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UNMANNED COMBAT AERIAL VEHICLE: A FUTURE RCAF CAPABILITY

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AIM

1. The aim of this service paper is to identify the need for the Royal Canadian Air Force (RCAF) to commit to and invest in an Unmanned Combat Aerial Vehicle (UCAV) program. The investment in this capability will be a force multiplier in future warfare.

INTRODUCTION

2. The recently approved RCAF's Remotely Piloted Aircraft System (RPAS) project is still in the *Definition Phase*. Initial Operational Capability (IOC) is expected in fiscal year (FY) 2025/26 and Full Operational Capability (FOC) in FY 2029/30.[1] Under this project, the RCAF will procure a fleet of armed Class III Medium Altitude Long Endurance (MALE) unmanned aerial vehicle (UAV). An example of a Class III MALE UAV is the much known and seen *Predator*. This project is fulfilling initiatives 50 and 91 of the *Strong, Secure, Engaged Defense Policy (SSE)* which calls for investment in medium altitude remotely piloted, including armed aerial vehicle capable of conducting ISR and strikes.[2]

3. Lacking in the SSE is a directive for the RCAF to invest in an UCAV capable of air-to-air or air-to-ground combat. This service paper will analyze the benefits of investing in a UCAV program that is still in its infancy, but booming. This paper will proceed by:

a. Reviewing history unmanned aerial vehicle (UAV);
b. Explore current UCAV being developed;
c. Advantages of a UCAV;
d. Industrial and technical benefits of a UCAV program;
e. Challenges;
f. Proposing a way forward to proceed with a UCAV program.

4. It is important to note that this paper is not advocating for a UCAV platform to replace the aging CF-18 fleet or its successor under the Future Fighter Capability Project (FFCP). Instead, this paper is advocating for the RCAF to commit to a UCAV program and start investing in it sooner rather than later. Investing in such a program would fall under the Initiative 92 of the SSE.

DISCUSSION

5. The terms UAV and UAS (unmanned aerial system) are often used interchangeably without distinction. However, it is important to understand the difference. UAV refers to the

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[1] Royal Canadian Air Force, "Remotely Piloted Aircraft System", accessed 24 October 2019, http://dgpaapp.forces.gc.ca/en/defence-capabilities-blueprint/project-details.asp?id=977
[2] Department of National Defence, "Strong, Secure, Engaged – Canada's Defence Policy". (Ottawa: DND Canada, 2017), 39.

aerial vehicle itself, whereas UAS refers to the entire system which comprises the vehicle, ground control station, communication systems, and other elements besides the actual air vehicle. For simplicity this paper will use “UAV” with the understanding that all its supporting elements will be included.

6. UAVs range in size from a micro air vehicle weighing less than a pound to large air vehicle weighing upward of 35,000 pounds. In 2015 the CAF adopted the NATO UAS Classification which has three classes of UAV: Class I (<150 kg), Class II (150-600 kg), and Class III (>600 kg)[3]. Each class is further divided into categories based on vehicle’s weight, employment, and operating altitude. The NATO UAS Classification does not categorize UAS based on its operating speed, thus bringing confusion between a Strike UAV and combat UAV (ie. UCAV). UCAV should distinct itself from other prevailing armed UAV such as the *Predator* or the *Global Hawk,* is the ability to fly at high subsonic speeds, enabling it to keep pace with an F-16 or F-35 fighter jet.[4] While these armed UAV may be able to conduct strikes over an uncontested sky, they cannot engage in air-to-air combat or evade sophisticated air defense system. As such they are not truly *combat* UAV. Hence the term UCAV in this paper will refer to Class III armed UAV with high subsonic speed capable of air-to-air and air-to-ground combat with high probability of survival against air defense system.

Some UCAV in development around the world

7. UCAV development has seen significant milestone in the last several years thanks to large investment by many militaries. For example, in 2017 the United States Air Force (USAF) alone dedicated $532M US Dollars (USD) for research and development, testing and evaluation of various UAVs.[5] The following are examples of UCAVs that are in different stages of development around the world:

a. X-47B: Designed by Northrop Grumman for the U.S. Navy (USN) for aircraft carrier operations, it has successfully launched and recovered from a carrier, conducted combined manned & unmanned operations, and conducted air-air refueling. A “flying wing” by design, two prototypes have been flight tested with USN since 2013. No entry to service date has been announced;[6]

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[3] J.Y Blondin, Implementation of NATO UAS Classification Table, CANFORGEN 080/15 C AIR FORCE 13/15 231956Z APR 15

[4] Aaron Gregg, “Air Force completes first flight test of Valkyrie unmanned fighter jet,” *The Washington Post*, 6 March 2019.

[5] Department of Defense, *Unmanned Systems Roadmap FY 2017-2042*, (Washington, DC: U.S Government Printing Office, 2017), 3.

[6] Northrop Grumman, accessed 24 October 2019, https://www.northropgrumman.com/Capabilities/X47BUCAS/Pages/default.aspx

b. XQ-58A Valkyrie: San Diego-based Kratos Defense and Security Solutions, in partnership with the U.S. Air Force Research Lab (AFRL), completed the first flight test of the Valkyrie on 5 March 2019. The Valkyrie is designed to fly alongside manned fighter jets and navigate autonomously;[7]

c. Boeing Airpower Teaming System (ATS): On 27 February 2019 Boeing unveiled its ATS, which "is fighter-like unmanned aircraft…designed to fly independently or in tandem with manned platforms, using artificial intelligence to maintain a safe distance between aircraft".[8] Boeing expects the prototype to achieve first flight in 2020;

d. UK Taranis: U.K's BAE Systems demonstrator completed Phase 2 of test flight trials in Summer 2014. Still undergoing trials and test flights, it is expected to enter service with RAF in 2030;[9]

e. France nEUROn: Dassault Aviation-led European consortium's nEUROn's first test flight was in December 2012. Achieved 100th sorties by February 2015. Still under operational testing & evaluation. No date given for entry into service;[10]

f. Russia S-70 Okhotnik: First successful test flight on 7 August 2019. It has a "flying wing" design, and looks similar to Taranis, nEUROn, and X-47B. No date given for entry into service;[11]

g. China CH-7: First introduced at the China Airshow in November 2018, it is still in development. It is dubbed the "baby" version of Northrop Grumman X-47B. Designed to "detect and destroy hostile strategic targets" with a maximum speed of 575 mph.[12]

Advantages of a UCAV

8. Autonomy: Unlike RPAS UAV, which has maximum speed of approximately 350 mph and incorporate many automated systems (autopilot), UCAV are designed for higher speed to keep up fighter jets. As such, they are also required to fly more autonomously. It is important to distinguish autonomy and automated systems.

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[7] Ibid.
[8] Graham Warwick, "Boeing Reveals 'Loyal Wingman' UAV," *Aviation Week Intelligence Network,* (26 February 2019).
[9] BAE Systems, accessed 24 October 2019, https://www.baesystems.com/en/product/taranis
[10] Dassault Aviation, accessed 23 October 2019, https://www.dassault-aviation.com/en/defense/neuron/programme-milestones/
[11] Garrett Reim, "Russia's Sukhoi S-70 Okhotnik flying wing unmanned air vehicle (UAV) has made its first test flight," *FlightGlobal.com*, (8 August 2019).
[12] William Kucinski, "The CH-7: China's latest unmanned combat air vehicle," *SAE Internationl*, (9 November 2018)

> The Autonomy is defined as the ability of an entity to independently develop and select among different courses of action to achieve goals based on the entity's knowledge and understanding of the world, itself, and the situation. Autonomous systems are governed by broad rules that allow the system to deviate from the baseline. This is in contrast to automated systems, which are governed by prescriptive rules that allow for no deviations.[13]

9. Autonomous flight relies on pre-flight input from operators with adjustment during flight due to change in mission or target, for example. As artificial intelligence (AI) improves and computing power get ever faster, the need for in-flight adjustment by operators will be minimized. With the advancing research in AI, the ability of UCAV to soon perform air combat against manned fighters or adversary UCAV is promising.

10. In 2016, a doctoral student at the University of Cincinnati developed a new AI dubbed ALPHA specifically for UCAV. ALPHA was assessed in a high fidelity combat simulator by a retired USAF fighter pilot, Colonel Gene Lee. Col Lee is a graduate of Fighter Weapons School with extensive fighter aircraft experience as an instructor and air battle manager. The result was "not only was Lee not able to score a kill against ALPHA after repeated attempts, he was shot out of the air every time during protracted engagements in the simulator."[14] As incredible as this may sound, it is only the beginning of AI application in UCAV.

11. Cost: When comparing the advantage of unmanned to manned air vehicles, a key advantage is cost. Cost saving for UCAV versus manned fighters are mostly realized during the operations phase of the life cycle. The developmental and procurement cost have shown to be very similar between unmanned and manned platforms, when ground control station and support equipment are factored in.[15]

12. The real saving is during the operational phase. For example, the F-35A unit cost is currently approximately $90M USD[16] and has a design life of 8000 hrs. Based on historic data of other fighters, about 95% of its flight hours will be flown for training and other non-combat missions, leaving 5% or 400 hours for actual combat.[17] Thus the cost per combat hour is $225K USD. For a UCAV, assuming a unit cost of $30M (very high end), a design life of 5000 hours, and that 50% flight hours will be training, leaving it with 2500 hours for combat, the cost per

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[13] Department of Defense, *Unmanned Systems Roadmap FY 2017-2042…,* 17.
[14] "Artificial Intelligence; New artificial intelligence beats tactical experts in combat simulation," *Defense & Aerospace Week*, Atlanta (13 July 2016), https://search.proquest.com/docview/1802270602/536E9C952B74A97PQ/2?accountid=9867
[15] Yvan Choinière, "Is the UCAV the answer to Canada's Northern Soveignty?" (National Security Program, Canadian Forces College, 2010), 39.
[16] Lockheed-Martin, accessed 24 October 2019, https://www.f35.com/about/cost.
[17] Carl Doyon, "Le remplacement du CF-18 en 2017-2020: Le Unmanned Combat Vehicle (UCAV) ou le Joint Strike Fighter (JSF)?", (CSC 30 Thèse de la maitrise, 2004), 47.

combat hour is $12K USD.[18] This cost per hour implies that the UCAV could suffer 18 times the combat loss rate of a F-35 and still be cost comparable.

13. Taking the human out of the cockpit allows the removal of the aircraft life supporting equipment (ALSE), thus further reducing weight and operating cost (and eliminate unserviceability due ALSE). It is estimated that without a cockpit, the size of the aircraft could be reduced by 40% and maintain similar performance.[19] In fact, maneuverability will be better as the aircraft is not constrained by human limits such as the maximum number of *g's* it can pull (and for how long) during combat manoeuver. In addition, mission or sortie will not be constrained a pilot's duty day (how many hours he/she can fly a day).

14. Another factor adding cost to manned aircraft is loss due to human error. Seventy-five percent of non-combat aircraft losses are attributed to human error.[20] Although operators and manufacturers learn from these accidents by modifying the aircraft, change or develop new procedures, this rate remain unchanged. Non-combat HCAV losses will likely occur, but advance in AI and software updates will likely eliminate loss due to repeated errors. Increased simulator fidelity and reduced training flight hours will also minimize non-combat loss rate. As with manned aircraft, losses due to mechanical or electrical failures will still occur because no design or manufacturing process are perfect.[21]

Industrial and technical benefits of a UCAV program

15. In 2017, the Canadian UAV sector was estimated at $750M with over 1000 companies (mostly Class I UAV).[22] Despite this value and the growth in the industry, there is no current capability in Canadian Industry for the development of a Class III UAV. This capability will likely change in the next few years as industry and academia look to join in the RCAF's RPAS project. Indeed several postsecondary institutions such as the University of Toronto, University of British Columbia, University of Victoria, and Carleton University have recently added unmanned aviation courses to their programs.[23] The RCAF could further ride the industry and academic interest by committing to a UCAV program to complement the future fighter force. Such a commitment will spur investment in research and development of UCAV program that will benefit Canadian industry and expertise in unmanned systems.

16. Even if Canada does not expect to develop a UCAV on its own, it should join a U.S. or international partnership (similar to Canada's participation in the F-35 JSF program). Such collaboration will have economic benefit for the Canadian UAV industry. For example, Canadian participation in the F-35 JSF program from 1997 to 2017 (and 250 aircraft built) has secured over $1.85 billion worth of work, and supported of 9,459 full time equivalent (FTE)

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[18] Ibid.
[19] "Unmanned Fighters: Flight without Limits," *Jane's Defence Weekly*, (10 April 1996), 29.
[20] David R. Oliver, "Unmanned Aerial Vehicles Roadmap 2000-2005", (*Office of the Secretary of Defense*, 2001), 54.
[21] Ibid.
[22] Mark Aruja (speech, Canadian Business Aviation Association Convention, Waterloo, ON, 13 Jun 2018).
[23] David Kennedy, "Canada's drone industry? It's just getting off the ground," MacLean's, 29 December 2015

jobs.[24] With a worldwide order of over 3100 aircraft and a production line beyond 2040, the total impact is estimated at over $11.4 billion and 132,426 (FTE) jobs supported (assuming current contracts are extended).[25]

17. The global UAV market (all Classes) was valued at $25.59 billion USD in 2018 and is estimated to reach $70.28 billion USD by 2029.[26] A Canadian collaboration in a UCAV program will economically and technologically be beneficial to the Canadian UAV industry.

Challenges

18. While UCAV is a promising future capability, there are challenges that need to be overcome before it can be fully integrated in the RCAF. The following for four areas of interest need to be taken into account as the development of UCAV advances:[27]

a. Interoperability: Warfighting systems need to efficient interactions, both manned and unmanned. As such, development must consider open and common architectures.

b. Autonomy: Advance in autonomy and IA is a significant force multiplier for manned and unmanned systems, and will greatly increase the efficiency and effectiveness of these systems;

c. Network Security: Unmanned systems operations rely on secure communications network, which must be addressed to prevent its disruption or manipulation;

d. Human-Machine Collaboration: Teaming between human and forces and machines will enable revolutionary collaboration where machines will be valued as critical teammates.

19. Future advanced autonomous systems will require the AI in UCAV to be capable of or incorporate of the following features:[28]

a. Identification of potential threats outside pre-programmed mission briefs;
b. Autonomous exploration and assessment of identified targets that autonomous control deems to be high priority;
c. Enhancement and update to intelligence supplied as part of the mission brief and plan, based on actual observation;

[24] Economic Impact Report: F-35 Lightning II Program in Canada, *OMX Data Analytics*, October 2017, 5.
[25] Ibid, 7.
[26] "The Global Unmanned Aerial Vehicle (UAV) Market to reach $70.28 Billion by 2029," *Bloomberg Business*, 30 May 2019.

[27] Industrial and technical benefits of a UCAV program…, 6-31.
[28] Amir Hussain and Bruce Porter, "Artificial Intelligence Approaches to UCAV Autonomy," *Cornell University*, 26 January 2017, https://arxiv.org/abs/1701.07103.

d. Ability to adjust to environmental conditions that cause system or any linked swarm systems to deviate from mission plan expectations;
e. Ability to adjust to loss of a Swarm asset, not just in terms of repositioning, but including potential re-tasking (i.e. assumption of a new role on the part of an individual asset);
f. Automated update to mission plan based on sensor detection of probable manned aerial intercept;
g. Automated update to mission plan based on detection of unexpected sensor presence;
h. Autonomous evasion in the event of a RWR (Radar Warning Receiver) activation or MAW (Missile Approach Warning) system activation;
i. Autonomous addition to target lists based on computer vision or alternate sensor based identification of threats to mission (including surface to air threats);
j. Autonomous addition to target lists in the event that primary targets have already been neutralized;

CONCLUSION

20. There is no doubt that in the future warfare, commanders will call for more and more UAVs, not only for their ISR capability, but also for their striking power without putting pilots in danger. To defeat future peer adversaries or evade sophisticated air defense system, autonomous UCAV will be the weapon of choice.

21. Canada, through the RCAF should partner with its allies to develop a new or join in an existing UCAV program to capitalize on the work already done while the program is still in its infancy. Delay in joining will not only deny the RCAF of a future critical capability, but deny its industry the economic benefits and expertise. Investing in a UCAV program is in line with SSE's 92 Initiative that direct the "conduct research and development of remotely piloted land, sea and aerial capabilities, in close collaboration with industry and academia."[29]

RECOMMENDATION

22. It is recommended that the RCAF commit and make the necessary investment in an UCAV program so to not deny itself of a crucial capability of future warfare.

[29] Department of National Defence, "Strong, Secure, Engaged – Canada's Defence Policy". (Ottawa: DND Canada, 2017), 73.

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