

Canadian
Forces
College

Collège
des
Forces
Canadiennes



NEXT-GENERATION FIGHTER AIRCRAFT

Lieutenant-Colonel John-Alec Bossence

JCSP 48

Service Paper

Disclaimer

Opinions expressed remain those of the author and do not represent Department of National Defence or Canadian Forces policy. This paper may not be used without written permission.

© Her Majesty the Queen in Right of Canada, as represented by the Minister of National Defence, 2022

PCEMI 48

Étude Militaire

Avertissement

Les opinions exprimées n'engagent que leurs auteurs et ne reflètent aucunement des politiques du Ministère de la Défense nationale ou des Forces canadiennes. Ce papier ne peut être reproduit sans autorisation écrite.

© Sa Majesté la Reine du Chef du Canada, représentée par le ministre de la Défense nationale, 2022

CANADIAN FORCES COLLEGE – COLLÈGE DES FORCES CANADIENNES

JCSP 48 – PCEMI 48

2021 – 2022

Service Paper – Étude militaire

NEXT-GENERATION FIGHTER AIRCRAFT

Lieutenant-Colonel John-Alec Bossence

“This paper was written by a student attending the Canadian Forces College in fulfilment of one of the requirements of the Course of Studies. The paper is a scholastic document, and thus contains facts and opinions, which the author alone considered appropriate and correct for the subject. It does not necessarily reflect the policy or the opinion of any agency, including the Government of Canada and the Canadian Department of National Defence. This paper may not be released, quoted or copied, except with the express permission of the Canadian Department of National Defence.”

“La présente étude a été rédigée par un stagiaire du Collège des Forces canadiennes pour satisfaire à l'une des exigences du cours. L'étude est un document qui se rapporte au cours et contient donc des faits et des opinions que seul l'auteur considère appropriés et convenables au sujet. Elle ne reflète pas nécessairement la politique ou l'opinion d'un organisme quelconque, y compris le gouvernement du Canada et le ministère de la Défense nationale du Canada. Il est défendu de diffuser, de citer ou de reproduire cette étude sans la permission expresse du ministère de la Défense nationale.”

NEXT-GENERATION FIGHTER AIRCRAFT

AIM

1. The service paper aims to examine the implications to the Canadian Armed Forces (CAF) and the Royal Canadian Air Force (RCAF) from the development of sixth-generation fighter aircraft and remotely piloted air systems (RPAS) such as the loyal wingman program. The implications for the RCAF are multifaceted and rely heavily on the need to complete the future fighter jet replacement project. The main implications focus on how these new capabilities will affect preparedness, training, doctrine, cyber defence, infrastructure, systems integration, data handling, and how the RCAF conceptualizes warfighting.

INTRODUCTION

2. The RCAF of today will face many challenges moving from a fourth to a sixth-generation fighter force and the potential inclusion of RPAS such as the loyal wingman. The current RCAF does not have the data processing, system integration, secure infrastructure, doctrine, training, and technical trades to adapt to a fifth-generation, let alone a sixth-generation fighter aircraft. Many of the RCAF implications remain the same, with the greatest one being the need to modernize the fighter force and replace the legacy CF-18 Hornet. The implications of the United States Air Force (USAF) and potential adversaries already looking toward a sixth-generation fighter situate the battlespace and allow the RCAF to look forward and position itself to best support allies.

3. The RCAF currently operates the CF-18 Hornet that is a fourth-generation fighter aircraft based mainly in 4 Wing Cold Lake and 3 Wing Bagotville.¹ The CF-18 was purchased for the RCAF in 1982 and was initially scheduled for replacement in 2016 but has seen service life extensions until 2032.² The latest upgrade to the CF-18 is the Hornet Extension Project (HEP) that will bring a total of 36 fourth-generation fighters up to 4.5-generation fighters minus new defensive jammers.³ The main difference between a fourth and a 4.5-generation fighter is the addition of improved sensors, avionics, active electronic scanned array (AESA) radar, armament, and modern data link.⁴

4. The Government of Canada started the Future Fighter Capability Project (FFCP) in 2017 to replace the RCAF CF-18 Hornet with 88 advanced fighter jets.⁵ The previous government contract awarded to Lockheed Martin F-35 Lightning II through a sole-source contract was cancelled because it was perceived as biased and unfair by the new

¹ National Defence Government of Canada, "CF-188 Hornet | Aircraft | Royal Canadian Air Force," June 16, 2020, Overview, <http://www.rcf-arc.forces.gc.ca/en/aircraft-current/cf-188.page>.

² National Defence Government of Canada, "Supplementary Estimates (A) Line Items - National Defence," navigation page, (September 15, 2020), Procurement Air, <https://www.canada.ca/en/department-national-defence/corporate/reports-publications/proactive-disclosure/supp-estimates-a-2020-21/supp-estimates-a-line-items.html>.

³ Ibid.

⁴ Gary Martinic, "Jet Fighter Aircraft - Five 'generations' Later, and Still Counting," *Naval Engineers Journal*, April 1, 2015.

⁵ Government of Canada, "Supplementary Estimates (A) Line Items - National Defence," FFCP.

government.⁶ The initial FFCP bidders included a mixture of fourth, 4.5, and fifth-generation fighter aircraft with the F/A-18 Super Hornet, F-35 Lightning II, and Saab JAS-39 Gripen as the finalists.⁷ The FFCP bid evaluation was completed in December 2021 with the F/A-18 Super Hornet removed from the FFCP bid process for not meeting the minimum requirements.⁸ The two fighter jets in consideration to replace the CF-18 are the JAS-39 a fourth-generation fighter and the F-35 a fifth-generation fighter.⁹ The contract for a new RCAF fighter jet to replace the CF-18 is expected to be awarded in 2022 with the delivery of the first replacement aircraft expected to be in 2025.¹⁰

5. The CAF does not currently own or operate any RPAS aircraft. However, Canada's Defence Strategy outlines the requirement for different RPAS aircraft capable of "conducting surveillance and precision strikes".¹¹ Based on the mandate in Strong, Secure Engaged, the RPAS project was started in 2019 to provide improved intelligence, surveillance, and reconnaissance (ISR) and strike capabilities to the RCAF.¹² The contract is scheduled to be awarded in 2022 to 2023 and the first expected delivery is expected by 2024 to 2025.¹³

CONTEXT

6. The term generations have been used since the early 1990s to refer to groups of fighter jets with similar combat capabilities.¹⁴ Each subsequent fighter jet generation represents a significant technological jump that sets them apart in combat capability from previous generation aircraft. For example, the CF-18 Hornet and JAS-39 Gripen are fourth-generation fighter jets capable of multi-role missions with advanced onboard integrated avionics and guided air weapons.¹⁵ However, both the CF-18 and JAS-39 are upgradable to 4.5-generation fighter jets with significant time and cost investments such as the CF-18 HEP project.¹⁶ The F-35 Lightning II represents a truly fifth-generation fighter jet and incorporates networked systems and stealth low observable materials and paint technology.¹⁷

⁶ Richard Shimooka, *The Fourth Dimension: The F-35 Program, Defence Procurement, and the Conservative Government, 2006-2015* (Ottawa: CDA Institute, 2016), 8.

⁷ Government of Canada, "Supplementary Estimates (A) Line Items - National Defence," FFCP.

⁸ National Defence Government of Canada, "Future Fighter Capability Project," education and awareness, (December 13, 2018), Project Updates, <https://www.canada.ca/en/department-national-defence/services/procurement/fighter-jets/future-fighter-capability-project.html>.

⁹ Ibid.

¹⁰ Ibid., Implementation.

¹¹ National Defence Government of Canada, *Strong, Secure, Engaged - Canada's Defence Policy*. (Ottawa, 2017), 73.

¹² Government of Canada, "Supplementary Estimates (A) Line Items - National Defence," Procurement Air.

¹³ Government of Canada, *Strong, Secure, Engaged - Canada's Defence Policy*, Procurement Air.

¹⁴ Martinic, "Jet Fighter Aircraft - Five 'generations' Later, and Still Counting."

¹⁵ Al Stephenson, *Anatomy of a Buy: The Four Dimensions of Procuring a Future Fighter for Canada*, 2019, 4, <https://www.deslibris.ca/ID/10100815>.

¹⁶ Martinic, "Jet Fighter Aircraft - Five 'generations' Later, and Still Counting."

¹⁷ Lockheed Martin, "5th Gen Capabilities," n.d., Unrivaled Capabilities, <https://www.f35.com/f35/about/5th-gen-capabilities.html>.

7. A sixth-generation fighter does not exist at this time, but many are under production in the United States, Russia, China, and the United Kingdom.¹⁸ The United States has the most mature prototype under the Next Generation Air Dominance (NGAD) program.¹⁹ The NGAD sixth-generation fighter is being designed to replace air superiority fighters such as the F-15 Eagle and F-22 Raptor.²⁰ Details about the capabilities of the sixth-generation fighters are classified. The expectation is that sixth-generation fighters will have the same capabilities as fifth-generation fighters with improved stealth, data processing, networked systems, and weapons capability.²¹ The USAF intent is to use new sixth-generation fighters to augment existing multi-role fifth-generation fleets in the United States Navy and Air Force like the F-35.²²

8. The loyal wingman program is another leading-edge research and development program funded by the USAF to generate fully mission-capable RPAS.²³ The systems integration computing power necessary for a loyal wingman to fly in formation while executing missions and processing data from multiple ISR platforms has required the USAF to launch Skyborg an artificial intelligence (AI) project.²⁴ The intent is that lead manned fifth or sixth-generation fighter jets control the loyal wingmen by assigning tasks to execute. Once tasked, the onboard AI program Skyborg will execute the mission while receiving and responding to all the integrated systems. The USAF plans to have RPAS controlled by Skyborg in operations by 2023.²⁵

DISCUSSION & ANALYSIS

9. The characteristics of air power most affected by the development of sixth-generation fighters and RPAS are sensitivity to technology and support dependency.²⁶ The sixth-generation fighter and RPAS will be resource-dependent and require a highly trained technical support team of pilots, engineers, and technicians to operate. The RCAF does not have personnel trained or qualified on low observable stealth technology, RPAS systems, and avionics systems integration. The implication is that the faster a decision on

¹⁸ Congressional Research Service, "Introduction to the Air Force's Next Generation Air Dominance Program," CRS Report, (October 6, 2020), <https://news.usni.org/2020/10/06/introduction-to-the-air-forces-next-generation-air-dominance-program>.

¹⁹ Jon Harper, "Air Force's NGAD Program 'Progressing Per Plan,'" 21 2021, <https://www.nationaldefensemagazine.org/articles/2021/9/21/air-forces-ngad-program-progressing-per-plan>.

²⁰ Ibid.

²¹ Congressional Research Service, "Introduction to the Air Force's Next Generation Air Dominance Program."

²² Ibid.

²³ Department of the Air Force United States Air Force, "United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047" (Washington, DC, May 18, 2009), 39, <http://apps.dtic.mil/sti/citations/ADA505168>.

²⁴ Kyle Mizokami, "The Air Force's AI Brain Recently Flew for the First Time," *Popular Mechanics*, May 13, 2021, <https://www.popularmechanics.com/military/aviation/a36412460/air-force-ai-brain-first-flight-skyborg-details/>.

²⁵ Ibid.

²⁶ National Defence Government of Canada, *B-GA-402-001/FP-001, Royal Canadian Air Force Doctrine: Command and Control*, 2018, 2, <http://www.rcf-arc.forces.gc.ca/en/cf-aerospace-warfare-centre/aerospace-doctrine.page>.

the FFCP replacement jet, the sooner the RCAF can arrange aircraft-specific training on advanced technology systems.

10. The new technology innovations that come with fifth and sixth-generation fighters and RPAS will have a positive transformational impact to increase RCAF effectiveness. Specifically, the new capabilities will alleviate many of the limiting characteristics of air power such as impermanence, payload, and stealth.²⁷ For example, the RPAS can increase impermanence by remotely monitoring and conducting northern sovereignty operations in the arctic. Increased permanence is a significant benefit of RPAS because it reduces the need for manned aircraft flights to conduct ISR and northern sovereignty operations in the arctic. In conflict, the RPAS can also increase payload by carrying extra munitions to support the manned fifth or sixth-generation fighter jets. The proposed aircraft have integrated low observable stealth characteristics that improves the time of exposure to enemy action. As a result, fifth and future sixth-generation fighter jets with RPAS stealth aircraft are ideal against anti-access/area denial and integrated air defence systems.²⁸

11. The most significant implication for the RCAF is low preparedness with allies already well on the way to fielding sixth-generation fighter aircraft and RPAS loyal wingman programs. Conversely, the RCAF is approximately two decades behind the CF-18 replacement project.²⁹ Canada's Defence Strategy discusses preparedness as a series of capital investments that "ensure the Canadian Armed Forces' preparedness for the future through the development, sustainment, and enhancement of the core combat and critical enabling capabilities".³⁰ Specifically, the RCAF is already behind the curve on secure infrastructure upgrades and conducting air force operations with fifth-generation fighter jets. Selecting and operating a fifth-generation fighter will prepare the RCAF to transition to a sixth-generation fighter if required. The reason it may not be required is that the sixth-generation fighter is designated an air superiority fighter like the F-22 Raptor that does not meet the multi-role requirement of the RCAF.³¹ The sixth-generation fighter jet is an air superiority fighter that will actively fight to control the air and achieve air superiority in contested air space against a near-peer threat.³²

12. Interoperability with allies in the North Atlantic Treaty Organization and North American Aerospace Defence Command is critical to ensure that the RCAF can still communicate, support, and operate with allies in a coalition force. As a result, the decision to replace the CF-18 with either the F-35 fifth-generation fighter or the JAS-39 fourth upgradable to 4.5 generation fighter will have a massive impact on the future role the RCAF can fill in a coalition force. Right now, the JAS-39 cannot communicate with

²⁷ Ibid.

²⁸ Bert Chapman, *Global Defense Procurement and the F-35 Joint Strike Fighter* (Cham: Palgrave Macmillan, 2019), 311, doi:10.1007/978-3-030-01367-7_6.

²⁹ Ibid., 212.

³⁰ Government of Canada, *Strong, Secure, Engaged - Canada's Defence Policy*, 41.

³¹ Harper, "Air Force's NGAD Program 'Progressing Per Plan.'"

³² David A. Deptula, Lawrence A. Stutzriem, and Heather Penny, "The Case for Fifth-Generation and NGAD Airpower," *Air Force Magazine*, Spring 2019, <https://www.airforcemag.com/article/the-case-for-fifth-generation-and-ngad-airpower/>.

USAF aircraft securely. However, Saab has stated they will make it compatible if they win the bid.³³ The current RCAF is unprepared to address the implications of operating and sustaining sixth-generation fighter jets and unmanned combat aircraft like RPAS. However, it is possible to learn from the current fifth-generation allied fighter fleets and apply lessons learned to prepare for a new FFCP jet.

13. General Charles Brown the current USAF Chief of Staff (COS), has proposed a modular approach to aircraft modernization for sixth-generation aircraft.³⁴ The RCAF has already started modular upgrades with HEP in coordination with the United States Marine Corps to extend the CF-18s capable service life through modular upgrades to 36 aircraft in the fighter force.³⁵ The implication for the RCAF is that the modular approach to aircraft modernization has been proven with the CF-18 HEP project and can be implemented in the future to maintain a credible air force with allies. Specifically, procurement delays for major equipment purchases become streamlined through lower-cost modular upgrades to existing aircraft systems.³⁶ This modular approach will also help the RCAF extend the operational capable service life of the next fighter jet.³⁷ Further, modular upgrades will manage downtime and costs associated with major in-service upgrades where traditionally, the aircraft was taken out of operational service for months at a time.

14. Cost implications are a reality for the RCAF because it is a small air force and cannot procure, train, sustain, and operate every new cutting-edge technology system or aircraft. An example is how F-35 cost estimates heavily impacted the initial CF-18 replacement program resulting in multiple delays directly attributable to the high costs associated with buying, supporting, and operating a fifth-generation fighter aircraft.³⁸ The current per aircraft price of the F-35 is \$80 million United States dollars.³⁹ The implication for the RCAF is that the sixth-generation fighter jet and RPAS will come with a much higher cost per aircraft. The USAF is planning to send in loyal wingman first as it is deemed expendable. The costs would then become prohibitive like the initial F-35 purchases, and not many allied nations will quickly adopt the new capabilities.

15. A possible solution explored by the USAF is the procurement of 4.5-generation fighter jets to fill the large capability gap that procuring high-cost fifth and sixth-

³³ Government of Canada, "Future Fighter Capability Project."

³⁴ Thomas Newdick, "The Air Force Might Make Two Distinct Versions Of Its Next Multirole Stealth Fighter," *The Drive*, 17 2021, <https://www.thedrive.com/the-war-zone/41138/the-air-force-might-make-two-distinct-versions-of-its-next-multirole-stealth-fighter>.

³⁵ Government of Canada, "Supplementary Estimates (A) Line Items - National Defence," Procurement Air.

³⁶ Public Works and Government Services Canada Government of Canada, "Canada First: Leveraging Defence Procurement Through Key Industrial Capabilities," February 8, 2013, xiv, <https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/samd-dps/eam-lmp-eng.html>.

³⁷ *Ibid.*, 26.

³⁸ Shimooka, *The Fourth Dimension: The F-35 Program, Defence Procurement, and the Conservative Government, 2006-2015*, 6.

³⁹ Lockheed Martin, "F-35: The Right Choice for Canada," n.d., <https://www.f35.com/f35/global-enterprise/canada.html>.

generation aircraft fleets will introduce to the force.⁴⁰ The force mixture suggested by the USAF COS General Brown is approximately 40% 4.5-generation and 60% fifth-generation fighter jets.⁴¹ This approach has considerable implications for the RCAF because it combines the stealth capabilities, systems integration, and sensors of the fifth-generation fighter jets with the cost savings associated with the 4.5-generation fighter jets. The CAF can take a similar approach to support a sixth-generation coalition fleet with RCAF 4.5 or fifth-generation multi-role fighter jets and RPAS. The sixth-generation air superiority aircraft would come from larger coalition partners like the United States military. The implication is that the RCAF may have a mixed fleet of 4.5 and fifth-generation fighters with RPAS that support multi-role missions. Sixth-generation fighter fleets would retain contested air superiority missions.

16. Another implication for the RCAF is the increased need for systems networking, data processing, and protection from cyber-attacks. The concept of every aircraft as a sensor integrates well with the employment concept of the fifth and sixth-generation fighters and RPAS capabilities.⁴² Each air, land, sea, and space sensor will share information and build a common operating picture or combat cloud. Retired USAF Lieutenant-General Deptula put forward the combat cloud idea as “desired effects of military operations will increasingly be attained through the interaction of multiple systems, each one sharing information and empowering one-another for a common purpose”. The RCAF will need to ensure the security and protection of the combat cloud from cyber-attacks and that systems exist to process the large data requirements. The USAF is developing AI to process the enormous amount of data from each sensor to inform and enable combat capability decisions.⁴³

17. RCAF doctrine will also need to be updated to account for the improved combat, sensors and ISR capability of sixth-generation fighters and RPAS. Currently, the USAF plans to control loyal wingmen aircraft from the backseat cockpit of a manned fighter jet or an airborne warning and control system aircraft.⁴⁴ A concern for the RCAF because after the FFCP concludes and the CF-18 retires, the CAF will not have any two-seat fighter variants or airborne warning and control systems. Specifically, the RPAS program will require a new set of doctrines to account for flying formation with an unmanned combat aircraft. Further, fundamental changes to aircraft operating instructions and combat tactics, techniques, and procedures are required. Doctrine updates will ensure proper safe methods to employ RPAS to the maximum extent possible during missions are available.

⁴⁰ Congressional Research Service, “Report to Congress on the F-35 Joint Strike Fighter,” CRS Report, (January 17, 2022), 37, <https://news.usni.org/2022/01/17/report-to-congress-on-the-f-35-joint-strike-fighter>.

⁴¹ Ibid.

⁴² Richard Evan Goette, *Preparing the RCAF for the Future: Defining Potential Niches for Expeditionary Operations* (Canada: Royal Canadian Air Force Warfare Centre, n.d.), 93, <https://www-deslibris-ca.cfc.idm.oclc.org/ID/10105952>.

⁴³ United States Air Force, “United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047,” 50.

⁴⁴ Ibid., 40.

18. The final significant implication of the loyal wingman program is that the RCAF will need to reconsider how it fights due to the attributable nature of the unmanned aerial vehicle. The USAF request for design proposal predicates the disposable nature of loyal wingman aircraft in combat such that they will take the most high-risk missions and provide cover for manned aircraft.⁴⁵ Disposable RPAS is a paradigm-shifting concept for the RCAF as a small air force with limited resources and budgetary concerns.⁴⁶ However, losing the RPAS aircraft is preferable to a manned fifth or sixth-generation fighter jet from a replacement cost and loss of life perspective.

CONCLUSION

19. The CF-18 replacement delays have placed the RCAF in a unique position to benefit from allied lessons learned on the best way to implement a modern fifth-generation fighter jet integrated air force. The significant implications are that the new sixth-generation fighter jet will be costly and result in a mixed force structure with augmentation from 4.5 and fifth-generation fleets for multi-role missions. Finally, the RCAF is experiencing low preparedness to transition to a fifth or sixth-generation fighter jet because of repeated CF-18 replacement delays. The sooner an FFCP jet is selected, the sooner the RCAF will be able to reach out to leverage allied experience to facilitate the transition to the next generation of fighter jets.

20. The highly advanced sixth-generation fighters and RPAS loyal wingman programs suffer from the air power characteristics of sensitivity to technology and support dependency but significantly improve impermanence, payload, and stealth. The opportunity exists to mitigate negative implications by capitalizing on the current FFCP program impetus to modernize infrastructure, security, doctrine, cyber defence, systems integration, data handling, interoperability, and invest in emergent technologies such as AI. Potential RCAF adversaries have already switched to fifth-generation fighters and are developing sixth-generation fighters. The RCAF needs to adapt and modernize to remain relevant in the highly contested air domain.

RECOMMENDATIONS

21. Recommend that the RCAF invest in recruiting and training software engineers and technicians focused on systems integration, data processing, and AI.

22. An opportunity exists for the CAF and RCAF to increase the involvement and number of liaison officers located worldwide with allies that have already transitioned to fifth or sixth-generation fighters and loyal wingman programs. Liaison officers can identify and benefit from lessons learned such that RCAF implementation challenges are mitigated with proven solutions.

⁴⁵ Ibid., 39.

⁴⁶ Goette, *Preparing the RCAF for the Future: Defining Potential Niches for Expeditionary Operations*, 9.

BIBLIOGRAPHY

- Chapman, Bert. *Global Defense Procurement and the F-35 Joint Strike Fighter*. Cham: Palgrave Macmillan, 2019. doi:10.1007/978-3-030-01367-7_6.
- Congressional Research Service. "Introduction to the Air Force's Next Generation Air Dominance Program." CRS Report, October 6, 2020. <https://news.usni.org/2020/10/06/introduction-to-the-air-forces-next-generation-air-dominance-program>.
- . "Report to Congress on the F-35 Joint Strike Fighter." CRS Report, January 17, 2022. <https://news.usni.org/2022/01/17/report-to-congress-on-the-f-35-joint-strike-fighter>.
- Deptula, David A., Lawrence A. Stutzriem, and Heather Penny. "The Case for Fifth-Generation and NGAD Airpower." *Air Force Magazine*, Spring 2019. <https://www.airforcemag.com/article/the-case-for-fifth-generation-and-ngad-airpower/>.
- Goette, Richard Evan. *Preparing the RCAF for the Future: Defining Potential Niches for Expeditionary Operations*. Canada: Royal Canadian Air Force Warfare Centre, n.d. <https://www-deslibris-ca.cfc.idm.oclc.org/ID/10105952>.
- Government of Canada, National Defence. *B-GA-402-001/FP-001, Royal Canadian Air Force Doctrine: Command and Control*, 2018. <http://www.rcf-arc.forces.gc.ca/en/cf-aerospace-warfare-centre/aerospace-doctrine.page>.
- . "CF-188 Hornet | Aircraft | Royal Canadian Air Force," June 16, 2020. <http://www.rcf-arc.forces.gc.ca/en/aircraft-current/cf-188.page>.
- . "Future Fighter Capability Project." Education and awareness, December 13, 2018. <https://www.canada.ca/en/department-national-defence/services/procurement/fighter-jets/future-fighter-capability-project.html>.
- . *Strong, Secure, Engaged - Canada's Defence Policy*. Ottawa, 2017.
- . "Supplementary Estimates (A) Line Items - National Defence." Navigation page, September 15, 2020. <https://www.canada.ca/en/department-national-defence/corporate/reports-publications/proactive-disclosure/supp-estimates-a-2020-21/supp-estimates-a-line-items.html>.
- Government of Canada, Public Works and Government Services Canada. "Canada First: Leveraging Defence Procurement Through Key Industrial Capabilities," February 8, 2013. <https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/samd-dps/eam-lmp-eng.html>.

- Harper, Jon. "Air Force's NGAD Program 'Progressing Per Plan,'" 21 2021.
<https://www.nationaldefensemagazine.org/articles/2021/9/21/air-forces-ngad-program-progressing-per-plan>.
- Martin, Lockheed. "5th Gen Capabilities," n.d. <https://www.f35.com/f35/about/5th-gen-capabilities.html>.
- . "F-35: The Right Choice for Canada," n.d. <https://www.f35.com/f35/global-enterprise/canada.html>.
- Martinic, Gary. "Jet Fighter Aircraft - Five 'generations' Later, and Still Counting."
Naval Engineers Journal, April 1, 2015.
- Mizokami, Kyle. "The Air Force's AI Brain Recently Flew for the First Time." *Popular Mechanics*, May 13, 2021.
<https://www.popularmechanics.com/military/aviation/a36412460/air-force-ai-brain-first-flight-skyborg-details/>.
- Newdick, Thomas. "The Air Force Might Make Two Distinct Versions Of Its Next Multirole Stealth Fighter." *The Drive*, 17 2021. <https://www.thedrive.com/the-war-zone/41138/the-air-force-might-make-two-distinct-versions-of-its-next-multirole-stealth-fighter>.
- Shimooka, Richard. *The Fourth Dimension: The F-35 Program, Defence Procurement, and the Conservative Government, 2006-2015*. Ottawa: CDA Institute, 2016.
- Stephenson, Al. *Anatomy of a Buy: The Four Dimensions of Procuring a Future Fighter for Canada*, 2019. <https://www.deslibris.ca/ID/10100815>.
- United States Air Force, Department of the Air Force. "United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047." Washington, DC, May 18, 2009. <http://apps.dtic.mil/sti/citations/ADA505168>.