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sUAS and Counter-sUAS: Essential Capabilities for the CAF

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Introduction

The use of Unmanned Aerial Systems (UAS) in the conduct of military operations is not new. Rather, most currently serving Canadian Armed Forces (CAF) members and North Atlantic Treaty Organization (NATO) partner forces have gained familiarity with UAS on deployments over the last twenty years. While UAS had previously been capabilities only well-resourced militaries could afford, rapid growth in the types of UAS available have made them affordable for non-state actors as well as states outside of the traditional major military powers. As a result of the rapid proliferation of UAS capabilities by potential adversaries, it is essential to understand how the platforms are being used and the threats they pose to CAF operations.

Within the broader UAS category, the employment of small UAS (sUAS) has been an area of particularly rapid growth. While sUAS use by terrorist organizations and other non-state actors has been commonplace in many recent conflicts, sUAS became increasingly note-worthy during the Russia-Ukraine war, with conventional forces leveraging them for a myriad of battlefield functions. While the benefits of sUAS in tactical applications are well documented, and new applications for sUAS are continually emerging, their ability to deliver strategic effects is questionable. Despite offering many tactical level advantages, sUAS have not been decisive war winning platforms for either Russia or Ukraine. Nevertheless, the growing list of military applications for sUAS make them attractive to conventional forces and non-state actors alike, and it must be assumed that the CAF will encounter adversarial sUAS on future deployments. To ensure the CAF is prepared to meet the challenges of an operating environment where sUAS are commonplace, it is essential to procure sUAS and counter-sUAS technologies for the CAF and provide comprehensive training on their use. This will guarantee the CAF employs effective force protection systems for its members and infrastructure, while simultaneously leveraging the advantages offered by modern sUAS platforms.

sUAS as a distinct class of UAS

As the technology has matured the number of systems within the wider category of UAS has greatly expanded, leading to potential confusion when using UAS as a general term. A UAS can be as large as a human-piloted aircraft with payload capacities exceeding 3,500 lbs or small enough to fit in the palm of one's hand and capable of only supporting the weight of a small video camera.[1] As a result of the variety of UAS available, the capabilities and tasks performed by the platforms can vary widely. This has necessitated a detailed system of categorization to eliminate misunderstandings when discussing UAS.

For this discussion, the NATO classification system will be used to define what a sUAS is. Within the NATO system a sUAS is considered a Class I UAS and has several characteristics that differentiate it from larger classes. A Class I UAS weighs less than 150 kg, can fly at an altitude not greater than 5,000 feet above ground level, and has a normal operational radius of 50

[1] General Atomics Aeronautical. "MQ-9A Reaper: Persistent Multi-Mission ISR." *Fact Sheet*. Accessed 20 April 2024. https://www.ga-asi.com/remotely-piloted-aircraft/mq-9a.

km or less.[2] While the Class I category can be further divided into micro, mini, and small, the term sUAS in this discussion will be referring to all three sub-categories of Class I UAS. It is essential to consider the classes of UAS separately, particularly when discussing defence considerations. While conventional air defence techniques can be used against larger UAS, those techniques are less effective against sUAS that fly at a lower speed and altitude.[3] A novel approach must therefore be taken to defend against the threats posed by sUAS.

The increased interest in sUAS can be explained by examining factors such as cost, infrastructure requirements, technological requirements, and level of control. The cost of larger UAS has prevented many states from procuring them. The Canadian procurement of 11 MQ-9 Reaper UAS, anticipated to cost $2.49 billion, is indicative of the financial commitment necessary to incorporate Class III UAS into a military.[4] By contrast, many of the popular commercial sUAS can cost less than one thousand dollars. The vastly lower price and wide availability of sUAS has facilitated rapid adoption, not only by non-state actors, but also conventional forces. Their low cost has become a crucial factor in their use in the Russia-Ukraine war, as sUAS are often considered disposable items, with life expectancies of 3-6 flights.[5]

The infrastructure requirements to operate large UAS are also prohibitive. Large UAS like the MQ-9 Reaper require aircraft hangers, maintenance facilities, runways, and buildings from which to pilot the UAS. By comparison, most sUAS require no dedicated facilities for maintenance, can be carried by an individual, and launched from unprepared positions. Similarly, the technologically advanced sensors and precision guided munitions found on large UAS are expensive and access to them is heavily restricted. Conversely, commercially purchased sUAS can be easily modified to carry and deliver conventional munitions on a much smaller scale, but are capable of achieving similarly high levels of accuracy.[6] Inexpensive sUAS have also proven highly valuable as an enabler to other functions such as finding targets for artillery and adjusting fires to achieve rounds on target faster and without the need of a human observer in a forward position.[7] While sUAS cannot replicate all of the functions performed by larger UAS, they still offer tangible benefits without the high costs and technological barriers of the larger systems.

The vastly lower price point has also enabled sUAS to be operated at much lower levels within the military hierarchy than other classes of UAS. While Class II and III UAS are typically assigned missions through conventional targeting processes, sUAS can be controlled below the unit level to provide real time information or strike capabilities to front-line soldiers. Capabilities

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[2] Joint Air Power Competence Centre. "A Comprehensive Approach to Countering Unmanned Aircraft Systems." Joint Air Power Competence Centre (JAPCC), Germany, 2021. 510-511.

[3] Joint Air Power Competence Centre. "A Comprehensive Approach to Countering Unmanned Aircraft Systems." 110.

[4] Government of Canada. "Canada Acquiring Remotely Piloted Aircraft Systems for the Canadian Armed Forces." National Defence, News Release, 19 Dec 2023. https://www.canada.ca/en/department-national-defence/news/2023/12/canada-acquiring-remotely-piloted-aircraft-systems-for-the-canadian-armed-forces.html

[5] Mykhaylo Zabrodskyi, Jack Watling, Oleksandr V. Danylyuk and Nick Reynolds. "Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February-July 2022." Royal United Services Institute for Defence and Security Studies. London, (2022). 37.

[6] Kristen D. Thompson. "How the Drone War in Ukraine is Transforming Conflict." *Council on Foreign Relations.* 16 January 2024. https://www.cfr.org/article/how-drone-war-ukraine-transforming-conflict.

[7] Dominika Kunertova. "Drones Have Boots: Learning from Russia's War in Ukraine." *Contemporary Security Policy,* vol 44, no. 4 (2023): 581.

which had been controlled at or above Division level have now been made more widely accessible. This lower-level of control has proven critical in Ukraine due to precision munitions forcing an increase in unit dispersion, with company sized elements dispersing on frontages of up to 3 km.[8] The ability for platoon and company commanders to have access to beyond line-of-sight sensors has become increasingly important for visualization of their sub-units. Currently, beyond-line-of sight capabilities are not readily available in the CAF at the sub-unit level.

Expansion of sUAS use in conflict

The role played by sUAS in previous conflicts contributed to a general underestimation of the impact they could have in conventional warfare. Initially used by non-state actors and terrorist organizations with limited effectiveness, it is not surprising that sUAS were not widely predicted to play a significant role in a major state-on-state conflict.[9] For the CAF, while it is important to train and equip for the current threats in Ukraine, the role sUAS may play in future conflicts must also be considered. As Canada is yet to distribute sUAS and counter-sUAS capabilities across the CAF, the conflict in Ukraine may be decided before any procured platforms are fully integrated within CAF units.

An early adopter of sUAS for surveillance and delivery of explosives was the self-proclaimed Islamic State of Iraq and Syria (ISIS). Despite being somewhat geographically isolated and unable to access a wide range of sUAS platforms, ISIS fighters proved capable of effectively employing the sUAS they had. They utilized sUAS for surveillance purposes, to drop small explosives, and capture high quality videos of their operations for recruiting and propaganda use.[10] Despite periodic successes, neither Russia nor western nations in Iraq or Syria were under significant threat from ISIS sUAS operations. As a result, no rapid advancements in counter-sUAS technologies were necessary in the fight against ISIS.

The use of modified commercial sUAS for military tasks was not limited to ISIS, but rather there were 520 documented attacks in the Middle East and Africa between 2006 and 2020.[11] Like the attacks conducted by ISIS, many were carried out by terrorist organizations or rebel fighters. While increasing in frequency, these incidents were still sporadic with limited impacts. Although the use of sUAS was growing and becoming more sophisticated, a more palpable threat would be necessary to instigate rapid capability development in the CAF.

Large scale sUAS use in conventional wars was not seen until the Nagorno-Karabakh conflict in 2020, followed by the ongoing Russia-Ukraine war. Although only six weeks in length, the Nagorno-Karabakh conflict demonstrated the importance sUAS can play in the conduct of limited precision strikes, and the difficulty of defending against sUAS with existing defensive systems.[12] In the Russia-Ukraine war sUAS have become indispensable, performing a

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[8] Mykhaylo Zabrodskyi et al. "Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February-July 2022." 62.

[9] Kerry, Chávez, and Ori Swed. "Emulating Underdogs: Tactical Drones in the Russia-Ukraine War." *Contemporary Security Policy,* vol 44, no. 4 (2023): 593.

[10] Kerry Chávez and Ori Swed. "Off the Shelf: The Violent Nonstate Actor Drone Threat." *Air and Space Power Journal*. Fall (2020). 33-34.

[11] Dominika Kunertova. "Drones Have Boots: Learning from Russia's War in Ukraine." 585.

[12] Jack Watling and Sidharth Kaushal. "The Democratisation of Precision Strike in the Nagorno-Karabakh Conflict." Royal United Services Institute for Defence and Security Studies. London, (2020).

continually expanding range of functions. The quantity and quality of modified civilian sUAS and custom military models have rapidly increased in both Russia and Ukraine and sUAS have become highly sought after donation items from many supporting nations.[13]

Over the previous decade the military applications for sUAS have rapidly expanded, with much of the innovations occurring in the last five years. While early models could drop a single grenade or performing surveillance tasks in daylight conditions only, sUAS can now provide far more valuable capabilities to modern militaries. Modern sUAS designed specifically for military purposes have greater operational range and payload capacities, offer an advanced suite of onboard sensors, and employ control systems that are less susceptible to counter-sUAS technologies.[14]

Increasing sUAS payload capacities and flight times was critically important for wider adoption in military operations. With the capability to find targets, loiter overhead for extended periods, and deliver munitions that can defeat armoured vehicles, sUAS have become valuable in an offensive role. The Taiwan made Revolver 860 quadcopter, for example, has achieved a payload capacity of eight 60 mm mortars, has a flight radius of up to 20 km, and is capable of loitering over a target for up to 20 minutes.[15] One-way attack (OWA), or kamikaze sUAS have also become increasingly capable platforms. The US built Switchblade and Russian built Lancet have demonstrated the ability to strike targets up to 80 km away, loiter over targets for up to 40 minutes, and can reach speeds of 100 km/hr.[16] As sUAS are now capable of delivering consistent precision strikes, it has become essential to employ effective counter measures when operating in an area where a credible sUAS threat exists.

Advances have not been limited to offensive capabilities, and the use of sUAS as intelligence, surveillance, and reconnaissance (ISR) platforms may have greater utility for the CAF. Through advances in optics, the size and weight of sensors have been reduced to the point that sUAS can easily carry them. Equipped with advanced sensors sUAS are highly effective in day and night ISR operations, offering enhanced situational awareness below the unit level.[17] The use of sUAS for ISR tasks is particularly compelling for risk averse militaries such as the CAF, as they allow for a machine to perform high risk functions that were previously performed by a soldier. Not only can the use of sUAS in an ISR role protect human lives, the collection

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https://www.rusi.org/explore-our-research/publications/commentary/democratisation-precision-strike-nagorno-karabakh-conflict.

[13] Fareed Zakaria. "Interview With President Volodymyr Zelenskyy and Mykhailo Fedorov About Ukraine's Army of Drones and Ukraine's Children of War." Fareed Zakaria Global Public Square aired (2023). https://transcripts.cnn.com/show/fzgps/date/2023-09-10/segment/01.

[14] Bradley Wilson, Shane Tierney, Brendan Toland, Rachel M. Burns, Colby Peyton Steiner, Christopher Scott Adams, Michael Nixon, et al. "Small Unmanned Aerial System Adversary Capabilities." *Policy File*. RAND Corporation, 2020. xiii-xiv.

[15] Drones Vision. "Revolver 860." Performance Specifications. Accessed 20 April 2024. https://dronesvision.com/mortar-revolver-bomber-drone/.

[16] Mohammad Eslami. "Iran's Drone Supply to Russia and Changing Dynamics of the Ukraine War." *Journal for Peace and Nuclear Disarmament*, vol 5, no. 2 (2022). 509-510.

[17] Andrew Lacher, Jonathan Baron, Jonathan Rotner, and Michael Balazs. "Small Unmanned Aircraft: Characterizing the Threat." The MITRE Corporation, (2019). 7.

function can potentially be performed faster while also distributing the collected information more efficiently through digitization.

Finally, sUAS have demonstrated utility in electronic warfare (EW) tasks and have become important components of information operations (IO) campaigns. While the applications for EW continue to evolve, global navigation satellite system (GNSS) jamming and spoofing has proven to be possible using sUAS. This allows for the disruption or confusion of global positioning system (GPS) signals within a targeted area.[18] Further, the 2020 Nagorno-Karabakh conflict and the ongoing conflict in Ukraine demonstrate the increasingly important role that sUAS are playing in larger IO campaigns.[19] Successful sUAS operations not only provide direct tactical benefits, but the suite of advanced sensors carried by sUAS enable global distribution of videos from the operations. Successful IO activities have the potential to have a disproportionately significant impact on public opinion and support for a military operation.[20] Canada may be at a considerable risk from adversarial IO, as the Canadian public has never been the target of a modern IO campaign that depicts large losses of Canadian service members.

Challenges with defence

As the number and effectiveness of sUAS increases on operations, possessing the capability to counter adversarial sUAS is essential. Failure to provide adequate force protection against a known threat would represent a grievous failure to protect deployed members and could jeopardize mission success for the CAF. Unfortunately, providing effective defence against sUAS is made challenging due to the number of functions that counter-sUAS technologies must perform. While defeating the sUAS may be the critical final step in countering it, a counter-sUAS capability must first be able to detect, identify, and track a threat sUAS.[21] Each of these functions are made more difficult under battlefield conditions, and some functions may not be able to be performed near critical infrastructure as a result of the interference they can cause to the electro-magnetic spectrum (EMS). Variations in the means of control of sUAS, such as radio frequency (RF), GNSS, cellular network, and fiber optic also makes countering them more challenging.[22] As a result, counter-sUAS technologies must be sufficiently flexible to detect, identify, track, and defeat sUAS in a variety of different ways and under different conditions.

Countering adversarial sUAS is made further challenging because of their size, speed, and advancements in noise reduction. While sizes vary, sUAS are significantly smaller than what traditional air defence assets were designed to detect. Their small radar cross-sectional area (RCA) requires sensors that can detect their size while also being capable of differentiating

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[18] Bradley Wilson et al. "Small Unmanned Aerial System Adversary Capabilities." 53.

[19] Jack Watling and Sidharth Kaushal. "The Democratisation of Precision Strike in the Nagorno-Karabakh Conflict." https://www.rusi.org/explore-our-research/publications/commentary/democratisation-precision-strike-nagorno-karabakh-conflict.

[20] Josef Danczuk. "Bayraktars and Grenade-Dropping Quadcopters: How Ukraine and Nagorno-Karabakh Highlight Present Aid and Missile Defense Shortcomings and the Necessity of Unmanned Aircraft Systems." *The Military Review: The Professional Journal of the US Army*, (2023). 26.

[21] US Department of Defence. "Army Techniques Publication No. 3-01.81: Counter-Unmanned Aircraft Systems (C-UAS)." Department of the Army, Washington DC. (2023). 3-7 – 3-15.

[22] Travis Cline, and J. Dietz. "Agent Based Modeling for Low-Cost Counter UAS Protocol in Prisons." *International Journal of Aviation, Aeronautics, and Aerospace,* vol 7, issue 2, article 2, (2020). 4-5.

sUAS from other small objects such as birds.[23] With sUAS capable of achieving speeds over 100km/hr, human reaction time may be too slow to initiate a counter measure once a sensor has identified a threat. To prevent a threat sUAS from reaching its intended target, defensive systems must incorporate a level of automation. As such, there is a requirement to link sensors and defeat mechanisms, creating a more technologically complex force protection system.[24] Finally, as sUAS have both military and civilian applications, several improvements in design for the civilian sector have also been desirable for the military sector which has accelerated their development. Of note is the shared interest in noise reduction. For civilian use this will result in fewer noise complaints, while for military applications noise reductions decrease detectability, presenting further challenges for counter-sUAS efforts.[25]

Beyond tactical tools

Despite the benefits sUAS offer for conducting ISR tasks and offensive operations, they have not emerged as decisive war winning platforms. Neither Russia nor Ukraine have used sUAS to completely break the will of the other, nor have non-state actors employed sUAS to effectively defeat or even deter a conventional force.[26] As such, despite the increasing utility that sUAS have delivered as their technologies have matured, sUAS remain platforms that deliver their effects primarily at the tactical level.

While sUAS may be platforms for tactical operations such as performing ISR tasks, delivering precision strikes, or supporting indirect fire, they may still have higher level impacts. A key element that has differentiated sUAS from other tactical systems is the ability to record video feeds. This has allowed them to play a key role in shaping IO campaigns for both Russia and Ukraine. By posting a constant stream of successful operations the will of an adversary's population base may be eroded, while simultaneously demonstrating to partner nations and one's own population that progress is being made towards the defeat of the enemy.[27] Further, it has been suggested that the persistent threat from sUAS has had a significant psychological impact on both Russian and Ukrainian soldiers who are constantly threatened by them.[28] While the primary effects of sUAS may be at the tactical level, their secondary effects may have strategic impacts.

For the CAF, force protection has always been of critical importance and therefore counter-sUAS capabilities represent an essential element to incorporate as soon as possible. Any inability to provide protection from a known and persistent treat has the potential to undermine the will and morale of a force or erode the support of a population towards a deployment. While

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[23] Juan A. Besada, Ivan Campaña, David Carramiñana, Luca Bergesio, and Gonzalo de Miguel. "Review and Simulation of Counter-UAS Sensors for Unmanned Traffic Management." *Sensors* (Basel, Switzerland), vol 22, no. 1 (2021). 2-3.

[24] Stamatios Samaras, Eleni Diamantidou, Dimitrios Ataloglou, Nikos Sakellariou, Anastasios Vafeiadis, Vasilis Magoulianitis, Antonios Lalas, et al. "Deep Learning on Multi Sensor Data for Counter UAV Applications-A Systematic Review." *Sensors (Basel, Switzerland)* vol 19, no. 22 (2019). 2.

[25] Bradley Wilson, et al. "Small Unmanned Aerial System Adversary Capabilities." 107.

[26] Conor Gallagher. "Naked Capitalism: Cult of the Drone: At the Two-Year Mark, UAVs Have Changed the Face of War in Ukraine but Not Outcome." *Newstex Finance & Accounting Blogs*, (2024).

[27] Josef Danczuk. "Bayraktars and Grenade-Dropping Quadcopters." 22.

[28] Kerry Chávez. "Learning on the Fly: Drones in the Russian-Ukrainian War." *Arms Control Today.* vol 53, no. 1 Jan/Feb (2023). 11.

sUAS should be procured by the CAF for their tactical benefits, counter-sUAS technologies are more critically needed to avoid a potential strategic level failure.

With the expanded role the CAF is assuming on OP Reassurance, doubling its commitment of soldiers by 2026, it is necessary for the CAF to rapidly adopt sUAS and counter-sUAS technologies.[29] The CAF is behind in the sUAS space and must move quickly to on-board capabilities that other militaries have already gained significant experience with. Unfortunately, counter-sUAS systems are expensive, highly technical, and require training for successful employment. While sUAS are likely more easily incorporated into training in a short time frame, they are also less urgently needed for current operations.

Establishment of counter-sUAS capabilities

In recognition of the significant threat posed by sUAS, Canada has committed $46 million for counter-sUAS technologies for Op Reassurance to "ensure freedom of action for land operations."[30] The proposed systems are to be tested at the Suffield UAS Sandbox in the summer of 2024, with an initial operating capability (IOC) delivered by the end of 2024.[31] While a welcome and necessary investment, this purchase is focused on the Op Reassurance mission and land operations, and may not fully consider other applications. Additionally, the proposed IOC target will provide minimal time to distribute the equipment across the CAF, and deploying units may receive limited training on the equipment in Canada prior to employing it on operations. As such, this procurement announcement should be considered a first step towards a fully integrated counter-sUAS capability for the CAF. Further consideration must be made on how counter-sUAS technologies will be used in other domains and on other operations.

To be effective in protecting CAF members and installations, any counter-sUAS technology must be able to detect, identify, track, and defeat a threat sUAS fast enough to prevent an adversary from achieving their intent. Due to the many variations of sUAS that potential adversaries could employ, a one size fits all solution will not be effective. Protection is further complicated as a result of the variety of things that need protection. Dismounted sub-units, bases, ships, and airfields will require different approaches to counter adversarial sUAS. To ensure comprehensive protection from modern sUAS threats, the CAF must invest in a system that employs multiple sensors to detect and track threats, is layered and scalable to provide adequate depth of protection for elements of diverse sizes and has the capability to defeat sUAS through multiple defeat mechanisms.

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[29] Government of Canada. "Our North, Strong and Free: A Renewed Vision for Canada's Defence." Prime Minister's Office. Press Release 8 Apr 2024. https://www.pm.gc.ca/en/news/news-releases/2024/04/08/our-north-strong-and-free-renewed-vision-canadas-defenc#:~:text=To%20protect%20our%20NATO%20Allies,Latvia%20Battle%20Group%20to%20Brigade.

[30] Government of Canada. "Canada Acquiring Air Defence and Anti-Drone Capabilities for Canadian Armed Forces Members Deployed with NATO in Latvia." National Defence, News Release, 15 Feb 2024. https://www.canada.ca/en/department-national-defence/news/2024/02/canada-acquiring-air-defence-and-anti-drone-capabilities-for-canadian-armed-forces-members-deployed-with-nato-in-latvia.html.

[31] Canadian Defence Review. "Leonardo to Equip Canadian Armed Forces with Counter-Drone Technology." 28 Feb 2024. https://www.canadiandefencereview.com/news/leonardo-to-equip-canadian-armed-forces-with-counter-drone-technolog.

A comprehensive detection and tracking system should leverage passive RF detection, visual sensors, acoustic sensors, and radar sensors to ensure adversarial sUAS detection. Passive RF detectors can sense the majority of unmodified civilian sUAS and do not emit a detectable signature.[32] As a broad-spectrum detector, passive RF sensors are a valuable component of a comprehensive detection system but are insufficient to detect all types of sUAS. Passive RF sensors also require multiple linked detectors to accurately determine the position and track the flight path of a sUAS and cannot detect a sUAS that has no data link to a controller.[33] Visual sensors include electro-optic (EO) and infrared (IR) and rely on cameras that perform well at close range but may have difficulty detecting sUAS over further distances. Visual sensors can also be undermined when obscurants like buildings, trees, or smoke are between the sensor and the sUAS. Further, while visual sensors have the potential to be highly accurate, they must be taught to separate the various types of sUAS from other objects in the sensor's surroundings to be effective.[34] Acoustic sensors have similar limitations to visual sensors. Acoustic sensors work better at close range but can be confused by background noise and physical objects that interfere with sound wave propagation. Like other sensor types, acoustic detection requires dispersion of multiple sensors over an area, and machine learning must also be incorporated to allow the sensors to separate specific frequencies from background noise.[35] Finally, radar and doppler radar emit electromagnetic radiation and detect objects by sensing the wave pattern that an object emits back towards the emitter.[36] Radar and doppler radar have been used successfully for higher altitude detection, but do not detect as well at low altitudes where objects such as trees can obscure signals.[37] As radar emits electromagnetic energy to function, it also has the potential to be targeted by an adversary capable of detecting those emissions.

Integration of inputs from multiple types of sensors requires an understanding of how to properly layer sensors in the area being protected as well as advanced data fusion capabilities. While requiring more resources to achieve, a layered system will provide superior detection and tracking performance than a single point sensor system. Scalability is also an important consideration as not all sensors would be required on all operations. There may also be circumstances when certain sensors may not be permitted, such as when employed near airfields or civilian airports. Ultimately, the CAF should purse a scalable multi-sensor system as it would provide a higher probability of detecting sUAS in a wider variety of situations.

The capabilities to detect, identify, and track an adversary sUAS are essential but defeat mechanisms must also be incorporated. To effectively defeat fast moving sUAS an automated means of defeat would be preferred over one that places a human decision maker in the kill chain. Human reaction time may be insufficient for fast moving threats and therefore an

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[32] Juan A. Besada, et al. "Review and Simulation of Counter-UAS Sensors for Unmanned Traffic Management." 6.

[33] Jacco Dominicus. "New Generation of Counter UAS Systems to Defeat of Low Slow and Small (LSS) Air Threats." Royal Netherlands Aerospace Centre NLR. 9.

[34] Georgia Lykou, Dimitrios Moustakas, and Dimitris Gritzalis. "Defending Airports from UAS: A Survey on Cyber-Attacks and Counter-Drone Sensing Technologies." *Sensors (Basel, Switzerland)* 10.

[35] Abdulhadi Shoufan, and Ernesto Damiani. "Contingency Clarification Protocols for Reliable Counter-Drone Operation." *IEEE Transactions on Aerospace and Electronic Systems,* vol 59, no. 6 (2023). 8946.

[36] Georgia Lykou, et al. "Defending Airports from UAS: A Survey on Cyber-Attacks and Counter-Drone Sensing Technologies." 8.

[37] Stamatios Samaras, et al. "Deep Learning on Multi Sensor Data for Counter UAV Applications: A Systematic Review." 5.

automatically initiated RF disruption, or kinetic defeat system would be preferred. RF disruptors represent a critical passive defeat capability as they can jam or spoof sUAS control frequencies including those controlled by satellite and cellular means. RF disruptors can cause a threat sUAS to crash by disrupting the signal from its controller or can take control of the sUAS and cause them to land in a specified area.[38] Kinetic defeat mechanisms including microwave effectors and interceptor sUAS must be available for use in cases where passive RF disruption fails. While kinetic defeat mechanisms such as microwave effectors can have significant negative effects on electronics near the microwave emission source, they have proven to be effective in defeating individual and swarms of sUAS threats.[39]

Each type of sensor has strengths and weaknesses. Relying on only some of the sensors, not having the ability to fuse sensor information, and not establishing a layered array of sensors will introduce vulnerabilities to a counter-sUAS capability. Similarly, relying on a limited number of defeat mechanisms will allow an adversary to find and exploit weaknesses in the defence. The Falcon Shield system by Leonardo Electronics which Canada has selected for evaluations offers RF, radar, and EO systems as part of the sensor suite, but does not incorporate acoustic sensors. Although the sensors are scalable and linked for sensor fusion, the defeat mechanism is limited to passive RF disruption only.[40] It is essential for the CAF to build on the proposed counter-sUAS capability and include acoustic sensors to enhance detection and add kinetic or hard kill options to defeat a wider array of potential sUAS threats.

The Canadian intent to procure counter-sUAS equipment for the mission in Latvia is necessary based on known threats in the region. However, Op Reassurance is not the only operation on which the CAF may deploy members soon. On every mission the CAF deploys there may be a sUAS threat, and it is therefore insufficient to focus on supplying Op Reassurance exclusively. Counter sUAS equipment must be incorporated CAF wide and be part of the force protection package for all future deployments. The equipment must be scalable to ensure that large installations are protected, while also offering dismounted equipment for patrols. Extensive training is also required so that operators understand how best to employ the equipment with consideration given to potential interference between the various EMS emitters and sensors in the battlespace. The CAF has a great deal of work to do to fully operationalize a counter-sUAS capability. With a potential IOC achieved at the end of 2024, CAF members will remain unable to effectively respond to threats from adversarial sUAS until 2025.

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[38] Jacco Dominicus. “New Generation of Counter UAS Systems to Defeat of Low Slow and Small (LSS) Air Threats.” 12.

[39] Apartim Sharma “Counter-Unmanned Aircraft Systems (C-UAS): Future of Warfare.” *Journal of Defence Studies.* Vol 16, Issue 4 (2022), 233.

[40] Leonardo Electronics. “Falcon Shield Counter Air System (C-UAS).” Company information sheet. Accessed 20 April 2024. https://uk.leonardo.com/documents/64103/6765824/Falcon+Shield+LQ+%28mm08605%29.pdf?t=1671446128764.

Developing sUAS competencies

While defence is critical, it is also necessary for the CAF to integrate sUAS across all elements and incorporate them in training to develop familiarity with their capabilities and limitations. The tactics being employed in Ukraine may not work within the CAF context and should not be transposed onto CAF units. To ensure sUAS complement existing CAF doctrine, tactics, and equipment they must be extensively trialed by soldiers in all types of units and environments. To date, the CAF has gained experience with UAS through the employment of the Scan Eagle and Blackjack platforms which are highly capable in an ISR role. However, the Scan Eagle and Blackjack are heavier and have higher flight ceilings than the Class I UAS parameters specify.[41] Further, the Scan Eagle and Blackjack cannot perform the same functions as sUAS. They do not carry munitions of any type, cannot be easily carried by a dismounted soldier, and are far too expensive to be used in a high threat environment where they may be destroyed in as few as three flights. They are also not well integrated across the CAF, with only a limited number of members having been trained on them.

While commercial off-the-shelf (COTS) models have been a primary source of sUAS for many state and non-state actors, there may be challenges and roadblocks with the CAF pursuing a COTS solution. The acquisition of loitering munitions and OWA sUAS would exclude COTS procurement as an option as they typically have custom built explosive warheads or are custom made to carry specific explosive payloads. While offensive sUAS should be integrated into CAF units, they are less urgently needed and could be purchased through normal procurement channels. COTS sUAS may also be inappropriate when advanced sensors and controls are required. While Ukrainian technicians have become proficient in modifying COTS sUAS as weapons and ISR platforms, the CAF should not seek to replicate that practice on deployed operations. The CAF lacks the existential threat required to mobilize a large workforce for the modification of hundreds of sUAS in the manner that has been achieved in Ukraine.[42] As such, even for ISR applications it is necessary for the CAF to procure custom military sUAS to ensure that existing sensor and encryption requirements are met.

While the CAF procurement process will add time and escalate the purchase price of purpose built military sUAS, the final per-unit cost must still be kept as low as possible. When employed on operations where a threat exists, sUAS have been proven to have a short life span.[43] A balance between cost and quality may be achieve by procuring an assortment of sUAS at different price points. A minimally equipped disposable option could be available for high-risk areas, and more expensive options available for use in more permissive environments including humanitarian and domestic operations.

While COTS sUAS may not be the best procurement approach for weaponized or technical ISR applications, COTS models should still be considered for use in the CAF. The purchase of inexpensive and readily available COTS sUAS would get the platforms into the

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[41] Boeing. "Scan Eagle Fact Sheet." Accessed 20 Apr 2024. https://www.boeing.com/defense/autonomous-systems/scaneagle#overview.

[42] Roman Vysochanskyy. "Redefining the Battlefield: Drone Warfare Tactics in Ukraine." *Ploughshares.* 27 Feb 2024. https://www.ploughshares.ca/publications/redefining-the-battlefield-drone-warfare-tactics-in-ukraine.

[43] Dominika Kunertova. "Drones Have Boots: Learning from Russia's War in Ukraine." 581.

hands of the CAF's soldiers, sailors, and aviators immediately. Like the drone literacy program pursued by the Australian Army, providing COTS models to CAF members will begin creating an organizational understanding of the capabilities of sUAS and can help guide procurement of military versions of sUAS in the future.[44]

To facilitate the purchase of COTS sUAS, the CAF should develop a list of approved civilian sUAS providers that meet security requirements for training. The US has developed an approved list of UAS providers through their Defense Innovation Unit, with the aim of facilitating the purchase of commercial systems more quickly than traditional procurement mechanisms could achieve.[45] As the CAF also struggles with slow procurements, a list of pre-approved providers would allow for units to purchase the latest civilian equipment without having to seek additional approvals. The use of COTS models in training will reduce costs while adequately familiarizing CAF members with sUAS. On deployed operations militarized options would be preferred, but COTS models may still be useful as the low-cost disposable option for tasks such as probing enemy counter-sUAS arrays to determine their weaknesses.

Training remains paramount

The acquisition of sUAS and counter-sUAS technologies must be completed in advance of deployments where CAF members may be threatened by adversarial sUAS or where a capable ISR platform will benefit forward units. It is therefore critical to consider the training time required before these new capabilities can be fully operationalized and employed effectively on missions abroad. Incorporating sUAS and counter-sUAS activities into routine training exercises and pre-deployment training will allow CAF members to better understand the capabilities and the limitations of the platforms. This will build confidence in the defensive systems and competence in the operation of sUAS as offensive and ISR platforms. Comprehensive training will ensure that counter-sUAS systems can be positioned to best protect CAF members in complex environments, and that emitters are positioned so as not to interfere with electronic equipment of units in the vicinity of their employment.

For training on sUAS systems to be most effective creativity must be prioritized. This will allow CAF members to approach existing tasks in new ways through the employment of new tools and may allow for the emergence of entirely new ways of operating. While examining operations in Ukraine may serve as a starting point for understanding how sUAS can be employed, future operating environments and CAF specific factors must also be considered. An environment that fosters experimentation and creativity will allow for novel uses of sUAS to emerge. Generating skilled and creative sUAS operators will ensure that counter-sUAS equipment is tested and validated in challenging real-world scenarios.

Developing an understanding of how sUAS can be leveraged on operations other than war must also be considered and can be realised through training. Domestic and humanitarian operations offer unique opportunities to use sUAS for activities such as infrastructure

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[44] Ewen Levick. "Army Targets Drone Literacy with Phantom Delivery." *Australian Defence Magazine*. 23 Aug 2018. https://www.australiandefence.com.au/land/army-targets-drone-literacy-with-phantom-delivery.

[45] Defense Innovation Unit. "About Blue UAS." Department of Defense, United States of America. Accessed 15 Apr 2024. https://www.diu.mil/blue-uas.

assessments, direct delivery of aid, and monitoring evacuation routes. Proficiency in the use of sUAS is essential for all operations across the spectrum of conflict and can only be achieved through the consistent use of these platforms on training exercises. The incorporation of sUAS in training may also improve recruitment and retention, as the Australian drone literacy program demonstrated a high degree of enthusiasm to train on the platforms.[46]

Conclusion

The CAF has been slow to adopt UAS technologies in general, and particularly slow to adopt sUAS and counter-sUAS technologies. The initial indifference towards sUAS adoption was understandable while they were primarily a tool used by non-state actors to achieve limited ISR capabilities or to drop small explosive munitions. After a decade of development and extensive employment by conventional forces in the Russia-Ukraine war, the potential impact that sUAS can have on military operations can no longer be ignored. Although the war in Ukraine may not be indicative of the potential significance of sUAS in future conflicts, the ability to protect CAF members from potential sUAS threats will remain of critical importance. Likewise, the ability to rapidly visualize terrain beyond the line of sight will remain a valuable capability across the spectrum of conflict and at all organizational levels.

As the CAF prepares to increase its commitment to NATO through the enhanced Forward Presence Battle Group in Latvia, the time has come for the CAF to prepare for a theatre of operations where sUAS capabilities have become greatly refined. Counter sUAS technologies must be procured, trained on, and fully integrated into units to provide protection to CAF members against a persistent threat. Failure to provide the tools to allow deployed CAF member to protect themselves could dramatically undermine public support for the mission in the event that CAF members are injured or killed due to adversarial sUAS use. Concurrently, the CAF must increase adoption of sUAS across the organization to enhance familiarity with the platforms and enable units to incorporate them into individual and collective training. While the CAF should invest in both ISR capable sUAS and sUAS that can deliver kinetic effects, the development of sUAS for ISR purposes should be prioritised as they offer the greatest capability advantages for the greatest number of CAF elements and branches. In preparation to confront well equipped and technologically advanced adversaries, it is essential for the CAF to be equipped with the most effective technologies to defend its members against emergent threats. As such, it is of the utmost importance for the CAF to incorporate sUAS platforms as widely as possible within the organization, while becoming fully capable of defeating adversarial sUAS.

[46] Ewen Levick. "Army Targets Drone Literacy with Phantom Delivery." *Australian Defence Magazine*. 23 Aug 2018. https://www.australiandefence.com.au/land/army-targets-drone-literacy-with-phantom-delivery.

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