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Transformation of Canada's Fighter Capability: A Generational Perspective

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History and historical analysis can prepare the RCAF as an institution for inevitable change, specifically on transitions initiated by advancements in the science and technologies of air power. Having personally experienced the transition from CF-104 to the CF-18 fighter aircraft during the Cold War and with the incorporation of the F-35 Joint Strike Fighter (JSF) underway in the RCAF, there are informative accounts to be told and lessons learned that may require reflection in the transition from fourth to fifth generation fighter.[1] With peer-on-peer great power competition re-emerging as a geo-political reality, there are many aspects of Canadian fighter operations and capabilities that do not have to be relearned.

War is a political condition between states or armed factions; warfare is the physical activity conducted between militaries in the context of war. "Technology shapes warfare, not war, …and conversely war, not warfare, shapes technology. Technology has been the primary source of military innovation throughout history. It drives changes in warfare more than any other factor."[2] Military technology is not deterministic as

[1] In this essay, the CF-104 is considered a third-generation fighter, the CF-18 a fourth-generation fighter, and the F-35 a 5th generation fighter. However, some analysts categorize the CF-104 as a second-generation fighter.

[2] Alex Roland, *War and Technology*, *Foreign Policy Research Institute*, 27 Feb 2009, online at https://www.fpri.org/article/2009/02/war-and-technology/ .

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advancements do not ensure success, but rather, technology facilitates innovation. The unique characteristics, or distinguishing features, of the air environment, provide air power with different strengths and weaknesses from those of sea and land power. Fundamental air power tenets, or organizational principles, ensure the optimization of air power. These characteristics and tenets do not change with technology but rather technology is used to optimize these features to gain advantage.[3]

The advent of the airplane not only introduced a third dimension to warfare, but the dual-use technology revolutionized societies through advancements in air transportation. While continental Europe focused on the development of fighter aircraft in the aftermath of World War I, the United States (US) and Great Britain were guided by Italian air power theorist Giulio Douhet in developing strategic bombers. This also coincided with the need for commercial aircraft with the same capabilities. Commercial technological innovation together with military research and development provided the ways and means for continuous improvement in air power capabilities in the interwar years. "Technology and airpower are integrally and synergistically related…. Airpower depends upon the most advanced developments in aerodynamics, electronics, metallurgy, and computer technology."[4] As flight posed more technological challenges than warfare on either land or sea, air forces established an organized model of institutionalizing innovations in military technology and pioneered scheduled obsolescence on a cycle shorter than the other services. "Even before one generation of airplanes was operational, its replacement was under development."[5]

In this essay, I will discuss the transformation of the RCAF's fighter capability through the transition from third to fourth generation fighters to the current transition from fourth to fifth generation. Without focusing on the specific technological definitions that differentiate these generations, they can simply be characterized as technological advancements in fighter capabilities that moved from the analogue to the information to the digital age of human endeavour. Historical methodology identifies the importance of

[3] Canada, Department National Defence (DND), *Royal Canadian Air Force Doctrine*, B-GA-400-000/FP-001, Commander Royal Canadian Air Force, fourth Edition, 21 August 2023.
[4] Colonel Phillip S. Meilinger, "Ten Propositions Regarding Airpower", *Air Power Journal 10*, no. 1, Spring 1996, Air University Press, Maxwell AFB, pp. 67-68.
[5] Alex Roland, *War and Technology: A Very Short Introduction*, Oxford University Press, New York, 2016, p.64.

putting research into the perspective of the day as it contextualizes the subject's worldview. To understand the technology of the CF-104 era and the mindset it engendered, one must visualize the constraints and limitations of the worldview of the time. Military college students were issued a slide rule (a hand-operated mechanical calculator) for mathematical calculations with the option to purchase a basic handheld electronic calculator that was recently on the market. In fighter operations, hours were spent in mission planning hand drawing lines on a map for tactical missions as there was no integral mission-centric navigation system onboard the CF-104 until just prior to decommissioning. Analogue stopwatches were Velcroed to the instrument panel to provide timings in navigation using a watch-map-ground technique [6] and briefings were presented on chalkboards and overhead projectors. Whiteboards were a new technology introduced with the CF-18. Telephone landlines were still used in the CF-104 days of the early 80s, so it is not too hard to see how much society and the way we function changed with the introduction of the flip phone in the 90s, allowing personal mobility, to the smartphones we use today that has been transformational in the way every aspect of business is conducted wherever we happen to be.

Organizationally, the Canadian Armed Forces (CAF) are divided into Force Generators, which 'own' (*sic*) the personnel and equipment, and Force Employers, which are assigned capabilities to perform specific missions and operations.[7] Like the Canadian Army and Royal Canadian Navy, the RCAF is a Force Generator, and it is important to understand the responsibilities this role entails. Through a continuous, centralized process of air force development via the Vice Chief of the Defence Staff managed Defence Services Program, the Department of National Defence (DND) / CAF provides the essential personnel, infrastructure, and materiel for the RCAF to generate air and space capabilities. The force generation process comprises the ways and means for the

[6] Preplanned flight routes were drawn on paper maps with times marked at minute intervals for a given planned speed. Precise times of day were calculated back from a specified time-over-target to the beginning of the routing (the hack) to the time of day for take-off to the time to start engines to the time to walk to the aircraft. Once airborne at the predetermined time of day, the pilot would start the stopwatch over the *hack* and then navigate by looking for ground features that corresponded to the time marking on the map, correcting for timing and navigation continuously along the route until the target was made (watch-map—ground-watch-map-ground-…).

[7] See Canadian Armed Forces 101 accessed online 24 Oct 23 at https://www.canada.ca/en/department-national-defence/corporate/reports-publications/transition-materials/defence-101/2020/03/defence-101/caf-101.html

production, sustainment, and readiness of air and space power that meet the Government of Canada's direction. Both the force development and force generation processes are causal to the creation of capabilities that are necessary and sufficient to produce the air and space power effects needed to successfully meet the RCAF's assigned functions of Control of the Air, Air Attack, Air Mobility, Aerospace Intelligence, Surveillance, and Reconnaissance (ISR), and Space Operations.[8]

Capabilities do not simply appear; they must be developed and nurtured. Singular capabilities do not deliver military power per se but require a *system of systems* or a *fabric of capabilities* to meet operational needs. The procurement of the F-35 fighter aircraft, for example, is not a capability in and of itself; the platform is simply one component. To be considered a new fighter capability, the supporting doctrine, infrastructure, materiel, and equipment need to be in place with trained, effective personnel integrated into functioning units. Once combat readiness training has been achieved, this F-35 capability component will be integrated into other cross-functional air and space power capabilities, such as Air Battle Management, to enable the RCAF to meet one or more of its primary functions. This is an example of the process of force generation where the RCAF produces, sustains, and readies elements of air and space power capabilities for force employment.

The customary use of the term *capability* – the power or ability to do something - is widely used to describe many facets of military operations, and as with many words,

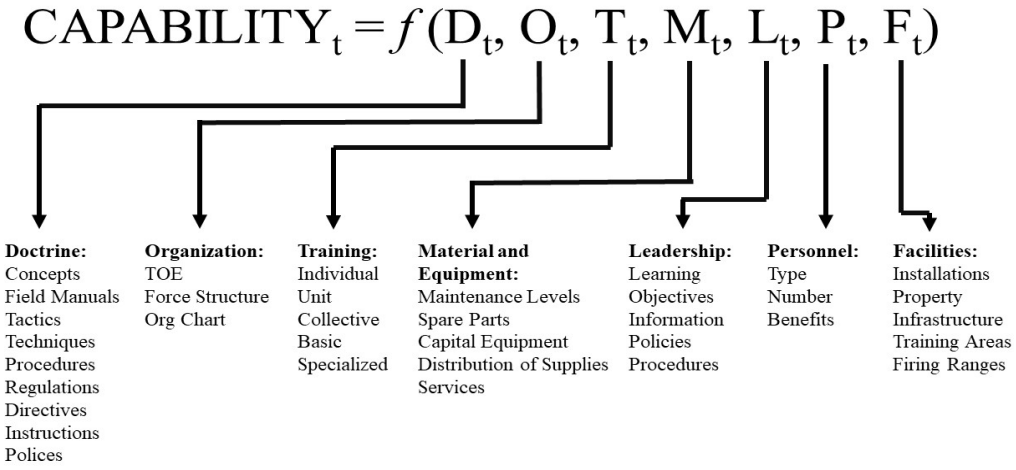

FIGURE 1 - CAPABILITY IS A FUNCTION OF ITS COMPONENTS

[8] See DND, B-GA-400-000/FP-001, RCAF Doctrine: Air and Space Power, 4th Edition, 21 August 2023.

a definitive overarching military definition is challenging as the lexicon varies with need. The accepted DND / CAF definition of capability is "the ability to create an effect through the employment of an integrated set of aspects categorized as doctrine, organization, training, materiel, leadership development, personnel, facilities, and interoperability"[9] and identifies the ingredients or variables required to produce a capability. The following equation was developed by the Institute for Defense Analyses[10] using multinational data including that of Canada to identify the factors that constitute a capability. The simplicity of this formula provides a means to understand that a capability is a function of multiple components. This visual synopsis shows that force generation of a capability is a function of seven variables where the *t* subscript identifies that a capability exists at a point in time greatly impacted by the technology available. It is from this framework that I will present an overview of how history and historical analysis can contribute to the current transition. Using each of these variables, I will provide an example of how the experience of the past transition from CF-104 to CF-18 can inform the present and hopefully provide insight into future developments.

Doctrine is often an afterthought at best or neglected at worst when enthusiasm for introducing advanced technology takes hold. There will be gaps that need to be addressed between where a given capability is technically feasible but its operational utility[11] is not useful in the demanding world of actual combat. Although the CF-104 was originally purchased and technically able to deliver nuclear weapons, doctrine changed as societal values constrained their use as contemporary socio-political factors will constrain the RCAF's use of the F-35. The introduction of Combat Collaborative Aircraft (CCA), a military uncrewed aerial vehicle with an onboard artificial intelligence control system capable of delivering a significant military weapons load, is but an emerging example. Moral and ethical questions on responsibility and accountability for weapons

[9] DND, Defence Terminology Bank, record 694720.
[10] Wade Hinkle et al, *Defense Governance and Management: Improving the Defense Management Capabilities of Foreign Defense Institutions*, Institute for Defense Analysis, March 2017, p.7. accessed 8 August 2023 at https://www.ida.org/-/media/feature/publications/d/de/defense-governance-and-management-improving-the-defense-management-capabilities-of-foreign-defense-institutions/p-5350.ashx
[11] Barry D. Watts, Doctrine, "Doctrine, Technology, and War", *Air & Space Doctrinal Symposium*, Maxwell AFB, Montgomery, Alabama, 1996 online at https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Chronicles/watts.pdf .

loads and concerns over intended targets may be legitimately raised as CCAs are intended to be paired as a force multiplier with manned fighters such as the F-35. Doctrinal implications will inevitably need consideration should CCAs eventually be offered for operational use by alliance partners in contingency planning or in determining future procurement by Canada.

The fighter force was consolidated from third-generation single-role fighters into one fleet of multi-role CF-18s. This required a significant cultural paradigm shift in operating concepts, tactics, techniques, procedures (TTPs), and policies. This became particularly evident in 1990 when the government decided to use the CF-18 for the first time in an expeditionary role as its coalition contribution to the Persian Gulf War. Contemporary fighter operations had been focused on two relatively predictable areas of responsibility (AORs), the North American Aerospace Defence Command (NORAD) and the North Atlantic Treaty Organization (NATO). However, the CF-18 fighter force sent to the Persian Gulf was able to adapt quickly and strengthened a seam between coalition land and sea AORs that resulted from United States military interservice conflicts.[12] The success of this doctrinal multirole operational flexibility, not present in third-generation fighter operations, was due in large part to the CAF unified military culture and to CF-18 pilots' training within both the United States Air Force (USAF) and United States Navy (USN) / Marine (USMC) fighter operations.

In all expeditionary combat operations in which the CF-18s have been engaged, they were armed with the latest beyond-visual-range (BVR) missile technology.[13] However, these weapons have never been used by Canada and are seldom employed by most 4th generation fighters due to doctrinal rules of engagement constraints that demand positive identification prior to BVR launch to avoid fratricide. This may change with the prospect of emerging technologies and advancements in F-35 target identification. "When it comes to destroying an enemy, an F-35 Advanced Electronically Scanned Array [radar] can see a threat object, a long-range infrared targeting sensor can produce a rendering of

[12] Richard Gimblett and Jean Morin, *Operation Friction: The Canadian Forces in the Persian Gulf*, Department of National Defence Directorate of History, Durham Press, Toronto, 1997, pp. 104-112.
[13] Barry D. Watts.

it, an onboard threat library database can positively ID the target and then precision-guided weapons can strike."[14]

Doctrine matters. It encompasses more than just technical manuals as it is rooted in social values that moderate operational utility. Initially, the doctrine for the F-35 will likely mirror that which our allies use, but sagacious thought needs to be exercised by the RCAF to put it into a Canadian context as early as possible.

Both the Canadian Armed Forces and the RCAF have seen significant changes in **Organization** over the past 50 years. Upon unification of the Canadian Armed Forces in 1968, the three services were merged and the RCAF lost its status as a separate legal entity. New unified commands were created where personnel and aircraft of the former RCAF were allocated between Mobile Command, Maritime Command, Air Defence Command, Air Transport Command, Training Command and Canadian Forces Europe (CFE). In 1975, consolidation of all air units occurred under a new CAF environmental command named Air Command, where all air force assets under the former CAF commands were reorganized into functional groups. With the repatriation of Canadian Forces Europe in 1994, 1 Canadian Air Division was stood up in Winnipeg to exercise operational command of all CAF air assets with the Commander of Air Command headquartered in Ottawa. In 2011, Air Command reacquired its original historic name, the Royal Canadian Air Force.

As expected, tables of organization and equipment (TOE), force structure, and organizational charts adapted to these new government and CAF policies in response to the changing threat environments over this period. Single-role fighter operations went from focused mission support siloed within NORAD, NATO, and Mobile Command needs to a more adaptable application of fighter air power as the CF-18 multirole fighter was entering service in 1982. Modernized electronic upgrades and the introduction of precision-guided munitions eventually led to an increase in expeditionary fighter operations as it provided the government with a more flexible tool of national power. This along with other factors precipitated the creation of an Air Expeditionary Wing in 2007 to facilitate rapid operational employment and effectiveness in the projection of

[14] Kris Osborn, "Sensor Fusion: The Secret Sauce that Makes the F-35 Revolutionary", *The National Interest*, 1 Septembe 2021, online at https://nationalinterest.org/blog/buzz/sensor-fusion-secret-sauce-makes-f-35-revolutionary-192873

RCAF air power capabilities. This flexible response was demonstrated in March 2011 when CF-18 fighter aircraft, accompanied by two CC-150 air-to-air refuelling (AAR) tankers deployed to the Mediterranean as part of the Government of Canada's contribution to a NATO-led effort to enforce an arms embargo and no-fly zone over Libya in support of the United Nations (UN) Security Council Resolutions 1970 and 1973. Within a day of arriving in the theatre, RCAF personnel were fully briefed and integrated into the Coalition battle plan and one day later the fighters with tanker support flew their first of 946 combat sorties enforcing the UN resolutions.[15]

The TOE is already in transition for 5th generation fighter operations with the procurement of supporting capabilities such as the nine CC-330 Strategic Tanker Transportation Capability aircraft and the integration of sensitive compartmented information facility (SCIF) multipurpose infrastructure equipment and facilities. In the transition to the CF-18, critical training in AAR and operational readiness suffered as the RCAF only possessed two AAR probes and drogue pods that were occasionally fitted on the high-demand CC-137 strategic transport aircraft. Essential AAR training for fighter pilots suffered as a result and creative ways to maintain minimum currency qualifications were conceived using USAF / USN / USMC AAR resources. Ten years after the CF-18's arrival, the problem was much alleviated when RCAF received five CC-130H Hercules transports that were converted to the CC-130HT tanker configuration and used extensively in training and operations.

With peer-on-peer contestation re-emerging as a real possibility, allies are developing Agile Combat Employment (ACE) concepts to address the long-range, precision-guided missile threat to fixed infrastructure. The challenges of conducting operations in a high-threat environment were well-known and addressed when CF-104 operations transitioned to the CF-18 at Canadian Forces Base Baden-Solingen. Many of the ACE solutions today were part of the operational fabric of the Cold War with infrastructure and force preservation capabilities available in situ. Will the requirement for ACE-enabled operations affect the required TOE and how F-35 deployments are organized given its need for specialized facilities, particularly in Canada's north where military and civilian aviation facilities are limited? Does Canada continue to support the

[15] Canada, DND, "The Role of Canada's CF-18 Fighter Fleet",22 November 2016, online at https://www.canada.ca/en/department-national-defence/news/2016/11/role-canada-18-fighter-fleet.html

Northern Flank as it has done in the past and partner with other F-35 users for its NATO commitment? Given the uniqueness of the F-35 operational and sustainment model, organizational adaptation is inevitable.

Training is the process that forges physical components of a capability (personnel, facilities, materiel and equipment) with the structural components (doctrine, organization, and leadership) into combat-ready units and formations over time. The ability of air forces to force generate is dependent on regular and realistic training to produce, sustain, and ready capabilities. Technology is at the heart of the training enterprise. As with fighter pilot production in the past and today, students complete a fighter lead-in course, followed by the basic CF-18 training course, before completing combat readiness training at the Tactical Fighter Squadrons. To remain current on the CF-104, a pilot was allocated 325 hours per year as a yearly flying rate (YFR). This was decreased to a 160-hour YFR with the CF-18, and it is projected that this will decrease again to a 90-hour YFR with the introduction of the F-35. Computer, simulation, and information technologies have provided pilots with greater situational awareness, reliable and actionable information, and the ability to achieve combat experience without the need to replicate it in the air.

In the CF-104 era, the computer was between the pilot's ears and repetitive proficiency was required to hone the human/machine interface into a weapon system. Simulators were nothing more than instrument and emergency procedure trainers. When purchased, the CF-18 had two basic mission computers (equivalent power of a Commodore 64K personal computer) and a revolutionary heads-up display (HUD) that provided unprecedented information for the time that eased the burden on the pilot to process the combat situation while flying the aircraft. The transition to the F-35 is transformational beyond just modernizing the platform for fighter operations as fifth-generation capabilities are being designed for net-centric warfare which seeks information dominance through digital technology to gain a competitive advantage through the computer networking of dispersed forces. While current CF-18 pilots will be familiar with leading-edge technologies such as a sophisticated helmet-mounted display and Active Electronically Scanned Array radars that will ease the transition, the F-35 itself is a flying computer with artificial intelligence (AI) enabled sensor fusion. With enhanced advanced sensors and networked connectivity, the F-35 is designed to gather, analyze

and seamlessly share critical information across platforms and services at top secret levels making it a critical Intelligence, Surveillance, and Reconnaissance (ISR) resource in 5th generation warfare. Training to maximize its effectiveness will need to be formalized at the onset as it will require cross-domain integration.

A key lesson from my experience with the transition from CF-104 to CF-18 has to do with mindset. We, as ab initio CF-18 instructors trained on Century series fighters, had a third generation mindset that crept into our use of this new platform. It was not until first-tour CF-18 pilots, unencumbered by past predispositions, became tactical leaders that we were shown the full potential of the CF-18. Fortunately for Canada, the F-35 training structure is already mature with most of our allies and the RCAF has embedded personnel in allied operational units as foreign exchange pilots. One United States Air Force F-35 experienced commander identified how tactics and training have changed from fourth to fifth generation fighter operations. "Our training must also evolve to maintain our competitive edge over our adversaries. The most effective way to train a fifth-generation fighter pilot for the demands of modern air combat includes increasing their level of autonomy, developing their problem-solving ability against a peer adversary, and increasing our threshold for what is basic fighter training."[16]

The training itself is a continual process of renewal as game-changing technologies such as the Global Positioning System (GPS), microprocessors, and solid-state devices, introduced new weapon system capabilities such as launch and leave missiles, precision-guided munitions and helmet-mounted sights. The operational application of these revolutionary technologies precipitated changes to TTPs which in turn required changes to training programs. Training opportunities have never been greater through simulation and pilots now gain tactical knowledge in a much shorter timeframe. However, the RCAF should remain vigilant for indications of declining airmanship and aviation-related problem-solving skills with the transition to fewer flight hours and time in the cockpit.

When most commentators discuss capabilities, they invariably focus on the *Materiel and Equipment* aspects with little consideration of the other six variables. Essentially, the CF-104 was a simple aluminum tube, with a big engine, full of gas and

[16] Col. Chris Hubbard, "Modernizing 5th Gen Fighter Pilot Training", *Wild Blue Yonder*, Air University, 9 February 2023 online at https://www.airuniversity.af.edu/Wild-Blue-Yonder/Articles/Article-Display/Article/3287863/modernizing-5th-gen-fighter-pilot-training/

basic analogue instruments with a place for the pilot to sit. Not too complicated to maintain and support. The transition to the CF-18 was interesting as the United States Navy / Marine Corps and Australia were the only other operators of the F/A-18A/B model. A Handi-pak prepared by the Air Force stated that "The CF-18 was built to fly at least 6,000 hours. This exceptional life expectancy is the culmination of exacting specifications, a thoroughly researched engineering design, a balance of superior materials and decades of aircraft-building experience." [17] Unfortunately, during the procurement process, no one researched the design details or understood the implication of the modelling criteria that were used in the conception of a navy fighter aircraft. As RCAF tactical fighter squadrons began to fly operational missions in earnest, it quickly became evident that the fatigue life of the aircraft was being used up at an exponentially faster rate than expected. Upon investigation, it was determined the USN used a Scatter Factor of 2 for fatigue analysis in aircraft design while the RCAF historically applied a factor of 3. This meant that the CF-18 was not a 6,000-hour aircraft but was limited to 4,000 hours. As aircraft started to reach operational service mid-life early, Canada and Australia teamed up to replace the centre barrel of their fighters to allow for extended use. Although the original life expectancy of the CF-18 was identified as 25 years, the centre barrel replacement and two upgrade programs[18] will allow Canada to transition a 50-year-old fighter and its fighter pilot cadre to the F-35.

The Incremental Modernization Project upgraded the CF-18 with much-needed technological improvements such as state-of-the art avionics, a Link 16 data system, and a helmet-mounted ceiling system following the 1998 Kosovo conflict. In 2020, twenty years after its purchase, the RCAF initiated the Hornet Extension Program (HEP) which will eventually include an AESA radar and advanced avionics to better support the AIM-120D air-to-air missile.[19] However, even with these upgrades that will make the transition easier, it would be a mistake to view the F-35 procurement as simply a CF-18 replacement program. The entire design concept of this fifth generation fighter focused on low

[17] Canadian Forces, "CF-18 Fighter Aircraft", Handi-pak Number 3, January 1988, p. 3.
[18] For Incremental Modernization Project Phase I/II and the Hornet Extension Program Phase I/II explanation see Wikipedia, "McDonnell Douglas CF-18 Hornet", 03 Nov 2023 online at https://en.wikipedia.org/wiki/McDonnell_Douglas_CF-18_Hornet
[19] Chris Thatcher, "Major upgrades incoming for Canada's fleet of CF-188 Hornets," *Skies Magazine*, MHM Publications,19 June 2020, online https://skiesmag.com/news/major-upgrades-canada-fleet-cf-188-hornets/

observability, advanced avionics and sensor fusion that enable a high level of situational awareness and long-range lethality. Although the CF-18 contained highly sensitive components, the resulting F-35 platform and integrated systems are highly classified necessitating significant increases in security measures from expanding personnel and infrastructure security clearances to digital transformation that will enable increased volumes of classified sensor data to be networked.

The purchase of the F-35 has significantly changed the landscape for the sustainment of material and equipment compared to earlier fighter platforms due to Canada's commitment to the Production, Sustainment, and Follow-on Development (PSFD) phase in signing the JSF PSFD MOU[20]. The MOU contractually established a shared, integrated global support system controlled by consortium partners and the F-35 Joint Program Office. Sustainment is operated as a global enterprise and, as such, Canada will be acquiring the aircraft and associated equipment, mission data reprogramming, training, and sustainment setup and services through the PSFD MOU. Fortunately for Canada, unlike starting from a clean slate with the ab initio purchase of the CF-18, the RCAF can leverage the lessons learned from the introduction and operation of the F-35 by other partners to facilitate the transition. Additionally, the war in Ukraine has provided pause for thought and renewed emphasis on preparing for peer-on-peer conflict, particularly with respect to force preservation, sustainment, and logistics.

A cautionary note with respect to reliance on external partners can be found in the CF-18 Project Lessons Learned report that pointed out, "problems must be anticipated in being tied to the prime user (in this case the United States Navy) program maturation. This was particularly evident in areas of logistics support where policy/program changes occurred. The cost of a few unique requirements quickly exceeded the estimates of cost."[21]

[20] Memorandum of Understanding among the Department of Defence of Australia and the Minister of National Defence of Canada and the Ministry of Defence of Denmark and the Ministry of Defence of the Republic of Italy and the State Secretary of Defence of the Kingdom of the Netherlands and the Ministry of Defence of the Kingdom of Norway and the Undersecretariat for Defense Industries on behalf of the Ministry of National Defense of the Republic of Turkey and the Secretary of State for Defence of the United Kingdom of Great Britain and Northern Ireland and the Secretary of Defense on behalf of the Department of Defense of the United States of America concerning the Production, Sustainment, and Follow-on Development of the Joint Strike Fighter, online at https://www.state.gov/wp-content/uploads/2019/02/06-1231-Multilateral-Defense-JSF.pdf , accessed on 3 March 2022.

[21] James Robinson and Julienne Jessup, "CF-18 Project," *Canadian Major Projects Association Digest*, University of Calgary and the Canadian Major Projects Association, April 1992, p. 26.

Thus, there will be both advantages and disadvantages to being a member of the F-35 consortium that need to be taken into consideration during the transition as economies of scale will conflict with sovereignty and operational flexibility.

Leadership starts at the top. Political and military leadership during the transition to the CF-18 was sound, once the decision to initiate the New Fighter Aircraft (NFA) project was initiated by the government of Pierre Trudeau in 1977 to replace the three fleets of fighter aircraft. An Interdepartmental Project Office (IPO) involving the Department of National Defence, the Department of Supply and Services, and the Department of Industry was established to evaluate potential replacement aircraft and provide a recommended short list of preferred solutions for contract evaluation. Proposals were received from Grumman (F-14), McDonnell Douglas (F-15), General Dynamics (F-16), McDonnell Douglas (F/A-18), Northrop (F-18L) and Panavia (Tornado). Based on the supplementary proposal evaluation, the Minister of National Defence recommended to Cabinet that the IPO enter into discussions with the manufacturers of the F-16 and F/A-18 to negotiate draft contracts. "The draft contracts were subjected to a rigorous comparative evaluation designed to enable the Government to select the best option for Canada. The results of the evaluation were aggregated into three broad classifications: 1. The military evaluation; 2. The contract evaluation; and 3. The industrial benefits evaluation."[22]

As there were only two aircraft manufacturers for the final evaluation, a side-by-side methodology was particularly appropriate "to provide decision-makers with a summary that would enable them to answer the question, "Which of the two programs, all things considered, would best meet Canada's national objectives?" [23] The military evaluation identified the CF-18 as the superior choice as it would provide *substantial advantages* for growth over time whereas the F-16 was deemed *to have many limitations and considerable risk*. Following negotiations, both companies produced draft contracts *that were favourable to the Crown* and it was judged that McDonnell Douglas had a better industrial benefits package compared to General Dynamics. The aircraft selection evaluation was reviewed by key Cabinet Committees before the Cabinet announced the selection of the McDonnell Douglas F/A-18. Although not without its detractors, many

[22] Ibid. CF-18 Project, p 10.
[23] Ibid, p. 10.

consider this to be a golden example of how major defence procurement projects should be run where the efficient and effective analysis leads to an evaluation of acceptable options that meet military needs for accountable decision-making by the responsible government.

This is in sharp contrast to the convoluted politicization that occurred over the replacement of the CF-18. In 1997, the Chrétien government enrolled Canada as a level three participant nation in the Joint Strike Fighter program with no obligation to purchase the F-35. Following a significant analysis of possible follow-on fighters by the Department of National Defence,[24] the Harper government announced the sole-source selection of 65 F-35 aircraft in July 2010. This miscalculated decision to sidestep a formal competition initiated the politicization of the CF-18 replacement as the Conservatives made use of the proposed acquisition for partisan purposes. In 2015, the Justin Trudeau government lifted a play from the Chrétien Red Book in politicizing a major military platform for cancellation stating, "We will not buy the F-35 stealth fighter-bomber. We will immediately launch an open and transparent competition to replace the CF-18 fighter aircraft."[25] Within one year of being elected, the Trudeau government unexpectedly announced the sole-source procurement of 18 Super Hornets with the promise of a competition by the end of their mandate.

Despite the negative assessment of most academics and experts to the government's planned purchase of interim Super Hornets – including 13 former RCAF commanders who publicly stated that an interim purchase was not necessary at all – the government was determined to move ahead until the Super Hornet's manufacturer, Boeing, successfully petitioned the US Commerce Department to impose a countervailing duty on Bombardier's C-series commercial passenger aircraft. The government then cancelled its planned purchase and invoked the so-called "Boeing Clause"[26] that would

[24] Over 40,000 person-hours were expended in an analysis of potential options to replace the CF-18 fleet conducted by public service subject-matter experts in the National Fighter Procurement Secretariat with the results verified by an independent review panel in 2014. The basis for a truncated competition in 2018 is readily available. Accessed on28 november 2017 at http://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/air/snac-nfps/cdp-nr-eng.html

[25] Liberal Party of Canada, *Real Change: A New Plan for a Strong Middle Class*, 2015, p. 70.

[26] Canada, *Budget 2021* formally stated what became known as the Boeing Clause, "In December 2017, the Government announced that the evaluation of bids for the competition to replace Canada's fighter aircraft would include an assessment of bidders' impact on Canada's economic interests, and that any

appear to marginalize Boeing's opportunity to bid on its Super Hornet in the forthcoming open Future Fighter Capability Project (FFCP) competition launched in 2017. In addition to this, it would take 18 months to modify the final Request for Proposal to overcome issues allowing both the Saab Gripen and Lockheed Martin F-35 to compete due to incongruities in Industrial and Technological Benefits (ITB) and security policies.[27]

On January 9, 2023, the government announced that Canada would purchase 88 F-35 aircraft making Canada the last member of the JSF program consortium to commit to purchasing the F-35. This 10-year drawn-out procurement by the Government of Canada has had detrimental effects on RCAF readiness as the CF-18 will be over 50 years old upon retirement and the delayed decision leaves the current military leadership scrambling to create the high security enabling capabilities infrastructure needed to operate the F-35 when it finally arrives. As the Commander of the RCAF, Lieutenant General Eric Kenny, responded when asked whether the RCAF was prepared to fight in a conflict, "I'm very concerned right now about our ability to do our job effectively against the current threats. As long as we stay in a competitive phase, we're fine. [But if] We get into conflict: We need to rapidly evolve our efforts because we're not ready, quite frankly, with what we have right now."[28] This force readiness posture is decidedly different than during the earlier fighter capability transition where military necessity appeared to have greater value than political gamesmanship.

A central lesson learned from the CF-18 procurement emphasized the need to create a Project Management Office that must be timely, robust, and staffed with qualified, knowledgeable, experienced personnel in all appropriate departmental positions. Given that the F/A-18 was entering service with the US Navy / Marine Corps at virtually the same moment in time, the RCAF leadership focused on adapting the CF-18 for national use while adopting US technical information for eventual

bidder that had harmed Canada's economic interests would be disadvantaged." Online at https://www.budget.canada.ca/2021/report-rapport/p3-en.html#chap9

[27] See Alan Stephenson, "Anatomy Of A Buy: The Four Dimensions Of Procuring A Future Fighter For Canada", *Canadian Global Affairs Institute*, May 2019 for more explanation online at https://www.cgai.ca/anatomy_of_a_buy_the_four_dimensions_of_procuring_a_future_fighter_for_canada

[28] James Careless, "Air Force Commander Says RCAF Not Ready for Conflict", *Canadian Defence Review*, p. 7. November 2023, online at https://www.canadiandefencereview.com/news/air-force-commander-says-rcaf-not-ready-for-conflict

Canadianization. The military leadership today is taking a similar approach and was proactive in standing up the Fighter Capability Office early on to manage the procurement and implementation process from a DND / CAF perspective. However, the late-to-need decision by the government on the replacement fighter and the loss of experienced personnel across all areas of the department has handicapped the RCAF's ability to effectively manage the transition. The inability to retain and replenish qualified personnel across the Canadian Armed Forces has a domino effect on being able to move essential force development projects forward in a timely fashion. Critically at this juncture, the lack of experienced fighter pilots to effectively implement this technological transition is unprecedented as requisite current experience cannot be replaced off the street but must be developed internally. Unlike the CF-18 transitional era where essential skills could be mobilized from non-essential workplaces; residual expertise no longer exists within the contemporary streamlined personnel structure that exists today.

Although security requirements were concerns in the earlier transition, the 5th generation security obligations for the F-35 are transformational across all levels of command from the Squadron / Wing to the RCAF / Component and Operational Commands to the CAF writ large. If there is a single point of failure in the implementation phase of transitioning to the F-35, it will be the CAF's inability to provide the security clearances to personnel and the classified infrastructure that allows all aspects within the capability variables to effectively move the transition forward in an efficacious way that meets expectations. Although digital transformation has been initiated CAF-wide, it is becoming an existential issue in meeting F-35 arrival times due to the demanding security constraints and the complexity of the networked infrastructure requirements. This is a CAF systemic problem that the RCAF leadership must manage to the best of their ability.

Personnel production and training are critical for any capability, but more so for specialized occupations that depend on limited resources. The CAF is currently 17,000 people understrength and is struggling to recruit and train enough personnel to replace those who are leaving, particularly aircraft technicians and pilots who are in high demand in the aviation industry. When I went through pilot training, the system produced over 200 pilots a year and the average age of a first-tour fighter pilot, or pipeliner, in the squadron, was in their early 20s. Today, annual pilot production is 125 graduates, and the average age of a pipeline fighter pilot is late 20s. There are many

reasons for this, from the just-in-time training culture that promoted need-related training programs to constraints imposed in the ability to draw pilots from non-operational platforms due to contracting out airborne training support that was once performed by the RCAF to bottlenecks created by early releases of experienced pilots needed to instruct. However, one variable that can be addressed is a change in the prerequisite to becoming a pilot and the unintended consequences that result.

I believe there is no need for a person to have a degree before becoming a pilot. One needs to be capable of obtaining a degree, but having one is not a prerequisite. A great number of the students with whom I went through pilot training in the third-generation era came out of high school or CEGEP (Collège d'enseignement general et professionnel) under the Officer Cadet Training Plan (OCTP). When these pilots arrived on operational squadrons, they had their tongues hanging out and their tails wagging, saying "Put me in boss, I want to be on the road doing my job"! By the time the current class of fighter pipeliners arrives on the squadron, they will likely be well established with a partner that works, a household pet, and perhaps a child or two. This creates tensions that result in less optimal use of graduate pilots as their desire to be away from home fulfilling their military duty is challenged.

The age demographics for pipeliners need to be reduced to be in line with their army and navy peers that reach operational units earlier. The change in policy that "Officers were henceforth to be degree holders"[29] resulted from recommendations made to the Minister of National Defence, Douglas Young, on the professionalization of the Canadian military following the Somalia Affair by a group of four experts.[30] The need for a professional officer corps, nor for obtaining a degree, is not in question, but its centrally controlled implementation has been detrimental to pilot production in particular and hinders the efforts in repopulating a quickly diminishing and irreplaceable capability component. Providing multiple intake vehicles beyond the current Regular Officer Training Program (ROTP), where recruits first attend one of Canada's two Canadian

[29] David J. Bercuson, "Up from the Ashes: The Re-professionalization of the Canadian Forces after the Somalia Affair", *Canadian Military Journal*, Vol. 9, No. 3, 2009, p. 36.
[30] Ibid. The four were Dr. David J. Bercuson, Dr. Albert Legault, Dr. Jack Granatstein, and Dr. Desmond Morton. Legault is a political scientist studying international relations. Morton and Granatstein are RMC graduates.

Military Colleges (CMC) or are sponsored at another Canadian university, will provide flexibility in training programs and spread out the age demographic.

Making use of modern technology can be part of the solution. Although distance learning has proven its effectiveness in acquiring higher education during the COVID-19 pandemic, it is not new. In the early 80s, a number of high school graduates gained their degrees through the University of Manitoba distance education program conducted by mail. Many of these officers eventually rose to senior ranks proving that gaining a degree before pilot training is not a prerequisite to professionalism as a pilot or as an officer. This is true today as well. Reintroducing the OCTP plan and enlisting high school graduates who would quickly receive a streamlined Basic Officer Training course would provide intake and production flexibility that could respond to market forces. Designing a degree program around pilot production that could be completed once graduates are employed as pilots on operational squadrons, making use of virtual learning tools during periods between official courses, and granting credits for requisite course material that are already recognized by current aviation degree-granting institutions[31], would increase productivity, ensure the professional integrity of the officer core, and decrease the time it takes to reach operational usefulness.

Two production streams would allow flexibility in the generation of pilots to meet preferred manning levels that address the ebb and flow of unforecast departures. Retention is a separate problem that most allied air forces are also experiencing due to market and lifestyle forces. However, empty cockpits are unacceptable and only exacerbate the situation. Not only are missions not completed, but the experience spiral only worsens when fewer and fewer pilots learn from the remaining tactical leaders. To meet current problems, pilot production is in the midst of being separated from the general CAF recruitment process but more needs to be done. This will require a paradigm shift within the CAF to meet operational needs if the RCAF is going to have and retain the personnel to operate and fly the F-35.

[31] Although the Royal Canadian Air Force Pilot Training Program at Seneca College has been suspended, it illustrates that higher education institutions have introduced programs such as the Seneca Honours Bachelor of Aviation Technology degree that could be leveraged for completion once pilots complete military training and were employed on operational units. See https://www.senecacollege.ca/school/aviation/rcaf.html accessed 17 November 2023.

Finally, the **Facilities** needed for the transition to the CF-18 were generally well handled with some leading-edge concepts not quite meeting expectations. The simulator in Cold Lake was a vast improvement over the previous third-generation simulators, but the domed complex meant to provide visuals never quite met expectations and was eventually replaced with digitally enhanced computer-generated visuals on screens. As software engineering was the emerging technology of the time, the RCAF created the Weapons System Support Unit (WSSU) which was tasked with creating unique CF-18 Operational Flight Program (OFP) software. Although successful, the need to continually update and develop the OFP as modifications to the aircraft and weapons system occurred, as well as the requirement to flight test each version before released to the field, proved to be cost-prohibitive and not flexible enough to meet operational requirements. From 1995 onwards, the RCAF purchased the USN OFP off-the-shelf from the US government. Fortunately, the RCAF learned this lesson and joined in establishing the Australia Canada United Kingdom Reprogramming Laboratory (ACURL), located at Eglin Air Force Base in Florida, which is designed to develop, verify and validate mission data files providing each country the capability to reprogram F-35 mission data to effectively execute sovereign missions.

The introduction of the multi-role CF-18 precipitated the closure of fighter units and the consolidation of operations from five to three main operating bases. Facilities were modified with some new bespoke infrastructure built to meet contemporary operations with the development of Canadian NORAD Region Forward Operating Locations (FOLs) extending the reach of fighter operations into Canada's arctic region. The Cold Lake Air Weapons Range (CLAWR), once the crown jewel of air-to-air and air-to-ground training ranges annually hosting the multinational Exercise Maple Flag, is in desperate need of modernization. With the transition to the F-35, we are witnessing the digital transformation of the physical infrastructure that is significantly more profound than the leading-edge technology that precipitated the CLAWR upgrades during the information transformation with the introduction of the CF-18. As the digital transformation throughout the CAF is late to need, the RCAF is facing far greater challenges than with the CF-18 in creating the necessary highly secure facilities and top-secret digital networks the US requires to operate the 5th generation platform. Failing to meet the security requirements to operate the F-35 will be a showstopper in meeting operational timelines. From hangars to Sensitive Compartmented Information Facilities

for planning, to Operational Training Infrastructure that will allow secure live-virtual-constructive training, to classified data networks needed for information transmission, the challenge will be to ensure the imperative of successfully implementing this digital transformation occurs cooperatively and collaboratively across all DND/CAF organizations.

As is evident, there are lessons to be learned from past experiences in transition from 3rd to 4th generation fighters that can be applied today. Not all issues are relevant of course but historical research and review will at a minimum be informative. Changes in warfare are inevitable as adversaries continually seek to gain advantage through advances in technology. Some changes are transitional while others are transformational. With the unique contractual arrangements for delivery and sustainment of the F-35, there will be both advantages and disadvantages in being a member of the F-35 consortium that need to be considered as economies of scale will conflict with national sovereignty and operational flexibility. Critical analysis of each capability variable during the transition from 3rd to 4th generation fighter as well as reflecting on how the CF-18 capability was transformational to Canadian air power is important, as history is in the midst of repeating itself with the re-emergence of great power competition. Many of the pilot production means material force protection measures and doctrinal concepts optimized for Cold War operations have been lost or forgotten. As the RCAF is in the midst of implementing the F-35 capability, historical reflection on the previous fighter transition and CF-18 operations will provide insight into peer-on-peer considerations that current personnel will not have experienced.

As Donald Rumsfeld famously said, there will be known-knowns, known-unknowns, and unknown-unknowns. The few examples I have presented are some of the known-knowns and analysis can be achieved by viewing them through the lens of each of the seven variables that make up a fighter's capability. In the CF-18 transition, the advancement in computer technology and the implications of micro-processing technology to weapons advancements were some of the known unknowns[32] at the time

[32] In 2002, US Secretary of Defense Donald Rumsfeld brought attention to the concepts of known knowns, known unknowns, and unknown unknowns, however, national security and intelligence professionals have long used this explanatory technique. Known unknowns refers to situations you are aware of but do not know the outcome, whereas unknown unknowns are situations that are so unexpected that they would not normally be considered.

as these advancements were in their infancy. The impact of GPS, space-based communications, and Night Vision Goggles are some of the unknown-unknowns of the time since development had not begun to affect fourth-generation platform operations. Today we can identify known-unknown disruptive technologies such as Combat Collaborative Aircraft (CCA), sensor fusion, cloud-based computing as well as laser, robotics, and nanotechnologies. Some of these will raise doctrinal issues that should be thought through early while others will need to be followed as they evolve. Other disruptive technologies fall into the unknown-unknown category such as the effects of artificial intelligence, machine learning, and quantum technologies which are emerging concepts that await military operationalization.

History and historical analysis of technological transition are useful in informing present transitions to similar capabilities by providing a basis from which assumptions and choices can be framed. Transformations, however, pose unique challenges as logic and calculus are not predictive and can only provide a limited understanding of where revolutionary technologies will lead. As to the future, another example of the historical mindset will help illustrate the unpredictability of human endeavour and the challenges in forecasting the unknown. During the transition from the CF-104, there was a newspaper comic strip called *Dick Tracy*®. Now Dick was a detective that solved crimes with the use of a watch from which he could talk and receive messages. At the time, there was no technology that even remotely predicted such a device was conceivable. Today, when I see my daughter using her smartwatch, I often reflect on whether this futuristic idea of the time was a prescient concept or whether it is life-imitating art. This is an example of an unknown-unknown technology that has shaped the world in which we live. As we embark on the transition to the fifth generation fighters, perhaps those currently engaged in the implementation of the F-35 will see the emergence of photon torpedoes or factor in warp speed seen in the visionary worldwide pop-culture media phenomenon *Star Trek*® as they transition to the next generation of RCAF fighter capabilities. As with my Dick Tracy moment, perhaps in fifty years, the former F-35 pilots may even be able to say, *Beam me up, Scottie*!