force and/or the Department of National Defence, the mitigation was applied and the ratings reflected the residual risk. For mitigating measures outside of Royal Canadian Air Force and/or Department of National Defence control, potential mitigations were identified but were not applied, leaving the risk ratings unchanged.

Summary of Operational Assessment Findings

As the table below indicates, all aircraft were assessed as low to medium risk in terms of their ability to accomplish five of the six *Canada First* Defence Strategy missions. This was due to the fact that most of these missions involve a relatively low level of threat and are less onerous for fighter aircraft. In contrast, in the state-on-state war fighting mission, the range was from low to significant in the first timeframe and medium to high in the second timeframe. This was largely due to the higher level of potential threat confronting fighter aircraft in that mission and the evolution of those threats from the first to second timeframe.

Range of Risk Ratings: Operational Assessment		
Missions	**2020-2030**	**Beyond 2030**
Defence of Canada	Low to Medium risk	Low to Medium risk
International Event in Canada	Low to Medium risk	All aircraft were rated as Low risk
Terrorist Attack	All aircraft were rated as Low risk	All aircraft were rated as Low risk
Peace Enforcement	Low to Medium risk	Low to Medium risk
State-on-State War Fighting	Low to Significant risk	Medium to High risk
Humanitarian Assistance/Disaster Relief	All aircraft were rated as Low risk	All aircraft were rated as Low risk
Risk Scale: Low, Medium, Significant, High, Very High		

Critical Enabling Factors Assessment

For the second step of the process, the same senior team that conducted the operational level assessment assessed mission risks through the lens of four high level critical enablers: acquisition, supportability and force management, integration and growth potential. During this stage of the assessment, the focus shifted to the various risk factors associated with maintaining a fighter's full operational capabilities over its entire life cycle.

Professional military judgement played a greater role at this stage of the process due to the uncertainty involved with future aircraft production, supportability and upgrade plans as well as the challenges in quantifying these risks. Assessors applied measures to mitigate risks when deemed to be within the control of the Royal Canadian Air Force and/or Department of National Defence. Some factors, such as other countries' fighter acquisition plans or the manufacturer's plans for technological improvements, were not within the Royal Canadian Air Force's ability to influence.

The assessment of risks associated with the procurement and sustainment of the aircraft during the 2020-2030 and beyond 2030 timeframes revealed a number of risks that must be considered when acquiring a replacement fighter for the CF-18. It is expected that a replacement fighter will be in service well past 2030; therefore, the second time period will represent the majority of the next fighter's service life. During the second time period the future is far less certain from the perspective of potential threats employing advanced technologies that will need to be countered with a credible and operationally relevant Canadian fighter. Nonetheless, given the steady advancement of technology and continued likely proliferation of weapons systems, representative threat scenarios were used for the evaluation in the second timeframe.

Summary of Critical Enabling Factors Assessment Findings
In the first time period, 2020-2030, there was a range of risk ratings assigned to different aircraft related to their respective delivery schedules, growth potential, developmental forecast as well as time to resolve integration issues and to accommodate Canada-unique requirements. The risks assessed for each aircraft varied according to when the aircraft would be available for delivery as well as the time necessary to resolve long lead-time issues such as cold weather testing and integration of Canadian-specific requirements in addition to the normal time required for aircraft assembly. This risk could be partially mitigated by a CF-18 life extension, but the technical and schedule risks of the life extension program itself become high at a certain point.

The assessed risk in the second time period, beyond 2030, generally increased for most fighters due to current expectations regarding the overall number of each aircraft being operated on a global basis, which had an impact on the serviceability rates related to access to spare parts and support, as well as growth potential related to planned or expected technological improvement plans. Economies of scale affect the shared risk, resources and expertise required for the resolution of aircraft engineering deficiencies and management of obsolescence issues. Economies of scale also affect development of improved capabilities and software reprogramming in response to a changing threat environment. Without the ability to effectively support and sustain a fighter's relative capabilities over the life of the aircraft, there is increased risk to its ability to successfully complete assigned *Canada First* Defence Strategy missions.

Range of Risk Ratings: Critical Enabling Factors Assessment

Missions	2020-2030	Beyond 2030
Defence of Canada	Medium to Significant risk	Low to High risk
International Event in Canada	All aircraft rated as Medium risk	Low to Medium risk
Terrorist Attack	Low to Significant risk	Low to Significant risk
Peace Enforcement	All aircraft were rated as Medium risk	Low to Significant risk
State-on-State War Fighting	Medium to Significant risk	Low to High risk
Humanitarian Assistance/Disaster Relief	All aircraft were rated as Low risk	All aircraft were rated as Low risk

Risk Scale: Low, Medium, Significant, High, Very High

Integrated Mission Risk Assessment

During the third and final part of the process, the assessment team combined the operational and critical enabling factors risk assessments into a single overall mission risk for each aircraft, over the two timeframes and for each of the six *Canada First* Defence Strategy missions. This stage was informed by guidelines provided to Royal Canadian Air Force assessors as well as by their own professional military judgement.

Assessors applied measures to mitigate risks when deemed to be within the control of the Royal Canadian Air Force and/or Department of National Defence. During the assessment it was assumed that two issues beyond the control of the Royal Canadian Air Force – namely, the replacement of aircraft lost in the course of non-combat use (attrition) and the ability to integrate alliance intelligence data on the aircraft – would be dealt with successfully by the Government. If these assumptions had not been made, the two issues would have increased some of the risk assessments.

Summary of Integrated Mission Risk Assessment Findings

The integrated assessment demonstrated that although the operational capabilities of the aircraft under consideration were essential factors for consideration, as the assessment progressed, it became apparent that the critical enabling factors that ensure the operational relevance of the aircraft over its life were of greater material impact to the integrated risk rating.

Range of Risk Ratings: Integrated Assessment		
Missions	**2020-2030**	**Beyond 2030**
Defence of Canada	Low to Significant risk	Low to High risk
International Event in Canada	Low to Medium risk	All aircraft were rated as Low risk
Terrorist Attack	Low to Significant risk	Low to Significant risk
Peace Enforcement	Low to Medium risk	Low to Significant risk
State-on-State War Fighting	Medium to High risk	Medium to Very High risk
Humanitarian Assistance/Disaster Relief	All aircraft were rated as Low risk	All aircraft were rated as Low risk
Risk Scale: Low, Medium, Significant, High, Very High		

9. Cost and Pricing

Objective

The Government commissioned KPMG to develop a Life-Cycle Cost Framework based on international and Government of Canada best practices, which was used as a basis to develop the cost estimates for acquiring 65 F-35A jets presented in Annual Updates by the Department of National Defence. The Framework divided life-cycle costs into broad cost categories: development, acquisition, sustainment, operating, disposal and attrition.

This Framework was used to inform the market analysis conducted as part of the evaluation of options. In particular, the market analysis included an Industry Engagement Request on price (pricing questionnaire) that sought information from companies in five broad cost categories: acquisition, sustainment, operating, disposal and attrition. Consistent with the Framework's recognition of the need to base cost estimates on the purpose for which it will be used, the pricing questionnaire sought rough order of magnitude, non-binding cost information, as appropriate for a market analysis.

Companies were asked to provide comments on the contents and scope of a draft pricing questionnaire prior to its finalization. Early engagement allowed companies to put forward all information relevant to the fair representation of pricing information, and supported a full and fair assessment of all options.

Assumptions

To ensure consistency, the pricing questionnaire provided companies with a number of identical assumptions so that they could generate estimates that were broadly comparable.

These assumptions were:

- *Acquisition*: 65 aircraft to be delivered in 2020.
- *Sustainment* (e.g. repair and maintenance): aircraft would be maintained for 30 years (2020-2050) and that the 65 aircraft would be flown 11,700 hours per year.

- *Operating*: the Department of National Defence provided fixed operating costs common to any aircraft fleet, such as pilot salaries and base support; companies were also asked to assume an annual flying rate of 11,700 hours.
- *Disposal*: Department of National Defence provided a fixed cost estimate to dispose of 65 aircraft in 2050.
- *Attrition* (replacement of aircraft lost during non-combat use): no assumptions were provided by the Department of National Defence in this category.

Methodology

Based on the assumptions provided to them by the Department of National Defence, companies then calculated the rough order of magnitude life-cycle cost estimates with inputs on their respective aircraft for each of the cost categories as follows:

- *Acquisition*: unit costs per aircraft – i.e. “unit recurring flyaway” (URF) costs
- *Sustainment*: cost of spare parts, maintenance and labour
- *Operating*: aircraft fuel consumption rate (“burn rate”)
- *Disposal*: no aircraft-unique costs in this category
- *Attrition*: historical attrition rate and cost per replacement aircraft.

In addition to this information, companies were asked to explain their assumptions regarding inflation and were provided a foreign exchange rate based on Bank of Canada historical rates. Companies were also asked whether the estimates were based on historical data (i.e. actual costs), or projections based on the best information available at the time. The pricing questionnaire requested estimates in Current Year (CY) 2013 Canadian dollars and nominal 2020 Canadian dollars – that is, future year dollars adjusted for inflation.

Once received from companies, cost information was reviewed to ensure that it was broadly comparable and consistent with what was requested in the price questionnaire. To ensure consistency, the cost estimate used for Lockheed Martin followed the same parameters provided to the other companies rather than the estimate provided in the Department of National Defence Annual Update, which is more detailed than what would normally be expected as part of a market analysis.

Summary of Cost and Pricing Findings

For fighter aircraft in general, the largest share of the costs over the life cycle of the fleet lies in operations and sustainment, even more so than acquisition. As with any long-range life-cycle cost estimates, these cost estimates are subject to further refinement as requirements are better defined. While there was a variance in the cost estimates provided by companies, the specific figures provided by each company cannot be identified due to commercial sensitivity. As these cost variances could be material to decision makers, more detailed cost information has been presented to the Government to inform a decision on the way forward.

10. Conclusion

The evaluation of options was a key component of the Government's Seven-Point Plan for the replacement of the CF-18 fighter aircraft fleet. Consistent with the principles of openness and transparency, which have been the guiding principles of the entire Seven-Point Plan process, this report discloses as much information as possible about the evaluation of options while respecting the non-disclosure agreements with other governments and industry that were needed for a comprehensive evaluation like this to succeed. Aircraft are not specifically identified in order to respect commercial sensitivities.

Conducted over a 14-month period, the evaluation was based on a comprehensive and rigorous methodology that involved subject matter experts from throughout the Royal Canadian Air Force and the Department of National Defence. The starting point for the assessment was the Government's *Canada First* Defence Strategy, which outlines the roles and missions expected of the Canadian Armed Forces. The purpose of the assessment was not to compare the four aircraft that participated, nor was it meant to identify the best option. Rather, it was to present a summary of risk-based assessments.

In addition to the market analysis of four fighter aircraft from companies that agreed to participate in the market analysis, the evaluation also included an analysis related to CF-18 Estimated Life Expectancy as well as a bridging and mixed fleet analysis.

The evaluation was based on available information received directly from companies through three Industry Engagement Requests, supplemented by government-to-government and open source information. The methodology was briefed to companies prior to the start of the assessment and companies were given the opportunity to comment on and influence draft industry engagement requests and provide their most up-to-date information.

The process was designed to be fair to all companies and included a high degree of traceability so as to ensure that there was a clear line linking findings with the information on which they were based. The assessment included the application of professional military judgment by Royal Canadian Air Force officers with experience in fighter operations and fleet management. Mitigation measures were applied for each aircraft where risk factors were within the Royal Canadian Air Force's control, such as how the aircraft were employed to accomplish a particular mission.

The entire evaluation included a strong element of third party oversight by the Independent Review Panel, which reviewed the methodology at the outset as well as every step of the assessment process. Key issues that arose during the assessment were brought to the Panel for its input and advice. The Independent Review Panel ensured that the process was rigorous and impartial and that results were comprehensive and understandable.

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.