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COUNTERING THE SMALL UNMANNED AERIAL SYSTEM THREAT TO THE CANADIAN ARMED FORCES

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COUNTERING THE SMALL UNMANNED AERIAL SYSTEM THREAT TO THE CANADIAN ARMED FORCES

AIM

1. The recent rapid expansion of the consumer small unmanned aerial system (sUAS) industry has made tools that were once the exclusive purview of nation states and researchers available to almost anyone. A variety of groups have demonstrated both the capability and the intent to use this technology for malicious purposes. Hostile use of sUAS presents unique challenges to the Canadian Armed Forces (CAF) for both domestic and expeditionary operations. The aim of this paper is to examine the implications of sUAS proliferation on the CAF and to recommend a way ahead.

INTRODUCTION

2. There are two main implications of an sUAS threat to the CAF. First, the North American Aerospace Defence Command (NORAD) has a standing mission under Operation Noble Eagle (ONE) to protect the civilian population of North America from a terrorist air attack.¹ Second, all elements of the CAF have a responsibility for force protection, be it for an airfield, field unit, or ship.² sUAS present several unique challenges for engagement. They are inexpensive, particularly when compared to the cost of military air defence systems. They are able to launch from close to potential targets and can be difficult to detect and engage based on their small size and signatures. They can be massed and used to swarm a target, overwhelming some conventional defences. Lastly, engagement with traditional kinetic defences can easily cause more collateral damage than the sUAS itself.

¹North American Aerospace Defense Command, "Canadian NORAD Region," last accessed 30 September 2015, <http://www.norad.mil/AboutNORAD/CanadianNORADRegion.aspx>.

²Department of National Defence, B-GJ-005-314/FP-000, *CF Joint Force Protection Doctrine* (Ottawa: DND Canada, 2006), 1-3.

3. This paper will begin with defining the threat. It will discuss the threat posed by three categories of users: benign users, insurgents, and terrorists. Next, it will provide a sampling of possible solutions applicable to the CAF, including readiness, detection measures, passive defences, and active defences. Lastly, it will make a recommendation for a way forward for the CAF.

DISCUSSION

Definition

4. There are varying military and civilian definitions, terminologies, and categories used for unmanned aircraft, such as unmanned aerial vehicles (UAV), remotely piloted aircraft systems (RPAS), unmanned aerial systems (UAS), and drones. For simplicity, this paper will use the FAA and Transport Canada (TC) definition of sUAS being an unmanned aircraft weighing less than 25kg plus all its associated systems, as this definition has specific implications on ease of purchase and legal use.³ Some authors differentiate between UAS and cruise missiles based on operator intent to recover the vehicle, however again for simplicity, this paper will use the term UAS regardless of user intent.⁴

Threat

5. The massive proliferation of sUAS in recent years is astounding. In 2014, the United States (US) Federal Aviation Administration (FAA) estimated that 200,000 recreational sUAS were operating in the US National Airspace System (NAS), not including those for commercial

³United States Congress, *Public Law 112-95: FAA Modernization and Reform Act of 2012* (Washington, DC: U.S. Government Printing Office, 14 February 2012), 126 Stat. 72; Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 9, 12.

⁴Dennis Gormley, "UAVs and Cruise Missiles as Possible Terrorist Weapons," in *New Challenges in Missile Proliferation, Missile Defense, and Space Security* (Monterey: Monterey Institute of International Studies, Center for Nonproliferation Studies, Occasional Paper 12, 2003), 3; Lynn Davis *et al*, *Armed and Dangerous? UAVs and U.S. Security* (Santa Monica: RAND Corporation, 2014), 4.

use. They estimate another 1.6 million were sold in 2015, and expect 1.9 million million in 2016, plus another 600,000 for commercial use.⁵ The growth in Canada has been similar, and indeed worldwide, with one estimate of 200,000 sUAS per month being sold globally in 2014.⁶

6. As recently as 2008, threat assessments generally concluded that malicious use of UAS by terrorist organizations was unlikely, based on the technical skills required and the other available means of attack.⁷ However, three important factors have changed in recent years. First, sUAS have become cheap and widely proliferated, with very capable models available off the shelf for a few hundred dollars. Second, advances in inexpensive miniaturized autopilot systems mean that very little experience is required to effectively operate an sUAS. Third, the widespread mobile access to the internet now allows control of sUAS from a distance.⁸ These changes have led several more recent academic assessments of the threat to generally agree that hostile sUAS present a realistic security threat.⁹

Benign Users

⁵Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule* (Washington, D.C.: U.S. Government Printing Office, 16 December 2015), 78597-78598.

⁶Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles* (Ottawa: Transport Canada, 28 May 2015), 2; Barbara Booth, "Is it time to buy your kid a drone for Christmas?" *CNBC*, 22 December 2014, last accessed 3 February 2016, <http://www.cnn.com/2014/12/22/kids-and-drones-booth-change-the-world-ec-141218.html>.

⁷Dennis Gormley, "UAVs and Cruise Missiles as Possible Terrorist Weapons," in *New Challenges in Missile Proliferation, Missile Defense, and Space Security* . . . , 7; B.A. Jackson *et al*, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles* (Santa Monica: RAND Corporation, 2008), 69.

⁸David Chandler, "Using a phone to fly a drone: Pilotless planes at MIT controlled via iPhones in Seattle," *MIT News*, 8 November 2012, last accessed 3 February 2016, <http://news.mit.edu/2011/iphone-drone-control-1108>.

⁹C. Abbott *et al*. *Hostile Drones: Supplementary Risk Assessment* (London: Oxford Research Group, 2016), 1; Ryan Wallace and Jon Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," *International Journal of Aviation Aeronautics, and Aerospace* 2, no. 4 (October 2015): 24; Bryan Card, "The Commercialization of UAVs: How Terrorists Will Be Able to Utilize UAVs to Attack the United States," (University of Texas at El Paso, 2014), 1; Birmingham Policy Commission, *The Security Impact of Drones: Challenges and Opportunities for the UK* (Birmingham: University of Birmingham, 2014), 74-75; Lynn Davis *et al*, *Armed and Dangerous? UAVs and U.S. Security* (Santa Monica: RAND Corporation, 2014), 1.

7. The first category of sUAS users is those that have no intention of deliberately causing physical harm to CAF personnel or civilians. This broad category includes uneducated recreational users, criminals, and activists. These users may pose an actual threat, for example by accidentally flying into the flight path of aircraft. More importantly, they often serve to highlight the vulnerabilities of vital assets to sUAS.

8. In 2015 the FAA received 1,133 UAS incident reports, over four times as many as in 2014. This included “reports of unmanned aircraft at high altitudes in congested airspace, unmanned aircraft operations near passenger-carrying aircraft or major airports, and interfering with emergency operations such as efforts to combat wildfires.”¹⁰ TC has had similar problems, launching over fifty investigations since 2010 into “reckless and negligent” UAS use.¹¹ An accidental crash of a sUAS on the White House lawn in January 2015 prompted a significant response in the US, including a congressional hearing on the issue.¹² Both the FAA and TC have launched education campaigns as well as reviews of UAS regulations. However, the trend indicates that the CAF may need to protect airfields and other airspace from inadvertent entry. Prompted by similar incidents in the UK, one study warned against the possibility of sUAS being used deliberately as “mechanical bird strikes.”¹³

9. Criminal use of sUAS has also been increasing. This has included cross-border drug smuggling as well as delivering contraband weapons and drugs into prisons (including one in

¹⁰Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule* (Washington, D.C.: U.S. Government Printing Office, 16 December 2015), 78597.

¹¹Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 3.

¹²House of Representatives, Committee on Homeland Security, Subcommittee on Oversight and Management Efficiency, *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Statement of Subcommittee Chairman Scott Perry*, 18 March 2015.

¹³Birmingham Policy Commission, *The Security Impact of Drones: Challenges and Opportunities for the UK* (Birmingham: University of Birmingham, 2014), 75.

Quebec).¹⁴ CAF units on stability operations may have a requirement to halt such operations without causing collateral damage.

10. Perhaps some of the most dramatic demonstrations of potentially hostile sUAS capability, without necessarily hostile intent, have been activist stunts. For example, in September 2013 an activist managed to fly an sUAS a few feet from German Chancellor Angela Merkel at a press conference.¹⁵ A string of sUAS sightings in France in 2014-2015 around nuclear plants, a submarine base, the Eiffel Tower, the US embassy in Paris, and the Charlie Hebdo offices have prompted the French government to adopt countermeasures.¹⁶ On three occasions in 2015, sUAS, whose operators were not located, were able to fly close to President Obama.¹⁷ In April 2015, an activist landed a small radioactive package on the roof of the Japanese Prime Minister's office.¹⁸ These incidents, while not necessarily hostile, highlight the vulnerability of some of the world's best protected people and sites to sUAS.

Insurgents

11. Perhaps the most acute threat sUAS pose to CAF units deployed abroad is from insurgents. Both insurgents and terrorists can use sUAS for two primary missions: intelligence,

¹⁴Marc Goodman, "Criminals and Terrorists Can Fly Drones Too," *Time*, 31 January 2013; Brian Anderson, "How Drones Help Smuggle Drugs Into Prison," *Motherboard*, 10 March 2014; Dan Gettinger, "Domestic Drone Threats," *Center for the Study of the Drone at Bard College*, 20 March 2015.

¹⁵Sean Gallagher, "German chancellor's drone 'attack' shows the threat of weaponized UAVs," *ARS Technica*, 18 September 2013.

¹⁶John Lichfield, "French government on high alert after unexplained drone flights over nuclear power stations," *The Independent*, 9 November 2014, last accessed 22 December 2015, <http://www.independent.co.uk/news/world/europe/french-government-on-high-alert-after-unexplained-drone-flights-over-nuclear-power-stations-9850138.html>; Samuel, Henry, "Drone spotted near Charlie Hebdo as 10 more fly over Paris," *The Telegraph*, 4 March 2015, last accessed 27 December 2015, <http://www.telegraph.co.uk/news/worldnews/europe/france/11449981/Drone-spotted-near-Charlie-Hebdo-as-10-more-fly-over-Paris.html>.

¹⁷Kellan Howell, "Drone spotted flying near Obama while he played golf," *Washington Times*, 25 August 2015, last accessed 30 September 2015, <http://www.washingtontimes.com/news/2015/aug/25/drone-spotted-flying-near-obama-while-he-played-go/>.

¹⁸"Japan radioactive drone: Tokyo police arrest man," *BBC News*, 25 April 2015, last accessed 2 January 2016, <http://www.bbc.co.uk/news/world-asia-32465624>.

surveillance, and reconnaissance (ISR) and attack. Hamas and Hezbollah both have long histories of using UAS, including some military models supplied by Iran.¹⁹ Initially mostly used for reconnaissance, several incidents have shown a shift to using UAS for attacks, such as the July 2006 attack on an Israeli warship and the September 2014 attack on a Syrian rebel base.²⁰

12. sUAS continue to play a significant role for both sides of the conflict in the Ukraine, primarily for ISR including for artillery spotting.²¹

13. The Islamic State of Iraq and the Levant (ISIL) has also been using sUAS on the battlefield. There are several reports of ISIL using sUAS for reconnaissance, such as prior to their successful attack on Syria's Tabqa air base.²² There has also been one report of ISIL attempting to use an sUAS as an airborne improvised explosive device.²³

Terrorists

14. To date, no terrorist plan to use sUAS has been successful. Several terrorists considered the use of remote control aircraft, including members of Aum Shinrikyo in the 1995 sarin gas attack in Tokyo, Osama Bin Laden in a 2001 plot to kill U.S. President George W. Bush, and Al-

¹⁹Gettinger, Dan and Arthur Michel. "A Brief History of Hamas and Hezbollah's Drones," *Center for the Study of the Drone at Bard College*, 14 July 2014.

²⁰Gettinger, Dan and Arthur Michel. "A Brief History of Hamas and Hezbollah's Drones," *Center for the Study of the Drone at Bard College*, 14 July 2014; Adiv Sterman, "Hezbollah drones wreak havoc on Syrian rebel bases," *The Times of Israel*, 21 September 2014, last accessed 2 February 2016, <http://www.timesofisrael.com/hezbollah-drones-wreak-havoc-on-syrian-rebel-bases/>.

²¹Patrick Tucker, "In Ukraine, Tomorrow's Drone War Is Alive Today," *Defense One*, 9 March 2015.

²²Brian Barrett, "When Good Drones Go Bad," *Wired*, 18 January 2016; Jamie Condliffe, "ISIS Militants Use the Same Drones as Ordinary Folks," *Gizmodo*, 29 August 2014.

²³David Hambling, "ISIS Is Reportedly Packing Drones With Explosives Now," *Popular Mechanics*, 16 December 2015.

Qaeda member Christopher Paul in his 2008 plot to attack targets in the U.S. and Europe.²⁴

Perhaps the first credible attempt was by an al-Qaeda affiliate, Rezwan Ferdaus, in September 2011. He had planned to fly three model aircraft, guided by the global positioning system (GPS) and loaded with C4 explosive into the Pentagon and Capitol building.²⁵ Another al-Qaeda attack using a remote controlled aircraft in Spain was foiled in August 2012.²⁶ Two plots to use unmanned aircraft were foiled in Germany in 2013, the first a terrorist attack in June and the second a political assassination in September.²⁷

15. Subsequent to these events, concerns related to sUAS terrorism have been raised by several law enforcement agencies worldwide including the New York police department, British counter-terrorism police, the Department of Homeland Security, and the Royal Canadian

²⁴John Villasenor, "The drone threat – in the U.S.," *Los Angeles Times*, 27 March 2012, last accessed 22 December 2015, <http://articles.latimes.com/2012/mar/27/opinion/la-oe-villasenor-license-domestic-drones-20120327>; Eugene Miasnikov, *Threat of Terrorism Using Unmanned Aerial Vehicles: Technical Aspects* (Moscow: Center for Arms Control, Energy, and Environmental Studies, Moscow Institute of Physics and Technology, 2005), 25; Peter Finn, "Mass. Man accused of plotting to hit Pentagon and Capitol with drone aircraft," *The Washington Post*, 28 September 2011, last accessed 20 December 2015, http://www.washingtonpost.com/national/national-security/mass-man-accused-of-plotting-to-hit-pentagon-and-capitol-with-drone-aircraft/2011/09/28/gIQAWdpk5K_story.html.

²⁵Peter Finn, "Mass. Man accused of plotting to hit Pentagon and Capitol with drone aircraft," *The Washington Post*, 28 September 2011, last accessed 20 December 2015, http://www.washingtonpost.com/national/national-security/mass-man-accused-of-plotting-to-hit-pentagon-and-capitol-with-drone-aircraft/2011/09/28/gIQAWdpk5K_story.html.

²⁶Soeren Kern, "Al Qaeda in Spain," *Gatestone Institute*, 15 August 2012.

²⁷Jeevan Vasagar, "Students 'planned terror attack using remote control planes,'" *The Telegraph*, 25 June 2013, last accessed 3 January 2016, <http://www.telegraph.co.uk/news/worldnews/europe/germany/10140642/Students-planned-terror-attack-using-remote-control-planes.html>; "German police bust far-Right model plane explosive plot," *The Telegraph*, 10 September 2013, last accessed 3 January 2016, <http://www.telegraph.co.uk/news/worldnews/europe/germany/10298734/German-police-bust-far-Right-model-plane-explosive-plot.html>.

Mounted Police.²⁸ In July 2015 British counter-terrorism officials warned that ISIL has been planning a terror attack using a “multi-drone attack on large numbers of people in a synchronised attack.”²⁹ Clearly, the potential for sUAS to be used maliciously against civilian targets in North America and against CAF assets is a real concern that must be addressed.

Defences

16. Prior to discussing specifics of possible counter-sUAS defensive measures, it is important to note that the CAF will need to coordinate its efforts with our allies and other government agencies, particularly for domestic force protection and for the ONE mission. In particular, plans and responsibilities will need to be synchronized with Transport Canada, Industry Canada, and Public Safety Canada.

17. It is also necessary to highlight that since the retirement of the Air Defence Anti-Tank System, the Canadian Army has no air defence systems.³⁰

²⁸“NYPD: Threat Of Terrorists With Drones Is A Growing Concern,” *CBS News*, 29 October 2014, last accessed 26 December 2015, <http://newyork.cbslocal.com/2014/10/29/nypd-threat-of-terrorists-with-drones-is-a-growing-concern/>; Ian Drury, “Model plane enthusiasts? Watch out, they might be terrorists: Police fear some of those practicing the hobby could be training for an attack,” *Daily Mail*, 12 July 2014, last accessed 3 January 2016, <http://www.dailymail.co.uk/news/article-2689474/Model-plane-enthusiasts-Watch-terrorists-Police-fear-practising-hobby-training-attack.html>; Jeff Pegues, “Homeland Security warns drones could be used in attacks,” *CBS News*, 1 August 2015, last accessed 20 December 2015, <http://www.cbsnews.com/news/homeland-security-warns-drones-could-be-used-in-attacks/>; Kellan Howell, “Drones over JFK airport prompts federal terror alert,” *Washington Times*, 4 August 2015. Last accessed 6 December 2015, <http://www.washingtontimes.com/news/2015/aug/4/terrorist-alert-issued-following-third-drone-sight/>; Tonda MacCharles, “RCMP warned Ottawa last year of possible drone terror threat,” *Toronto Star*, 1 March 2015, last accessed 30 September 2015, <http://www.thestar.com/news/canada/2015/03/01/rcmp-warned-ottawa-last-year-of-possible-drone-terror-threat.html>; Douglas Quan, “RCMP fears terrorists could use off-the-shelf drones to attack VIPs, internal documents reveal,” *National Post*, 29 December 2014, last accessed 21 December 2015, <http://news.nationalpost.com/news/canada/rcmp-fears-terrorists-could-use-off-the-shelf-drones-to-attack-vips>.

²⁹Chris Hughes, “ISIS planning to use toy helicopters as bombing drones fear security chiefs,” *Mirror*, 22 July 2015, last accessed 2 February 2016, <http://www.mirror.co.uk/news/world-news/isis-planning-use-toy-helicopters-6119888>.

³⁰David Pugliese, “Canadian Forces selling equipment, mothballing base housing to meet cuts,” *Ottawa Citizen – Defence Watch* (blog), 4 October 2012, last accessed 5 February 2016, “Japan radioactive drone: Tokyo police arrest man,” *BBC News*, 25 April 2015, last accessed 2 January 2016, <http://www.bbc.co.uk/news/world-asia-32465624>.

Readiness

18. As with any threat, a critical component of defence is readiness. This includes keeping abreast of the latest technology as well as tactics, techniques, and procedures (TTPs) for countering a threat. To this end, the U.S. regularly runs a counter-UAS technology exercise called Black Dart and a counter-UAS TTP exercise called Blue Knight.³¹ Australia also plans to host an annual counter-UAS exercise based on the limited participation allowed by the U.S. exercises.³²

Detection and Tracking

19. sUAS present a challenge to standard detection and tracking systems, especially radar, since they typically have very small radar cross sections. They are often mistaken by display filters as birds.³³ However, specialized radar systems are available, in particular as part of integrated sUAS defence systems such as the British built Anti-UAV Defence System (AUDS), the SRC LSTAR radars, the CACI Skytracker, or the Airbus Counter-UAV System.³⁴ The British government deployed LSTAR radars for the 2012 London Olympics, the 2013 G8

³¹“Blue Knight 2010 Demonstration Concludes in Nevada,” *Defense-aerospace.com*, 22 November 2010, last accessed 31 January 2016, http://www.defense-aerospace.com/article-view/release/120324/us-exercise-looks-at-counter_uav-capabilities.html; Ryan Faith, “Inside ‘Black Dart,’ the US Military’s War On Drones,” *Vice*, 28 October 2014.

³²Australian Certified UAV Operators Inc, “ACUO-Press-Release-01-2015.pdf,” last accessed 2 January 2016, <http://www.acuo.org.au/assets/docs/blog/ACUO-Press-Release-01-2015.pdf>.

³³Ryan Wallace and Jon Loffi, “Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis,” . . . : 16.

³⁴Blighter Surveillance Systems, “Blighter | AUDS Anti-UAV Defence System – Counter Drone and Counter UAS Technology from Blighter Surveillance Systems,” last accessed 22 December 2015, <http://www.blighter.com/products/blighter-auds-anti-uav-defence-system.html>; Joe Charlaff, “Analysis: Hostile UAVs . . . And The Defenses Against Them,” *Homeland Security Today*, 8 September 2015; CACI International Inc, “SkyTracker – Overview,” last accessed 8 December 2015, <http://www.caci.com/skytracker/index.shtml>; Airbus Defence & Space, “Counter-UAV System from Airbus Defence and Space protects large installations and events from illicit intrusion,” last accessed 2 January 2016, <https://airbusdefenceandspace.com/newsroom/news-and-features/counter-uav-system-from-airbus-defence-and-space-protects-large-installations-and-events-from-illicit-intrusion/>.

Summit, and the 2014 North Atlantic Treaty Organization Summit.³⁵ They plan to deploy the AUDS to major public events in the future.³⁶ The FAA signed an agreement in 2015 to test the Skytracker's ability to protect airports from sUAS incursions.³⁷

20. In addition to modified radars, most of the integrated sUAS defence systems incorporate a combination of passive radio frequency (RF), electro-optical, infrared, and acoustic detection and tracking. Several other systems employ these without radar, including Dedrone, Domestic Drone Countermeasures, and DroneShield.³⁸ The passive RF systems typically are able to detect both the sUAS and the operator.³⁹ DronesShield's acoustic detection system was deployed for the 2015 Boston Marathon.⁴⁰ Of course, human observers remain one of the most effective measures, particularly in congested areas.

Passive Defences

21. Some of the most effective defences against a sUAS threat are also the simplest and cheapest. These can include camouflage and concealment, static nets, and simply being

³⁵Joe Charlaff, "Analysis: Hostile UAVs ... And The Defenses Against Them," *Homeland Security Today*, 8 September 2015

³⁶Corey Charlton, "Sophisticated drone-jamming technology is to be deployed by anti-terror officers at major events after a successful trial at Remembrance Sunday," *Daily Mail*, 27 December 2015, last accessed 2 January 2016, <http://www.dailymail.co.uk/news/article-3375435/Sophisticated-drone-jamming-technology-deployed-anti-terror-officers-major-events-successful-trial-Remembrance-Sunday.html>.

³⁷Federal Aviation Administration, "FAA Expands Unmanned Aircraft Pathfinder Efforts," 7 October 2015.

³⁸Dedrone, "Advanced drone detection and warning device," last accessed 2 February 2016, <http://www.dedrone.com/en/dronetracker/drone-detection-hardware>; Domestic Drone Countermeasures, "Domestic Drone Countermeasures," last accessed 22 December 2015, <http://www.ddcountermeasures.com/home.html>; DroneShield, "DroneShield," last accessed 23 December 2015, <https://www.dronesshield.com/>.

³⁹Blighter Surveillance Systems, "Blighter | AUDS Anti-UAV Defence System – Counter Drone and Counter UAS Technology from Blighter Surveillance Systems," last accessed 22 December 2015, <http://www.blighter.com/products/blighter-auds-anti-uav-defence-system.html>; CACI International Inc, "SkyTracker – Overview," last accessed 8 December 2015, <http://www.caci.com/skytracker/index.shtml>; Airbus Defence & Space, "Counter-UAV System from Airbus Defence and Space protects large installations and events from illicit intrusion," last accessed 2 January 2016, <https://airbusdefenceandspace.com/newsroom/news-and-features/counter-uav-system-from-airbus-defence-and-space-protects-large-installations-and-events-from-illicit-intrusion/>.

⁴⁰Kelsey Atherton, "Drone-Proofing the Boston Marathon," *Popular Science*, 21 April 2015.

indoors.⁴¹ One effective passive defence for unskilled sUAS users is manufacturer imposed geofencing. Geofencing involves a sUAS manufacturer building automatic limitations on vehicle use based on GPS position, such as not allowing it to take off or forcing it to land. DJI, one of the main consumer sUAS makers, has implemented geofencing in its products around 10,000 North American airports and around Washington, D.C.⁴² The FAA's future plans for control of sUAS in the NAS include the possible use of dynamic geofencing, for example around active wildfires.⁴³

Active Defences

22. Several different types of active defences against sUAS have been developed. Some of the more traditional military solutions, such as Lockheed Martin's Extended Area Protection and Survivability (EAPS) Counter Rocket Artillery Mortar (C-RAM) weapon or the Israeli Iron Dome are expensive and have the potential to cause more collateral damage than an sUAS itself.⁴⁴ The EAPS C-RAM, for example, launches a 10 pound interceptor that costs \$16,000 per round.⁴⁵

⁴¹B.A. Jackson *et al*, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles* (Santa Monica: RAND Corporation, 2008), 80-81.

⁴²Mario Aguilar, "Maker of Drone That Crashed at White House Will Block Flights Over DC," *Gizmodo*, 28 January 2015.

⁴³National Aeronautics and Space Administration, "UTM: Air Traffic Management for Low-Altitude Drones," last accessed 27 December 2015, <http://www.nasa.gov/sites/default/files/atoms/files/utm-factsheet-11-05-15.pdf>.

⁴⁴Gettinger, Dan and Arthur Michel. "A Brief History of Hamas and Hezbollah's Drones," *Center for the Study of the Drone at Bard College*, 14 July 2014; Lockheed Martin, "Extended Area Protection and Survivability," Last accessed 22 December 2015, <http://www.lockheedmartin.ca/us/products/eaps.html>.

⁴⁵Lockheed Martin, "Extended Area Protection and Survivability," . . .

23. Directed energy weapons have also been proposed for counter-UAS systems, such as the Rafael Iron Beam, the U.S. Navy Laser Weapon System, the Boeing High Energy Laser Mobile Demonstrator, and an unnamed Chinese system.⁴⁶
24. A much cheaper alternative to these systems is to use small arms. Snipers can be effective against sUAS, but shots can be challenging and collateral damage remains a concern.⁴⁷ Shotguns, on the other hand, have proven to be very effective.⁴⁸ According to some experts, a shotgun loaded with birdshot would cause very little collateral damage due to the low terminal velocity of the small grains.⁴⁹
25. Net guns have been proposed as another low collateral damage option. Droneshield deployed net guns as part of their defensive system for the 2015 Boston Marathon.⁵⁰ Similar systems can be mounted on sUAS in order to function as interceptors. Some examples of this include the MALOU net-carrying interceptors, the Rapere wire-dangling sUAS, and the Delft

⁴⁶Gareth Jennings, "ADEX 2015: Rafael showcases Iron Beam C-RAM & C-UAV laser," *IHS Jane's Defence Weekly*, 19 October 2015; Sean Gallagher, "Navy will deploy first ship with laser weapon this summer," *ARS Technica*, 6 March 2014; Jordan Golson, "Army's New Laser Cannon Blasts Drones Out Of The Sky, Even In Fog," *Wired*, 5 September 2014; "China develops anti-drone laser," *Xinhua*, 2 November 2014, last accessed 26 December 2015, http://news.xinhuanet.com/english/china/2014-11/02/c_133760714.htm.

⁴⁷"China develops anti-drone laser," *Xinhua*, 2 November 2014, last accessed 26 December 2015, http://news.xinhuanet.com/english/china/2014-11/02/c_133760714.htm; Eric Limer, "How to Shoot Down a Drone," *Popular Mechanics*, 6 August 2015; David Pugliese, "Open season on drones...just how do you shoot down unmanned aerial vehicles?" *Ottawa Citizen – Defence Watch* (blog), 1 September 2015, last accessed 31 January 2016, <http://ottawacitizen.com/news/national/defence-watch/open-season-on-dronesjust-how-do-you-shoot-down-unmanned-aerial-vehicles>; Stephanie Chasteen, "Can you be killed by a bullet falling from the sky?" *Sciencegeekgirl* (blog), 29 December 2009, last accessed 2 February 2016, <http://blog.sciencegeekgirl.com/2009/12/29/can-you-be-killed-by-a-bullet-falling-from-the-sky/>; Dean Weingarten, "Celebratory Gunfire in Dallas," *Ammoland Shooting Sports News*, 4 January 2015, last accessed 2 February 2016, <http://www.ammoland.com/2015/01/celebratory-gunfire-in-dallas/#axzz3z1qztGD9>.

⁴⁸Eric Limer, "How to Shoot Down a Drone," *Popular Mechanics*, 6 August 2015; Cyrus Farivar, "Kentucky man shoots down drone hovering over his backyard," *ARS Technica*, 29 July 2015; Ryan Wallace and Jon Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," . . . : 21, 23.

⁴⁹Eric Limer, "How to Shoot Down a Drone," *Popular Mechanics*, 6 August 2015; Stephanie Chasteen, "Can you be killed by a bullet falling from the sky?" *Sciencegeekgirl* (blog), 29 December 2009, last accessed 2 February 2016, <http://blog.sciencegeekgirl.com/2009/12/29/can-you-be-killed-by-a-bullet-falling-from-the-sky/>; Dean Weingarten, "Celebratory Gunfire in Dallas," *Ammoland Shooting Sports News*, 4 January 2015, last accessed 2 February 2016, <http://www.ammoland.com/2015/01/celebratory-gunfire-in-dallas/#axzz3z1qztGD9>.

⁵⁰Kelsey Atherton, "Drone-Proofing the Boston Marathon," *Popular Science*, 21 April 2015.

Dynamics sUAS mounted net gun.⁵¹ France and Japan have already deployed net carrying interceptors, while South Korea is actively researching the technology.⁵²

26. An unconventional means to counter sUAS is to train and equip hawks or eagles for the task. The Dutch National Police recently announced that they are pursuing this tactic.⁵³

27. Hacking presents a possible defence, particularly for countering off-the-shelf sUAS. Several experts have demonstrated the ability to seize control of an sUAS.⁵⁴ Some have even used malware to have one sUAS take over others, who in turn take over other vehicles.⁵⁵

28. Jamming of RF signals is currently the most widely accepted solution for protecting assets where collateral damage is a concern. Most of the integrated defence systems such as AUDS and Skytracker employ RF jamming.⁵⁶ This will often either freeze the sUAS or cause it to crash. These systems are also mostly highly directional, minimizing collateral jamming effects. RF jamming also has the potential to be effective against large swarms of sUAS.⁵⁷ As an

⁵¹Mission Aérienne Légère à Organisation Unique, “M.A.L.O.U.,” last accessed 2 January 2016, <http://www.malou-tech.fr/indexUS.php>; Rapere, “Rapere Interceptor Drone,” last accessed 22 December 2015, <http://rapere.io/>; Delft Dynamics, “DroneCatcher catches drone,” last accessed 22 December 2015, <http://www.delftdynamics.nl/index.php/en/news-en/117-dronecatcher-catches-drone>.

⁵²Kelsey Atherton, “France Tests Kamikaze, Netted Interceptor Drones To Protect Nuclear Reactors,” *Popular Science*, 10 February 2015; James Vincent, “Tokyo police unveil net-wielding interceptor drone,” *The Verge*, 11 December 2015; Kelsey Atherton, “South Korea Gets Ready For Drone-On-Drone Warfare With North Korea,” *Popular Science*, 2 April 2015.

⁵³Michael Rundle, “Police train eagles to take down drones on sight,” *Wired*, 1 February 2016.

⁵⁴Aerial Sports League. “Aerial Sports.” Last accessed 22 December 2015, <http://aerialsports.tv/>; Thomas Fox-Brewster, “Maldrone: Watch Malware That Wants To Spread Its Wings Kill A Drone Mid-Flight,” *Forbes*, 27 January 2015.

⁵⁵Kamkar, Samy. “Samy Kamkar – SkyJack: autonomous drone hacking.” Last accessed 27 December 2015. <http://samy.pl/skyjack/>; Andrew Tarantola, “This Virus-Copter is a Digital Typhoid Mary,” *Gizmodo*, 10 December 2012.

⁵⁶Blighter Surveillance Systems, “Blighter | AUDS Anti-UAV Defence System – Counter Drone and Counter UAS Technology from Blighter Surveillance Systems,” last accessed 22 December 2015, <http://www.blighter.com/products/blighter-auds-anti-uav-defence-system.html>; CACI International Inc, “SkyTracker – Overview,” last accessed 8 December 2015, <http://www.caci.com/skytracker/index.shtml>.

⁵⁷Laurent Beaudoin, *et al.*, “Potential Threats of UAS Swarms and the Countermeasure’s Need,” in *Proceedings of the 10th European Conference on Information Warfare and Security: The Institute of Cybernetics at the Tallinn University of Technology Tallinn, Estonia 7-8 July 2011*, 2011: 6.

alternative to larger, more expensive systems, Battelle's DroneDefender RF jamming system is about the size of a rifle and claims to jam control, detonation, and GPS signals.⁵⁸

29. The variety of counter-sUAS defences available to the CAF come at a broad range of costs and different levels of effectiveness in different environments. The correct mix of equipment to defend the wide array of assets for which the CAF is responsible will likely require an equally wide range of equipment, with costs proportionate to the value of assets and the threat posed to them.

CONCLUSION

30. The probability of the CAF encountering malicious sUAS users is ever increasing. Both for the ONE mission and for force protection, the CAF has a responsibility to consider this threat and how to counter it. There are clearly many options for defence, with widely varying costs, target effects, and collateral damage concerns. These options must be considered in the context of the operating environment and with close coordination with our allies and other government agencies.

31. Prior to implementing countermeasures, it is vital that the CAF first consider what it needs to defend then conduct a risk analysis. The result should be a tiered defence strategy with simple inexpensive measures for lower value, lower risk assets and more robust measures for vital, high risk assets.

RECOMMENDATION

⁵⁸David Szondy, "Battelle's DroneDefender anti-drone beam gun grounds UAVs," *Gizmag*, 16 October 2015.

32. The CAF should conduct a thorough risk analysis of the threat posed by hostile sUAS in the contexts of the ONE mission and force protection, and develop an integrated, coherent, tiered strategy for sUAS defence.

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