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SIXTH-GENERATION FIGHTER AIRCRAFT

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Service Paper

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SIXTH-GENERATION FIGHTER AIRCRAFT

AIM

1. “The RCAF COS, Gen Charles Brown, sees sixth generation fighter aircraft more about how fighters are procured and produced in a distributed modular fashion and less about the systems and capabilities on board.”¹

2. The purpose of the paper is twofold. First, it details the strategic need for Canada to develop and maintain an interoperable and generationally relevant fighter program. Second, it explores the necessity of procurement strategy evolution, highlighting the opportunities this presents for the Royal Canadian Air Force (RCAF) and industry.

INTRODUCTION

3. A decision is still outstanding on Canada’s future fighter program. While Canada dawdles, allies and adversaries have moved on from fifth generation and are developing sixth-generation capability at pace.² This paper reiterates the requirement for smaller air forces, such as the RCAF, to remain relevant and interoperable and highlights the unique opportunity Canada has to fix a broken procurement strategy.

4. Cost, time and performance are three competing constraints of project management.³ From initial concept to warfighting delivery of capability, fighter procurement takes far too long.⁴ Moreover, fighter programs are always over budget and rarely deliver the capability promised; this must change. When the Olympic Games committee delivers an Olympics, the schedule remains fixed while cost and performance, although controlled, remain variable. Defence procurement must adopt this mindset, prioritizing time (schedule) over cost and performance.

5. The discussion is broken into four sections. First, a review of Canada’s high-level requirement for fighter aircraft explains the importance of maintaining generational relevancy and interoperability. The second section introduces next-generation procurement strategies. The third section includes an analysis of the benefits and challenges of new procurement methodologies. The fourth hypothesizes opportunities for the RCAF and Canadian industry. Concluding remarks and recommendations are at the end.

¹ Canadian Forces College, *JCSP Research Topic List*, 2021, 4.

² Gary Martinic, *Jet fighter aircraft: five 'generations' later, and still counting*, Headmark, 2015

³ John Rodney Turner, *The Handbook of Project-Based Management: Improving the Processes for Achieving Strategic Objectives*, (Cambridge University Press, 1999), 8-9.

⁴ Matthew Uttley, *Defence procurement. Routledge Handbook of Defence Studies*, 2018, 77.

DISCUSSION

Canada's requirement for fighter aircraft

6. Canada has a requirement to maintain an organic fighter program that meets national defence and security strategy, remains technologically relevant and is economically palatable to the government of the day. As with other smaller air forces, this presents a challenge that requires compromise between flexibility, capability and economics.⁵

7. Strong, Secure, Engaged (SSE) outlines, in priority order, the high level mandates to “defend Canada, defend North America and contribute to international peace and security.”⁶ Arguments against a fighter fleet exist.⁷ However, SSE outlines the RCAF commitments to North America Defence (NORAD), North Atlantic Treaty Organisation (NATO) and the United Nations (UN) and the dependence on fighter aircraft. It states the “fighter aircraft fleet is a critical RCAF capability necessary to enforce Canada’s sovereignty, enable continental security, and contribute to international peace and stability.”⁸ The defence and security policy and international commitments outline the need for a fighter fleet and RCAF doctrine supports this. However, they need to remain generationally relevant to be effective.

8. For the RCAF to stay relevant, it requires the political will and appetite to commit financial investment. “Resource constraints at the national strategic level remain a perennial challenge for modern air forces.”⁹ Not all air forces need to fulfill the full suite of air power capabilities. For example, a large air force possesses “the entire spread of air power capabilities in sufficient quantity and with adequate redundancy to conduct major, long-drawn campaigns independently.”¹⁰ Whereas, smaller air forces, “are balanced and possess the capabilities to deliver the full spectrum of air power functions and conduct operations independently, but they have limited depth to sustain capacity.”¹¹

9. The RCAF is a smaller air force. “The relevance of smaller air forces to national security is dependent on their capacity to evolve in synchronization with national security imperatives.”¹² Kanikara stresses that capacity and resource to evolve is of paramount importance to national security. They also portray smaller forces positively, stressing they make highly capable allies and coalition partners noting also that the demands

⁵ Gary Martinic, *Jet fighter aircraft: five generations' later, and still counting*, Headmark, 2015; Sanu Kainikara, *The Future Relevance of Smaller Air Forces*, Air Power Development Centre, 2009, 25.

⁶ National Defence. *Strong, Secure, Engaged: Canada's Defence Policy*, 2017, 16.

⁷ Charles Nixon, “Canada does not need fighter jets, period,” *The Globe and Mail* last modified 8 July 2017. Opinion: Canada does not need fighter jets, period - *The Globe and Mail*

⁸ *Ibid*, 38.

⁹ Richard Evan Goette, *Preparing the RCAF for the Future*, National Defence, 2020, 6.

¹⁰ Sanu Kainikara, *The Future Relevance of Smaller Air Forces*, Air Power Development Centre, 2009, 25.

¹¹ *Ibid*, 26.

¹² *Ibid*, 29.

placed on smaller forces are extremely high.¹³ The criticality of prioritizing resources and assets to evolve is significantly increased.

10. Kanikara suggests, “unless [smaller] air forces can achieve the status of an effective element within or as a partner to the broader national security agencies, their relevance as a whole will continuously be eroded.”¹⁴ It is unthinkable that Canada would ever act in defence of Canada or North America without the United States (US). In reality, the dominating fear in Ottawa is that the US would act unilaterally.¹⁵ Therefore, in the RCAF context, any national security agency includes the US. Unless there is a seismic strategic policy shift, Canada’s air power capabilities must remain as ‘common’ and interoperable with those of the US as possible.

Next-generation fighter procurement

11. Eras or ‘generations’ categorize aircraft. Further explanation of this is at Annex A. The next generation of fighter aircraft are dubbed sixth generation. The allure of capabilities such as smart skin technology, subsonic and multi-Mach stealth, directed energy laser weapons, airframe morphing, uncrewed swarm technology and Artificial Intelligence (AI) dominate the sixth generation narrative.¹⁶ However, legacy fighter programs show that over ambition will lead to cost and schedule overruns with shortfalls in performance delivery.¹⁷

12. The United States Air Force (USAF) Next-Generation Air Dominance (NGAD) program seeks to deliver capability rapidly in five-year sprints.¹⁸ Capability that could include a mix of crewed and uncrewed platforms within a networked air enterprise. Under Joint All Domain Awareness Command and Control (JADC2) the US are also fielding advanced command and control (C2) capability that utilize a myriad of platform sensors and Artificial Intelligence (AI) to maintain “decision making superiority.”¹⁹ Both NGAD and JADC2 programs seek to fix the broken procurement strategy. Revolutionizing procurement processes, deemed unfit for purpose, requires significant policy and cultural change. However, this represents change that Canada must make to remain relevant, fulfill strategic defence objectives and keep pace with the mounting threats to international security.²⁰

¹³ *Ibid*, 26.

¹⁴ *Ibid*, 29.

¹⁵ Adam Chapnick and J. Craig Stone, *From Policy and Strategy to Outcomes*, Canadian Defence Policy in Theory and Practice, Springer, 2020, 91.

¹⁶ Gary Martinic, *Jet fighter aircraft: five generations' later, and still counting*, Headmark, 2015

¹⁷ Heather Penney, *"The Future Fighter Force Our Nation Requires: Building a Bridge,"* The Mitchell Institute for Aerospace Studies, 2021, 5.

¹⁸ Dwyer, Morgan, *The Air Force Digital Century Series*, Center for Strategic International Studies (CSIS), 2019.

¹⁹ CDA Institute, *NORAD Modernization: Report Three: JADC2/JADO*, 2020, 1.

²⁰ *Ibid*.

13. Plagued by cost and schedule overruns, fighter programs have often failed to deliver on the technical promise advertised at inception.²¹ The F-35 program, conceived under the Joint Strike Fighter brand, took twenty years to accept into service. With at least a 15-year shelf life, trying to predict and understand the strategic landscape that far into the future is incredibly challenging.

14. The NGAD program “departs radically from the approach used to field F-35 and F-22.”²² “F-35 and F-22 acquisition strategies sought to field multiple revolutionary capabilities simultaneously”.²³ The failure of this approach has sparked a move to historical methodologies that also draw on digital age technology. The 1950s era Century Series saw groundbreaking innovation and rapid development that produced multiple new designs on individual capability platforms.²⁴ A willingness to fail enabled the speed of design and fielding. However, flexibility comes at financial cost. The Century Series prioritized time (schedule) over cost and performance.

Methodology - The Digital Century Series

15. NGAD is coined the Digital Century Series. Drawing on the mindset of the 1950s, the USAF looks to leverage the three concepts of agile development, open architecture and digital engineering within a large and repeatable fighter development program. Each concept promises a number of benefits but also presents a number of challenges.

16. **Agile development.** “Since the formulation of the agile manifesto in 2001, agile methods have transformed software development practice by strongly emphasizing change tolerance, evolutionary delivery and active end-user involvement.”²⁵ This has resulted in widespread interest for utility outside the software development domain. The Digital Century Series uses agile as a methodology to develop, test and deliver not just software but hardware and air systems. This will require a drastic departure from traditional Department of Defence (DoD) procurement norms.²⁶

17. In a highly iterative process, the USAF will need to apply corrections to design through production rather than retrofit.²⁷ This may see an increased cost of failure as designs fail to become operational. There appears to be high financial risk within this change in design methodology, but the benefits of delivering significant capability flexibly and quickly are very attractive. It is unknown whether agile methodologies are

²¹ Matthew Uttley, *Defence procurement. Routledge Handbook of Defence Studies*, (2018), 77; Heather Penney, *"The Future Fighter Force Our Nation Requires: Building a Bridge,"* The Mitchell Institute for Aerospace Studies, 2021, 4-6.

²² Dwyer, Morgan, *The Air Force Digital Century Series*, Center for Strategic International Studies (CSIS), 2019.

²³ *Ibid.*

²⁴ *Ibid.*

²⁵ Torgeir Dingsøy and Nils Brede Moe, *Towards Principles of Large-Scale Agile Development*, Springer, 2014, 1.

²⁶ *Ibid.*

²⁷ *Ibid.*

scalable beyond projects with small, co-located teams.²⁸ Adoption of this methodology will require a cultural shift away from risk aversion to risk acceptance and management.

18. **Open architecture.** Open architecture seeks to develop systems that have common interfaces and modular design that enable competition for future upgrades to incentivize innovation. However, open architecture is not a new concept. “DoD-5000 series policies mentioned open architecture as early as 1996.”²⁹ Even though the appetite for open architecture is high, cultural barriers mean DoD has failed to incentivize industry and contract in this manner.³⁰ A recent Government Accountability Office (GAO) report highlighted the inability of DoD to implement the current policies and processes to deliver the benefits of open architecture in air system procurement.³¹ This was largely due to a lack of program oversight and contract monitoring.

19. The same challenges will exist for the Digital Century Series. This means, correctly prioritizing resource for commercial, engineering and acquisition professionals to manage and monitor the system interfaces and Intellectual Property (IP) across multiple contracted products. Otherwise, the potential benefits from competition will be lost as DoD loses bargaining power. Incentivizing and drawing a diverse industrial base towards the program enables true innovation.

20. **Digital engineering.** Digital engineering uses simulation to optimize the production, upgrades, operation and maintenance of new systems.³² This represents the newest technological methodology aimed at reducing life cycle costs by modelling systems for reliability, manufacturability and upgradability. Programs like the F-35 aimed to reduce life cycle costs through commonality and economies of scale across design variants.³³ However, diverging and unique user requirements, gave priority to performance without understanding the subsequent effect to complexity and cost growth. Through modelling and simulation, the Digital Century Series will inform requirements decision-making based on through life impacts.

21. **Summary.** The Digital Century Series strategy “depends on rapid and predictable technology development, short design lives and a willingness to retire systems from operations quickly and on schedule.”³⁴ While the benefits are clear, the challenges this new approach brings are also significant. Calculating value for money differently and acceptance of failure will require a change of mindset. The focus on schedule, over cost and performance will require a fundamental and cultural procurement shift. Adoption of a

²⁸ Torgeir Dingsøyr and Nils Brede Moe, *Towards Principles of Large-Scale Agile Development*, Springer, 2014, 1.

²⁹ Dwyer, Morgan, *The Air Force Digital Century Series*, Center for Strategic International Studies (CSIS), 2019.

³⁰ *Ibid.*

³¹ US Government Accountability Office, *Defence Contracting: GAO-14-395*, 2014, 22.

³² *Ibid.*

³³ *Ibid.*

³⁴ *Ibid.*

flexible and risk based approach requires incentivizing industry away from sustaining old systems to developing and delivering new ones.

Opportunities for the RCAF and Canadian industry

22. In ensuring armed forces are equipped to meet national security objectives, the scholar Matthew Uttley suggests four procurement goals. First, the equipment bought must be state-of-the-art. Second, achieving national autonomy through security of supply. Third, value for money. Fourth, and importantly for this paper, to “realize ‘indirect’ national economic, technological, industrial and employment benefits arising from their defence procurement expenditure.”³⁵ Politicians are worried about national security but they are also worried about votes linked to jobs, industry and the economic benefits of defence spending.³⁶

23. Canada First set out the mandate to “provide Canadian industry the opportunity to more effectively meet defence procurement requirements.”³⁷ The aim being to “better position industry to compete for defence contracts at home and abroad.”³⁸ While Canada does not have the industrial capacity or capability to develop an organic fighter, they have significant industrial expertise in emerging technologies associated with both fifth and sixth-generation fighter programs. The fields of data analytics, Artificial Intelligence (AI), command and control (C2) systems and software development nicely complement the traditional aerospace industrial base.

24. Despite the lack of commitment to the aircraft, Canadian aerospace industry is heavily involved in F-35. Canadian contractual participation in F-35 had expanded to circa \$CAN 637 million in 2014.³⁹ The identified potential opportunities for Canadian companies were \$CAN 10.8 billion in 2014. Leveraging similar industrial partnering initiatives across next-generation programs, such as NGAD, could significantly benefit Canadian industry.

25. Shorter development sprints, designed around competition and innovation represent a unique opportunity for Canadian industry. Lobbying traditional and non-traditional Canadian aerospace companies for interest in this area could lead to industrial growth. This should specifically include companies with success employing agile software development, digital engineering techniques and open architecture.

³⁵ Matthew Uttley, *Defence procurement. Routledge Handbook of Defence Studies*, 2018, 75.

³⁶ *Ibid.*

³⁷ National Defence. Canada First Defence Strategy, 2008, 4.

³⁸ *Ibid.*

³⁹ Bert Chapman, *Global Defense Procurement and the F-35 Joint Strike Fighter*. Springer International Publishing, 2019, 211.

CONCLUSION

26. Overwhelming air superiority for the West is no longer a fait accompli. Recognizing it will be increasingly difficult to sustain a technically competitive full suite of air power capability, the allied forces must clearly understand who brings what to any coalition.⁴⁰ Legacy procurement strategies are no longer fit for purpose. Canada must factor the US shift in procurement strategy into its future fighter ambitions. Mindful Canada labored over decisions regarding fifth-generation aircraft, investment in NGAD presents a unique opportunity for Canada to strengthen the North American relationship, and remain interoperable and relevant as a smaller air power with international ambition. It also represents a unique opportunity for Canadian industry to realize national economic, technological, industrial and employment benefits.

27. Procurement culture change is necessary to adopt and implement agile development, digital engineering and open architecture. The Olympics mindset is essential for next-generation fighter procurement and NGAD seeks to do this. Whilst there remains uncertainty in the processes underpinning the Digital Century Series, what is clear is that fighter procurement strategy must change. A recent NORAD modernization forum recommended that Canada's industry must be involved in next-generation programs.⁴¹ Unfortunately, political will and archaic procurement cycles stand in the way of Canadian participation.⁴²

28. The CAF needs a new fighter to meet the mandate of SSE and commitments to NORAD, NATO and the UN. The potential benefits that sixth-generation technology and a streamlined procurement methodology brings are significant. However, there are also a number of pitfalls and risks associated with the relatively untested Digital Century Series procurement strategy. Culture change is hard and significant financial and political risk exists with investment in unproven methodologies on capital programs of this scale.

29. The aerospace industry has become highly regulated since the original Century Series. Greater onus on risk-to-life means the appetite to accept risk and failure has changed. However, should a program such as this be sufficiently resourced, the benefits of the RCAF remaining interoperable, relevant and credible are politically essential. In the end, this methodology could very well save money and deliver the capability the RCAF needs, on time.

RECOMMENDATIONS

30. This paper has reviewed the need for RCAF next-generation fighters and explored the necessity for procurement strategy change.

⁴⁰ Sanu Kainikara, *The Future Relevance of Smaller Air Forces*, Air Power Development Centre, 2009, 25.

⁴¹ CDA Institute, *NORAD Modernization: Report Three: JADC2/JADO*, 2020, 1.

⁴² *Ibid.*

31. Director General Air and Space Force Development is invited to **note** the following recommendations:

32. A woeful fighter procurement record necessitates urgent procurement strategy overhaul. Achieving this requires greater focus to procurement schedule, interoperability with the US and correctly resourced program oversight and contract monitoring. Whilst challenges and unknowns exist, agile development, digital engineering and open architecture methodologies are worthy of further study.

Recommendation 1: Urgently review CAF fighter procurement strategy, ensuring:

- Program schedule has priority over cost and performance.
- Interoperability with the US.
- Program oversight and contract monitoring is correctly resourced.
- Conduct of a further study into the potential benefits of NGAD methodologies.

33. NGAD represents a step change in procurement strategy and presents a unique opportunity for RCAF participation.

Recommendation 2: The RCAF seek every opportunity to collaborate with the US on next-generation fighter programs and investigate the feasibility of RCAF participation in NGAD.

34. Next-generation fighter programs represent a significant area of investment for Canadian industry.

Recommendation 3: Encourage Canadian industry to investigate feasibility (e.g. security, Intellectual Property (IP)) of participation in NGAD. Promote and encourage Canadian industry with proven expertise in agile development, digital engineering and open architecture to compete for NGAD contracts.

35. This paper aimed to detail the strategic need for Canada to develop and maintain an interoperable and generationally-relevant fighter program. It also explored the necessity of procurement strategy change, highlighting potential opportunities this presents for the RCAF and Canadian industry.

Annex: A. Aircraft Generations

AIRCRAFT GENERATIONS

Gen.	Era	Main features (non-exhaustive)	Examples
1 st	1945-55	Subsonic (no afterburner), rudimentary avionics, no radar, machine guns/cannons, unguided bombs/rockets	F-86 Sabre, Mig-15, Mig-17
2 nd	1955-65	Supersonic (advances in aerodynamics and engine design), radar, infrared and semi-active guided missiles	T7 Hunter, F-104 Starfighter, Mig-19, Mig-21
3 rd	1960-70	First multi-role aircraft, combat beyond visual range via Doppler radar, significant improvements to weapon systems, avionics and aerodynamics	F-4 Phantom, BAe Harrier, Mig-23, Mig-25, F-1 Mirage, Su-17, Su-20
4 th	1970-90	Improvements to avionics, aerodynamics and fly by wire, heads-up displays, swing-wing	Tornado, F-16, F-18, Su-27, Mig-27
4.5 th (4+ or 4++)	1990- 2000	<i>Existing airframes used to incorporate new technology (hence the half generation):</i> Stealth, thrust vectoring and engine performance, ordnance carriage, electronically scanned array radar for Airborne Early Warning (AEW), network-centric battlespace theory	F/A-18 Super Hornet, F-15E, Su-27/35, Mig-29, Mig-30
5 th	2000- TBD	Information age interoperability and data fusion, increased software reliance, step change in processing power (x100), low observable data links, chins, high performance engines, increased stealth	F-22, F-35, Su-57, J-20
6 th	TBD	<i>Potential features:</i> smart-skin, subsonic and multi-Mach, directed energy laser weapons, airframe morphing, counter cyber and Electronic Warfare, un-crewed, move from 'air system' to 'air enterprise' that includes loyal Uncrewed Air Vehicles	F/A-XX, Raptor II, BAe Tempest, FCAS, Mig-41, Houlong

*Table 1. Aircraft generations and main features over time.*⁴³

⁴³ *Ibid.*

1. 'Generations' describe the innovative features or capabilities of the aircraft era. Sometimes generations are described slightly differently, leading to confusion.⁴⁴ Table 1 shows an explanation of aircraft generations over time, their innovative features with platform examples.

2. Between WW2 and the turn of the century fighter aircraft moved from first to 4.5 generation with huge strides made across the four key aircraft components of avionics, armaments, airframes and engines.⁴⁵ Fifth-generation aircraft now dominate as a product of the information age.⁴⁶ Whilst improvements continue to be realised in the four key components, it is with increased processing power, software parameters, big data manipulation and interoperability that truly earns an aircraft the fifth-generation tag.

3. Potential sixth-generation features hint at technological quantum steps forward. However, as described in this paper, sixth generation promises a change of procurement mindset that delivers innovative technology, iteratively and rapidly within a suite of air systems or an interoperable air enterprise.

⁴⁴ Gary Martinic, *Jet fighter aircraft: five 'generations' later, and still counting*, Headmark, 2015

⁴⁵ *Ibid.*

⁴⁶ *Ibid.*

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