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COUNTERING THE EMERGING SMALL UAS THREAT: THE CASE FOR A COHERENT CANADIAN COUNTER-SUAS STRATEGY

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ABSTRACT

This paper examines the benefits and threats posed by small unmanned aerial systems (sUAS) as well as the possible defences against hostile users in the Canadian context. It addresses the following questions. What benefits does the blossoming sUAS industry provide to Canada's aerospace sector and to Canadian society in general? What is the potential threat posed by hostile sUAS and how likely is it to materialize? What are Canada and Canada's allies' current stance on hostile sUAS? What can and should the country do to protect vital assets while balancing the need for economic growth? The paper reaches several conclusions. The myriad benefits of sUAS to Canada, both in terms of the many sUAS uses and in terms of the growing Canadian UAS industry, should drive policies that minimize restraints on commercial and recreational use. However, the advent of mass produced, low-cost, and easily piloted sUAS has resulted in an increased potential for malicious use of these systems, both against civilian targets at home and against Canadians abroad. Canada's UAS policies, while progressive in addressing regulatory issues and commercial needs, are lagging our allies' acknowledgement of potential security threats. Given the tremendous benefits but grave potential threats presented by sUAS, the government of Canada must implement a domestic sUAS defence strategy that balances the need to promote expanded sUAS use with the need to ensure public safety. This strategy should be layered to include attack prevention, readiness measures, detection measures, passive and active defences, and post-attack forensics, while weighing cost and effort against threat severity and probability. In order to do so, the Government of Canada should create an inter-agency task force to develop a counter-sUAS plan based on a thorough risk assessment and cost-benefit analysis.

There is a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered seriously looks strange; what looks strange is thought improbable; what is improbable need not be considered seriously.

– Thomas Schelling, Foreword to Roberta Wohlstetter's *Pearl Harbor: Warning and Decision*

CHAPTER 1 – INTRODUCTION

At 3 A.M. on January 26, 2015, a quadcopter small unmanned aerial vehicle (sUAV) flew over the fence surrounding the White House. It was too small for to be detected by the radar system protecting the U.S. President's official residence and workplace. One Secret Service officer saw it, but no one was able to bring it down. The sUAV eventually hit a tree and crashed (see Figure 1.1).[1] Shawn Usman, a scientist at the National Geospatial Intelligence Agency, immediately came forward. It was an innocent mistake: he lost control of his friend's DJI Phantom FC40, a $400 small unmanned aerial system (sUAS) simple enough for anyone to buy and fly out of the box. He had no idea that a no-fly zone had existed around Washington, D.C. since September 11, 2001.[2] The incident sparked calls for sUAS registration, operator licensing, and other measures to prevent accidental misuse. It also added fuel to a debate that was already heating up: could someone with malicious intent, a criminal or terrorist perhaps, use this technology? Could they spy on, or even attack, the White House? If they did, how could they be stopped?

[1]Michael Schmidt and Michael Shear, "A Drone, Too Small for Radar to Detect, Rattles the White House," *The New York Times*, 26 January 2015, last accessed 6 February 2016, http://www.nytimes.com/2015/01/27/us/white-house-drone.html.

[2]Faine Greenwood, "Man Who Crashed Drone on White house Lawn Won't Be Charged," *Slate*, 18 March 2015.

Figure 1.1 – Crashed DJI Phantom sUAS on White House Grounds

Source: Schmidt and Shear, *The New York Times*, 26 January 2015.

Small unmanned aerial systems (sUAS) provide a multitude of benefits to Canada, but can also have sinister uses. This paper examines the benefits and threats posed by sUAS and the possible defences against hostile users in the Canadian context. It will aim to address the following questions. What benefits does the blossoming sUAS industry provide to Canada's aerospace sector and to Canadian society in general? What are the potential threats posed by hostile sUAS and how likely are they to materialize? What is Canada's current stance on hostile sUAS? What are our allies' stances? What can and should the country do to protect vital assets while balancing the need for economic growth? This paper will show that, given the tremendous benefits but grave potential threats presented by sUAS, the government of Canada must implement a domestic sUAS defence strategy that balances the need to promote expanded sUAS use with the need to ensure public safety. This strategy should be layered to include attack prevention, readiness measures, detection measures, passive and active defences, and post-attack

forensics, while weighing cost and effort against threat severity and probability. In order to do so, the Government of Canada should create an inter-agency task force to develop a counter-sUAS plan based on a thorough risk assessment and cost-benefit analysis.

After this brief introduction and a few definitions, this paper will proceed as follows. Chapter 2 will examine the benefits of sUAS to Canada. It will aim to show that the myriad benefits of small UAS to Canada, both in terms of their many uses and in terms of the growing Canadian UAS industry, should drive policies that minimize restraints on commercial, developmental, and recreational use. Chapter 3 will explore the potential threats posed by sUAS to Canada. The advent of mass produced, low-cost, and easily piloted small UAS has resulted in an increased potential for malicious use of these systems, both against civilian targets at home and against Canadian interests abroad. Chapter 4 will look at current Canadian UAS policies. Although several other countries overseas have policies even more conducive to UAS development, Canada's fairly liberal policies have resulted in a distinct industrial advantage over the U.S. However, Canada's UAS policies, while fairly progressive in addressing regulatory issues and commercial needs, are lagging the rest of the world's acknowledgement of potential security threats. Chapter 5 will discuss the possible defences against malicious sUAS users. Any potential Canadian sUAS defence strategy should be layered, including attack prevention, readiness measures, detection measures, passive and active defences, and post-attack forensics. Finally, Chapter 6 will offer conclusions and recommendations for Canadian policy.

Definitions

Prior to delving into discussion, it is important to clarify some terminology. There are several different terms used to describe unmanned aircraft. Transport Canada (TC) currently uses

the term "unmanned aerial vehicle," or UAV.[3] Many commentaries and news reports use the lay term "drone." Most countries in Europe use the term "remotely piloted aircraft systems" or RPAS.[4] Australia calls the vehicle "remotely piloted aircraft" or RPA.[5] These are only a few of the many variations that exist.[6] Some definitions also refer separately to the aircraft, for example as the "unmanned vehicle" (UV), "unmanned aircraft" (UA), or the UAV, while not including the operator or ground systems.[7] The U.S. Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO) prefer the term "unmanned aircraft system" or UAS.[8] This definition includes the aircraft, data link, control station, and operator. It is an overarching term including vehicles that are directly operated by a pilot as well as vehicles that can operate with autonomy. [9] This is also the term that TC plans to use in the future.[10] For simplicity, this paper will therefore primarily use the term UAS as defined by the FAA and ICAO. ICAO's UAS definition is straightforward: "An aircraft and its associated elements which are operated with no pilot on board."[11] When referring only to the vehicle itself, this paper will use the term UAV. It should be noted that many of the quotes in this paper use the other terms;

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[3]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles* (Ottawa: Transport Canada, 28 May 2015), 12.

[4]European RPAS Steering Group, *Roadmap for the integration of civil Remotely-Piloted Aircraft Systems into the European Aviation System: Final report from the European RPAS Steering Group* (June 2013), 5.

[5]Civil Aviation Safety Authority, "Remotely Piloted Aircraft (RPA)," last accessed 30 September 2015, https://www.casa.gov.au/operations/standard-page/remotely-piloted-aircraft-rpa.

[6]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles* . . ., 12.

[7]*Ibid*.

[8]Federal Aviation Administration, *Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap: First Edition – 2013* (Washington D.C: Federal Aviation Administration, 2013), 8; International Civil Aviation Organization. *ICAO Circular 328 AN/190: Unmanned Aircraft Systems (UAS)* (Monreal: International Civil Aviation Organization, 2011), x.

[9]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles* . . ., 12.

[10]*Ibid.*

[11]International Civil Aviation Organization. *ICAO Circular 328 AN/190: Unmanned Aircraft Systems (UAS)* . . ., x.

this paper will not correct the quotes, understanding that they mean roughly the same thing. As an aside, the term sUAS is invariant; the plural of sUAS is sUAS.

UAS size categories are also defined in several different ways. For example, Table 1.1 shows the North Atlantic Treaty Organization (NATO) classification system. The Royal Canadian Air Force (RCAF) uses the NATO classification system.[12]

Table 1.1 – NATO UAS Classification Table

Class	Category	Normal employment	Normal Operating Altitude	Normal Mission Radius	Primary Supported Commander	Example platform
CLASS I (less than 150 kg)	SMALL >20 kg	Tactical Unit (employs launch system)	Up to 5K ft AGL	50 km (LOS)	BN/Regt, BG	Luna, Hermes 90
	MINI 2-20 kg	Tactical Sub-unit (manual launch)	Up to 3K ft AGL	25 km (LOS)	Coy/Sqn	Scan Eagle, Skylark, Raven, DH3, Aladin, Strix
	MICRO <2 kg	Tactical Pl, Sect, Individual (single operator)	Up to 200 ft AGL	5 km (LOS)	Pl, Sect	Black Widow
CLASS II (150 kg to 600 kg)	TACTICAL	Tactical Formation	Up to 10,000 ft AGL	200 km (LOS)	Bde Comd	Sperwer, Iview 250, Hermes 450, Aerostar, Ranger
CLASS III (more than 600 kg)	Strike/ Combat	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	
	HALE	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre COM	Global Hawk
	MALE	Operational/Theatre	Up to 45,000 ft MSL	Unlimited (BLOS)	JTF COM	Predator B, Predator A, Heron, Heron TP, Hermes 900

Source: *Strategic Concept of Employment for Unmanned Aircraft Systems in NATO*, 6.

The various U.S. military services use different categorization systems, often according to mission role vice size. The U.S. Department of Defense (DoD) UAS group categories are shown in Table 1.2.

[12]Department of National Defence, *CANFORGEN 080/15 C AIR FORCE 13/15 231956Z APR 15 SUBJ: IMPLEMENTATION OF NATO UAS CLASSIFICATION TABLE* (Ottawa: Department of National Defence, 2015).

Table 1.2 – U.S. DoD UAS Groups

UAS Groups	Maximum Weight (lbs) (MGTOW)	Normal Operating Altitude (ft)	Speed (kts)	Representative UAS	
Group 1	0 – 20	<1200 AGL	100	Raven (RQ-11), WASP	
Group 2	21 – 55	<3500 AGL	< 250	ScanEagle	
Group 3	< 1320	< FL 180		Shadow (RQ-7B), Tier II / STUAS	
Group 4	>1320		Any Airspeed	Fire Scout (MQ-8B, RQ-8B), Predator (MQ-1A/B), Sky Warrior ERMP (MQ-1C)	
Group 5		> FL 180		Reaper (MQ-9A), Global Hawk (RQ-4), BAMS (RQ-4N)	

Source: *Department of Defense Unmanned Aircraft System Airspace Integration Plan*, D-3.

While these definitions are useful, for this paper the concern is malicious civilian users. This paper will therefore use the FAA and TC definitions of sUAS or small UAV (sUAV). Both the FAA and TC use equivalent definitions for small UAS, specifically any UAS for which the aircraft maximum weight is less than 25 kilograms (55 pounds).[13] In both countries recreational use of unarmed UAS of this size requires no user licensing or training and there are no purchasing restrictions. As will be discussed in Chapter 4, there is a slight nuance to TC's definition. TC currently considers small UAVs to be up to 35 kilograms for certain applications.[14] However, they plan to align with the FAA in the near future with and implement a

[13]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 9; Department 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), 78595.

[14]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles, . . .*, 9.

single limit of 25 kilograms. Note that while this category agrees with the U.S. DoD UAS Groups 1 and 2, it does not agree with the NATO definition of small UAS (20-150 kilograms).[15] As a final note on sUAV weight categorization, the FAA excludes sUAVs weighing less than 0.55 pounds (250 grams) from requiring registration, and TC will likely follow suit when it implements UAS registration.[16]

Two other terminology nuances should be addressed. First, some authors and regulators differentiate between model aircraft and UAS based on factors such as payload cameras or autopilot capability.[17] This is the case with TC but not with the FAA.[18] This paper will not make such a distinction, but will discuss some of the implications of such differentiation in Chapter 4. Second, some authors distinguish UAS from cruise missiles based on the user's intent to recover the vehicle.[19] As this paper will discuss the modification of consumer sUAS to be employed as single-use weapons, it will again not make this distinction.

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[15]Department of Defense, *Department of Defense Unmanned Aircraft System Airspace Integration Plan* (Washington, D.C.: U.S. Government Printing Office, March 2011), D-3; North Atlantic Treaty Organization, *Strategic Concept of Employment for Unmanned Aircraft Systems in NATO* (Kalkar: Joint Air Power Competence Centre, January 2010), 6.

[16]Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule . . .*, 78595; Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 26-30.

[17]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 11; RCFlightLine.com, "Drones vs. Radio-Controlled Aircraft: A Look at the Differences between the Two | RCFlightline.com," last accessed 6 February 2016, https://rcflightline.com/drones-vs-radio-controlled-aircraft-a-look-at-the-differences-between-the-two/.

[18]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 2; Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule . . .*, 78595.

[19]Dennis 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.

CHAPTER 2 – BENEFITS OF SUAS

The recent growth of the small UAS industry is astounding. The FAA estimated that in 2014, 200,000 sUAS were operating in the U.S. national airspace structure (NAS) for recreational purposes. Based on sales estimates, they expected another 1.6 million recreational sUAS to join in 2015, with over half that number being sold in the last quarter of the year. The FAA predicts 2016 will bring another 1.9 million recreational sUAS plus another 600,000 for commercial use.[20] TC has no estimate of total sUAS numbers, but they have tracked increases in applications for Special Flight Operating Certificates (SFOCs). SFOCs are required to operate heavier UAS and for commercial or research applications that do not meet specific exemption conditions.[21] The number of SFOC applications to TC has grown exponentially, from 135 in 2011 to 1,672 in 2014.[22] One industry analyst estimated that in 2014, about 200,000 new sUAS were being sold around the world each month. His prediction is for that figure to double by 2020.[23]

This chapter will discuss the benefits gained by this incredible proliferation of sUAS. It will first explore a sampling of the wide variety of sUAS applications, from recreation to emergency services, highlighting some specific Canadian examples. It will then examine the economic benefits of the sUAS industry, again noting specific Canadian gains. The theme of this chapter is that there are significant benefits to both the Canadian society and economy of maintaining UAS regulations as permissive as possible in order to enable technological

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[20]Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule . . .*, 78597-78598.

[21]Transport Canada, *Advisory Circular 600-004: Guidance Material for Operating Unmanned Air Vehicle Systems under an Exemption* (Ottawa: Transport Canada, 27 November 2014), 2.

[22]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 2; Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014* (Ottawa: National Research Council Canada, 2015), 11.

[23]Barbara Booth, "Is it time to buy your kid a drone for Christmas?" *CNBC*, 22 December 2014, last accessed 3 February 2016, http://www.cnbc.com/2014/12/22/kids-and-drones-booth-change-the-world-ec-141218.html.

development and growth. This will be important to consider when exploring the threat likelihood and severity of possible hostile sUAS users.

sUAS Applications

A 2014 report prepared for the National Research Council (NRC) of Canada noted that "there is a general recognition that Canada is particularly application rich" for the UAS industry.[24] One of the authors put it: "We found dramatic growth in this sector since 2008, and the potential for Canada to command a global leadership position in the UAS marketplace."[25] Since 2008, the number of Canadian universities researching UAS technology increased from 11 to 31. The number of Canadian companies using or developing UAS had likewise risen from 88 in 2008 to 312 in 2014, with small UAS specifically as the core focus in Canada.[26]

Recreation

As the FAA's estimates of total sUAS in the NAS indicate, the vast majority of sUAS are for recreational use. Most of these cost between about $100 and $1000 and include some kind of camera payload.[27] Some recreational sUAS, such as the Parrot AR 2.0, are designed to play augmented reality games.[28] Some other popular recreational uses are sUAS fighting, racing, and hacking. There is even an Aerial Sports League, which calls itself the "worldwide leader in drone sports, entertainment and media" and a world "Drone Games," formerly known as "Drone Olympics."[29]

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[24]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 10.
[25]Unmanned Systems Canada, *Media Release: USC-STC Releases Report – Canadian Civil UAS 2014* (Ottawa: Unmanned Systems Canada, 25 February 2015), 1.
[26]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 2-3.
[27]Anna Attkisson, "Best Drones 2016," *Tom's Guide*, 5 January 2016.
[28]Parrot, "AR.Drone 2.0. Parrot new wi-fi quadricopter – AR.Drone.com – HD Camera – Civil drone – Parrot," last accessed 7 February 2016, http://ardrone2.parrot.com/.
[29]Aerial Sports League, "Aerial Sports," last accessed 22 December 2015, http://aerialsports.tv/; DroneGames, "Drone Games – A NodeCopter style programming competition powered by drones and JavaScript," last accessed 7 February 2016, http://dronegames.co/.

Law Enforcement

According to the 2014 NRC report, there are three well established UAS applications in Canada: law enforcement, precision agriculture, and media (photography and cinematography).[30] It defines established applications fairly broadly as those that have an "initial client base" served by UAS technology that is currently capable of "meeting at least some of the clients' needs" within the framework of current Canadian regulations.[31]

sUAS are used by law enforcement for three main activities: forensics, tactical support, and search and rescue.[32] For forensic support, they are used primarily to take high quality still images, while for tactical support and search and rescue they are mostly used for timely colour or infrared (IR) video.[33] sUAS have been adopted by the Royal Canadian Mounted Police (RCMP) as well as several provincial and municipal police departments, including the Ontario Provincial Police (OPP), the Saskatoon Police Service, and Halton Regional Police Services.[34] By 2014 the OPP had up to five systems in service and the RCMP had over 20.[35] There is also evidence that the quality of sUAS products used in court has "improved the quality, accuracy, and efficiency of many criminal trials."[36] Figure 2.1 shows an RCMP officer operating a specialized sUAS.

[30]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 47.
[31]*Ibid.*
[32]*Ibid.*, 48.
[33]*Ibid.*
[34]*Ibid*, 48-49.
[35]*Ibid*, 49.
[36]*Ibid*, 48.

Figure 2.1 – An RCMP Officer operating an sUAS

Source: Makowichuk, *Calgary Sun*, 14 March 2014.

Agriculture

sUAS are being used extensively for precision agriculture. Typical use involves flying automatic routes over crops, taking images in multiple spectra to determine plant health, water temperature and quality, plant height, and several other important indices.[37] These are used for everything from seed spacing to application patterns for herbicides, pesticides, and fertilizers.[38] Figure 2.2 shows an example of using sUAS imagery to count plants. Researchers at Harvard University are even developing tiny insect-sized sUAS that could be used to pollinate crops, among other applications, although this particular technology is not yet fielded.[39] At least 16 Canadian companies are involved in agricultural use of sUAS.[40]

[37]Aeryon Labs, "Aeryon small Unmanned Aerial Systems," last accessed 19 December 2015, http://aeryon.com/.
[38]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 50.
[39]Harvard University, "Robobees," last accessed 19 December 2015, http://robobees.seas.harvard.edu/.
[40]*Ibid.*

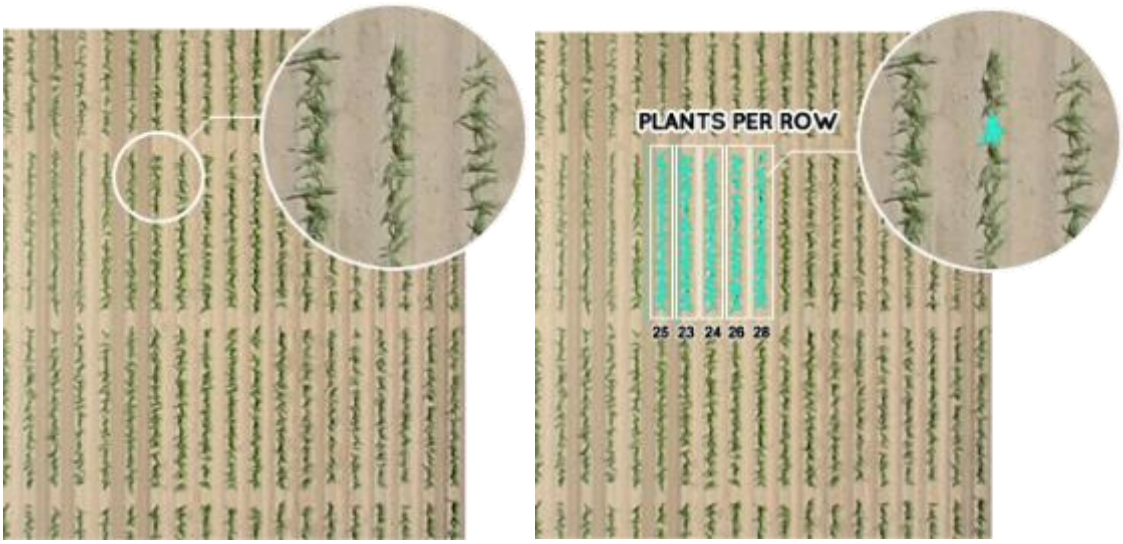

Figure 2.2 – Plant counting, one of many agricultural sUAS applications

Source: Precision Hawk, www.precisionhawk.com.

Precision agriculture is one of the most important developing applications of UAS in the U.S. A 2013 report on the economic impact of UAS in the U.S. by the Association for Unmanned Vehicle Systems International (AUVSI), a non-profit organization dedicated to "advancing the unmanned systems and robotics community," found that agricultural UAS sales would dominate the market in the near future (Figure 2.3).[41] sUAS have a particular niche in Japan, where they are used to monitor crops on steep hillsides.[42]

[41]Association For Unmanned Vehicle Systems International, "About – Association for Unmanned Vehicle Systems International," last accessed 22 February 2016. http://www.auvsi.org/about/about77; Darryl Jenkings and Bijan Vasigh, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States* (Arlington: AUVSI, March 2013), 6.

[42]Evan Mitsui, "Commercial drones have 'endless' uses under Canada's laws," *CBC News*, 12 November 2013, last accessed 19 December 2015, http://www.cbc.ca/news/technology/commercial-drones-could-have-endless-uses-under-canada-s-laws-1.1386300.

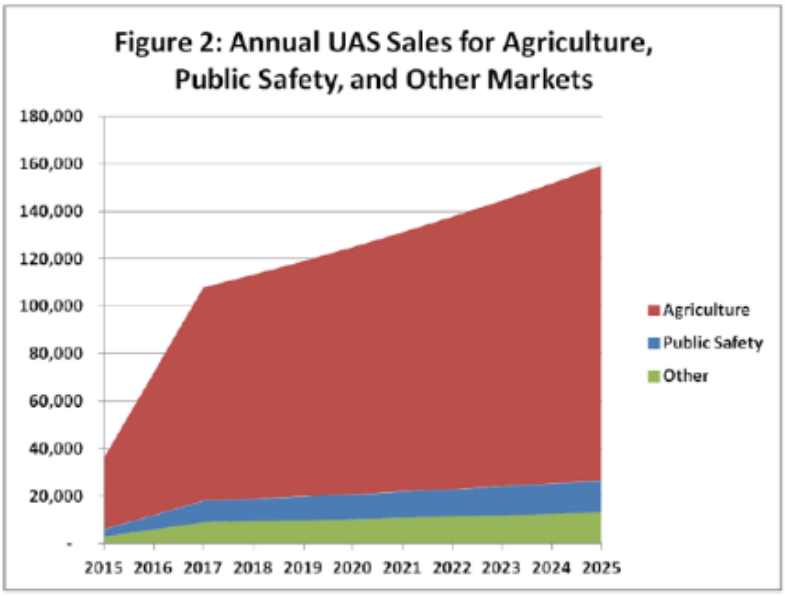

Figure 2.3 – Forecast of Annual UAS Sales (units) in the U.S.

Source: Jenkins and Vasigh, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States*, 6.

Photography and cinematography

sUAS are rapidly becoming standard equipment for a variety of photographic and videographic roles. The film industry has been using them for some time, but was restricted from using them in the U.S. by the FAA. Until 2014, Hollywood aerial filming was either done by helicopter, at about five times the cost of a sUAS per day, or done by sUAS in South America, Europe, or Canada.[43] Although less than 10% of film productions use sUAS, their use is rapidly expanding.[44] In 2014 there were over 20 Canadian companies in the business of sUAS filming, and at least two Canadian colleges offered "drone journalism" programs.[45] Some critics have pointed out safety issues with sUAS videography, particularly due to lax operator training

[43]Richard Verrier, "Drones are providing film and TV viewers a new perspective on the action," *Los Angeles Times*, 8 October 2015, last accessed 7 February 2016, http://www.latimes.com/entertainment/envelope/cotown/la-et-ct-drones-hollywood-20151008-story.html.
[44]*Ibid.*
[45]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 51.

requirements. For example, a sUAS filming a commercial in Vancouver in May 2014 hit a downtown building and crashed to the ground.[46] However, proponents also point out that helicopter filming can also be risky, and crashes are usually much more catastrophic.[47] For example, three people were killed in a helicopter crash while filming in 2013, and another ten in a crash in March 2015.[48]

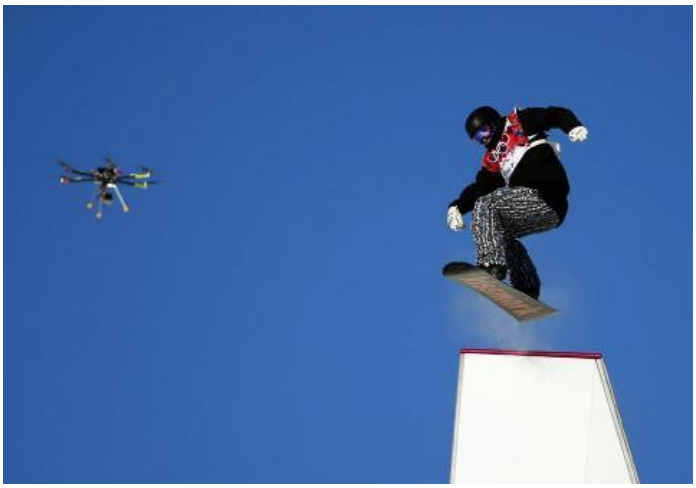

Figure 2.4 – An sUAS filming a snowboarder at the 2014 Sochi Winter Olympics

Source: Bailie, Meredith, and Roughley, *Canadian Civil UAS 2014*, 51.

sUAS have begun to be used extensively in sports photography as well, replacing helicopters and cable systems. sUAS were notably used to a great extent during the 2014 Sochi Winter Olympics (Figure 2.4).[49] Several consumer drones have automatic following systems. Once launched, they automatically track a device worn by the athlete, capturing impressive

[46]Jason Proctor and Bal Brach, "Drone crash prompts Vancouver to review film industry use," 11 June 2014, last accessed 8 December 2015, http://www.cbc.ca/news/canada/british-columbia/drone-crash-prompts-vancouver-to-review-film-industry-use-1.2671977.
[47]*Ibid*.
[48]Richard Verrier, "Drones are providing film and TV viewers a new perspective on the action," *Los Angeles Times*, 8 October 2015, last accessed 7 February 2016, http://www.latimes.com/entertainment/envelope/cotown/la-et-ct-drones-hollywood-20151008-story.html.
[49]Drones Daily, "Drones and the Future of Sports Photography," *Hoverhi* (blog), 6 January 2016, last accessed 7 February 2016, http://www.hoverhi.com/drones-and-the-future-of-sports-photography/.

scenes.[50] However, safety concerns with sUAS filming have again been raised. The dramatic on-screen crash of a sUAV filming a World Cup ski race in Dec 2015 led to a ban by the international ski federation (Figure 2.5).[51]

Figure 2.5 – A skier is almost struck by a crashing sUAV

Source: Henderson, "Skier Marcel Hirscher nearly killed by falling camera drone," *The Telegraph*, 23 December 2015.

Real Estate

Real estate agents have increasingly been using sUAS for photo and video shots of properties. Canadian realtors enjoy an advantage in this field, as TC regulations are fairly accommodating.[52] By contrast, the U.S. National Association of Realtors still recommends that realtors not use sUAS "for any purpose related to selling property" due to FAA restrictions.[53] This is not surprising. In October 2015 the FAA proposed a potential massive $1.9 million civil

[50]Arshiya, "Drones that follow you (follow me mode)," *We Are Champions Magazine*.
[51]Eric Willemsen, "Ski federation bans camera drones after close-call crash," *The Globe and Mail*, 23 December 2015, last accessed 7 February 2016, http://www.theglobeandmail.com/sports/more-sports/ski-federation-bans-camera-drones-after-close-call-crash/article27921348/.
[52]Josh O'Kane, "Drones reach new heights in real estate," *The Globe and Mail*, 4 May 2015, last accessed 7 February 2016, http://www.theglobeandmail.com/report-on-business/industry-news/property-report/drones-reach-new-heights-in-real-estate/article24191536/.
[53]National Association of Realtors, "Field Guide to Drones and Real Estate," last accessed 7 February 2016, http://www.realtor.org/field-guides/field-guide-to-drones-and-real-estate.

penalty against SkyPan International, an sUAS filming company operating around Chicago and New York. SkyPan, who offers aerial photography for a variety of purposes including real estate, is alleged to have operated without FAA authorization including 43 flights through "highly restricted New York Class B airspace."[54]

Airborne Delivery

A nascent use for sUAS is the airborne delivery of goods. For example, Amazon is developing a service called Amazon Prime Air (Figure 2.6). They plan to "deliver packages up to five pounds in 30 minutes or less" to customers within about ten miles of distribution centres.[55] Of particular note is that FAA restrictions to testing drove Amazon to move its testing efforts to Canada and several other less restrictive countries.[56] Similar plans are being developed by UPS, Google, Walmart, and Apple.[57] The textbook company Zookal has been experimenting with sUAS delivery in Australia and New Zealand for about two years.[58] At least two companies in China are working towards sUAS deliveries, one of which – Alibaba – has already conducted a small pilot program for tea delivery.[59]

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[54]Federal Aviation Administration, "Press Release – FAA Proposes $1.9 Million Civil Penalty Against SkyPan International for Allegedly Unauthorized Unmanned Aircraft Operations," 6 October 2015, last accessed 8 December 2015, https://www.faa.gov/news/press_releases/news_story.cfm?newsId=19555.

[55]Amazon, "Amazon Prime Air," last accessed 27 December 2015, http://www.amazon.com/b?node=8037720011.

[56]Mike Hager, "Canadian airspace is friendly to U.S. drones," *The Globe and Mail*, 30 March 2015, last accessed 31 January 2016, http://www.theglobeandmail.com/news/british-columbia/amazon-testing-delivery-drones-in-bc/article23693387/.

[57]Ben Popper, "UPS researching delivery drones that could compete with Amazon's Prime Air," *The Verge*, 3 December 2013; "Google's delivery drones newest front in war with Amazon," *CBC News*, 28 August 2014, last accessed 19 December 2015, http://www.cbc.ca/news/technology/google-s-delivery-drones-newest-front-in-war-with-amazon-1.2750104; "Wal-Mart applies to test delivery drones," *CBC News*, 27 October 2015, last accessed 19 December 2015, http://www.cbc.ca/news/technology/wal-mart-drones-1.3290313; Will Gomez, "Apple To Copy Amazon, Test Delivery of Macs, iPhones, iPads, By Drone," *Mac360*, 4 December 2015.

[58]Adam Bender, "Watch drones deliver textbooks in video demo by Zookal," *Computerworld*, 7 March 2015.

[59]Gwynn Guilford, "China could become the first country to legalize parcel delivery by drone," *Quartz*, 3 September 2013; Lulu Chen, "Alibaba Drones Fly Over Beijing While Amazon Pleads for U.S. Tests," *Bloomberg Business*, 4 February 2015.

Figure 2.6 – One of Amazon's prototype delivery sUAS

Source: Fingas, *Engadget,* 29 November 2015.

Plans exist for sUAS to deliver more than retail items. U.S. based Matternet used sUAS in both Haiti and Papua New Guinea to deliver medicine and other relief supplies to inaccessible areas. With a sUAS capable of carrying up to 1kg over 20km, they are currently working on a mail delivery program for Swiss Post.[60] Manayunk Cleaners, a dry cleaning establishment in Philadelphia, delivers customers' clean clothes by sUAS (albeit with an operator watching at all times).[61] Dominos in the U.K. explored pizza delivery by sUAS.[62] South Africa's OppiKoppi music festival boasts sUAS beer delivery.[63] Darwin Aerospace, a small group out of California, is developing a "Burrito Bomber" to deliver Mexican food (Figure 2.7).[64] Based on the

[60]Matternet, "Matternet," last accessed 19 December 2015, http://mttr.net/.
[61]Vince Lattanzio, "Dry Cleaner Drone Delivers Clothes to Customers," *NBC News*, 9 July 2013, last accessed 16 February 2016, http://www.nbcphiladelphia.com/entertainment/the-scene/Dry-Cleaning-Drone-Delivering-Clothes-to-Customers-214736141.html.
[62]Hugo Gye, "Now that's a special delivery: Domino's builds DRONE to deliver pizzas by air and beat the traffic," *Daily Mail*, 5 June 2013, last accessed 17 February 2016, http://www.dailymail.co.uk/news/article-2336324/Dominos-builds-DRONE-deliver-pizzas-air-beat-traffic.html.
[63]Chenda Ngak, "Beer drone? Festival goers may see booze fall from the sky," *CBS News*, 8 May 2013, last accessed 19 December 2015, http://www.cbsnews.com/news/beer-drone-festival-goers-may-see-booze-fall-from-the-sky/.
[64]Darwin Aerospace, "Burrito Bomber: The world's first airborne Mexican food delivery system," last accessed 27 December 2015, http://www.darwinaerospace.com/burritobomber.

incredible interest in sUAS delivery around the world, it seems likely that the proliferation of thousands of accurate, heavy lifting sUAS will accelerate in the future.

Figure 2.7 – The Burrito Bomber With Payload Attached

Source: Fincher, *Gizmag*, 17 December 2012

Infrastructure Inspection and Surveying

It is often said that UAS are useful for jobs that are dull, dirty, or dangerous. The dull jobs of inspection and surveying are becoming a growing niche application for sUAS. The 2014 NRC report suggests three UAS applications worth pursuing in Canada, two of which are "pipeline and power line monitoring" and "oil, gas, and mineral surveys."[65] Several oil companies in Canada are already using sUAS, including Royal Dutch Shell PLC, Syncrude

[65]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 82-84.

Canada, and Cenovus.[66] The Canadian company Accuas claims to be "the world's first commercial UAV surveying company."[67]

Science

There have been a wide array of research applications for sUAS. For example, researchers at McGill University use them to track wildlife populations of birds and bears.[68] The 2014 NRC report suggests that wildlife surveying and protection could be a valuable field to pursue.[69] In addition to being able to easily spot and track wildlife, sUAS can be used for more dangerous scientific applications. For example, students at Oklahoma State University designed UAS to deliberately follow tornadoes.[70]

Emergency Services

sUAS are being increasingly used to respond by emergency service providers. Forest fire surveying is one of the UAS growth areas highlighted by the 2014 NRC report.[71] The Halifax fire department uses sUAS equipped with IR and optical cameras to survey fires.[72] They have proven their use in disaster zones, for example by mapping affected areas after Typhoon Haiyan struck the Phillipines in 2013.[73] Using sUAS for search and rescue is becoming increasingly

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[66]Omar El Akkad and Kelly Cryderman, "Canadian technology and the flight of the drones," *The Globe and Mail*, 7 April 2014, last accessed 19 December 2015, http://www.theglobeandmail.com/technology/tech-news/canadian-technology-and-the-flight-of-the-drones/article17849259/.

[67]Accuas, "Accuas | Unmanned Aerial Surveys (UAS)," last accessed 17 February 2016, http://www.accuas.com/#!/splash-page.

[68]Evan Mitsui, "Commercial drones have 'endless' uses under Canada's laws," *CBC News*, 12 November 2013, last accessed 19 December 2015, http://www.cbc.ca/news/technology/commercial-drones-could-have-endless-uses-under-canada-s-laws-1.1386300.

[69]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 84.

[70]Kelsey Atherton, "Oklahoma Students Design Drones That Can Fly Into Tornadoes," *Popular Science*, 21 May 2013.

[71]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 84.

[72]Paul Withers, "Halifax Fire drone use complicated by controlled airspace, says consultant," *CBC News*, 9 September 2015, last acessed 19 December 2015, http://www.cbc.ca/news/canada/nova-scotia/halifax-fire-drone-use-1.3221284.

[73]Adam Klaptocz, "Mapping the Philippines after Typhoon Haiyan," *Drone Adventures* (blog), May 2014, http://blog.droneadventures.org/post/85863359885/mapping-the-philippines-after-typhoon-haiyan.

common and several agencies have been experimenting with them.[74] For example, the RCMP credited an sUAS with helping a successful search and rescue near Saskatoon in May 2013.[75]

Military

Exploring the friendly military uses of sUAS is beyond the scope of this paper. However, it is worth noting the economic and technological benefits of the industry. For the most part, the military UAS industry is dominated by the U.S.[76] However, a few Canadian companies have carved a foothold in the market. For example, Libyan rebels made use of Canadian Aeryon Labs' sUAS in their advance to Tripoli in 2011.[77] The Canadian company ING Robotic Aviation operated Boeing ScanEagle sUAS for the Canadian Army (CA) in Afghanistan in 2008 and for the Royal Canadian Navy (RCN) ships in 2011.[78] They also supported the CA's mini-UAV program in 2010.[79]

Peace Support

sUAS have taken on an increasingly important role in peace support operations. For example, the Organization for Security and Co-operation in Europe use sUAS for ceasefire

[74]"Search and rescue drones tested in B.C.," *CBC News*, 7 September 2013, last accessed 8 December 2015, http://www.cbc.ca/news/canada/british-columbia/search-and-rescue-drones-tested-in-b-c-1.1703609.
[75]Evan Mitsui, "Commercial drones have 'endless' uses under Canada's laws," *CBC News*, 12 November 2013, last accessed 19 December 2015, http://www.cbc.ca/news/technology/commercial-drones-could-have-endless-uses-under-canada-s-laws-1.1386300.
[76]David Common, "Drones go commercial, take on tasks from industry to farming," *CBC News*, 30 May 2014, last accessed 19 December 2015, http://www.cbc.ca/news/technology/drones-go-commercial-take-on-tasks-from-industry-to-farming-1.2657036.
[77]Omar El Akkad and Kelly Cryderman, "Canadian technology and the flight of the drones," *The Globe and Mail*, 7 April 2014, last accessed 19 December 2015, http://www.theglobeandmail.com/technology/tech-news/canadian-technology-and-the-flight-of-the-drones/article17849259/.
[78]ING Robotic Aviation, "ING Robotic Aviation: Professional Drone Solutions," last accessed 19 December 2015, http://ingrobotic.com/.
[79]*Ibid.*

monitoring in Ukraine.[80] The UN also deployed unarmed UAS to the Democratic Republic of Congo to support its stabilization mission, MONUSCO.[81]

UAS Development

In addition to the many direct applications of sUAS, a significant Canadian UAS development industry exists. As of 2014, 35 Canadian companies were building complete UAS, 85 companies were selling UAS components, and 44 companies were selling UAS sensors.[82] These companies have benefited both from permissive Canadian regulations and from several test sites across the country. Four such sites were operative in 2014: the Canadian Centre for Unmanned Vehicle Systems in Medicine Hat, Alberta, Southport, near Portage la Prairie, Manitoba, the Unmanned Aerial System Centre of Excellence at Alma, Quebec, and Canadian Forces Base (CFB) Goose Bay, Labrador. Three of these four sites have access to restricted airspace which allows advanced testing such as beyond visual line of site (BVLOS) operations.[83]

Others

Some other creative uses for sUAS highlight that other unforeseen applications are likely to emerge in the near future. For example, a sUAS led icebreakers to resupply Nome, Alaska in 2012 after a storm prevented their fall fuel delivery.[84] The sUAS scouted ahead of the ships, assessing ice conditions to find an optimum route. On a much less serious mission, a New York

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[80]"Kiev authorizes OSCE to deploy drones to monitor ceasefire," *RT*, 13 September 2014, last accessed 6 May 2016, https://www.rt.com/news/187632-ukraine-osce-drones-ceasefire/.

[81]"UN launches unmanned surveillance aircraft to better protect civilians in vast DR Congo," *UN News Centre*, 3 December 2013, last accessed 7 May 2016, http://www.un.org/apps/news/story.asp?NewsID=46650#.Vy3vu74bhXs.

[82]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014 . . .*, 33.

[83]*Ibid*., 46-47.

[84]"Drone helps mission to ship fuel to Alaska town," *Navy Times*, 11 January 2012, last accessed 19 December 2015, http://www.navytimes.com/article/20120111/NEWS01/201110319/Drone-helps-mission-ship-fuel-Alaska-town.

man rigged his sUAS to walk his dog in 2014.[85] A Canadian company uses sUAS to chase defecating geese from Ottawa beaches.[86] Montreal's famous Cirque de Soleil troupe even developed a performance that included sUAS playing the parts of flying lampshades.[87] These examples again demonstrate the incredible variety of sUAS applications possible.

Economic Benefits

Given the recent proliferation of UAS and the wide range of applications, it is not surprising that the predicted economic impact of the industry is significant. Two in-depth estimates come from the U.S.

The first estimate comes from the Teal Group, who examined the world UAS industry in 2015. Their study looked at all forms of UAS including military systems. They predicted a worldwide growth in the value of the industry from $4 billion per year in 2015 to $14 billion per year in 2025, for a total of $93 billion over ten years plus an addition $30 billion in military research. For perspective, they estimate that the 2015 market was about 72% military, but that the civil market was growing rapidly.[88] Although it is difficult to find a direct comparison of the overall global aerospace industry, Research and Markets predict that "the global aerospace market is expected to grow to $352.5 billion by 2023."[89] So while the UAS industry certainly will not dominate the world aerospace market, it will be a significant component.

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[85]"Drones For Walking Dogs: Flying Robots Could Be Your Dog's Next Best Friend," *The Huffington Post UK*, 20 May 2014, last accessed 19 December 2015, http://www.huffingtonpost.co.uk/2014/05/20/dog-walking-drone_n_5358091.html.

[86]Lauren O'Neil, "'Goosebuster' drone keeps geese from pooping on Ottawa beach," *CBC News*, 30 April 2014, last accessed 19 December 2015, http://www.cbc.ca/newsblogs/yourcommunity/2014/04/goosebuster-drone-keeps-geese-from-pooping-on-ottawa-beach.html.

[87]Ryan Sager, "Watch These Beautiful Drones Dance With Cirque du Soleil," *Time*, 25 September 2014.

[88]Teal Group Corporation, "Press Release: UAV Production Will Total $93 Billion," 19 August 2015, last accessed 25 February 2016, http://www.tealgroup.com/index.php/teal-group-news-media/item/press-release-uav-production-will-total-93-billion.

[89]"Global Aerospace Market Trends and Forecast: 2014-2033," *PR Newswire*, 2 February 2015, last accessed 7 May 2016, http://www.prnewswire.com/news-releases/global-aerospace-market-trends-and-forecast-2014-2033-300029287.html.

The second estimate comes from the previously mentioned 2013 AUVSI report. They studied the economic impact in the U.S. of integrating civil UAS into the NAS. They estimated a total economic impact of over $13 billion in the first three years of integration, with a total impact of over $82 billion between 2015-2025. They further estimated that the UAS industry would create over 103,000 new jobs in the U.S. by 2025, many of which would be high paying. They also predicted almost half a billion dollars in tax revenue over the first 11 years of integration. It should be noted that their study appears to be motivated by a strong desire to push FAA regulatory changes, as evidenced by their warning that each year of integration delay would result in a loss of more than $10 billion.[90]

Estimates of the value of the UAS industry in Canada are less clear. The 2014 NRC report estimated an impact of between $100-260 million for procurement and operations over ten years.[91] The relatively smaller value could be due to the dominance of the U.S. in the military UAS sector. However, the Canadian civil UAS industry has enjoyed an advantage over the U.S. based on regulatory permissiveness, as evidenced by moves by companies like Amazon to develop their systems in Canada.[92] However, as will be discussed in Chapter 4, the FAA is now progressing with a much more robust integration plan. This puts the tenuous Canadian foothold in the industry at risk. As the chief operating officer of ING Robotic Aviation put it, "We're falling behind the world. The U.S. will pass us and what was a huge economic disadvantage will disappear."[93]

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[90]Darryl Jenkings and Bijan Vasigh, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States* . . ., 2.
[91]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014* . . ., 3.
[92]The Canadian Press, "Experts disagree on permissiveness of Canada's drone regulations," *Maclean's*, 16 August 2015.
[93]*Ibid.*

The sUAS industry clearly presents incredible potential, both in terms of its wide ranging applications and its economic benefits. This is important to keep in mind when considering possible threats and regulatory countermeasures. Canada's position is delicate, and public safety must be carefully balanced with allowing our industries to develop and thrive.

CHAPTER 3 - THE THREAT

Less than a decade ago, the conclusion of many scholars was that malicious use of UAS systems by non-state actors was unlikely.[94] The cost and technical expertise required to conduct a UAS attack simply did not give criminals, insurgents, or terrorists a clear advantage over other methods (with some exceptions). Several factors have changed that now warrant re-examining the possibility of a threat. First, very capable off-the-shelf sUAS, in particular, are now cheap to acquire. They are proliferated to the point that they are ubiquitous among the general public. Second, they are easy to control by untrained operators, thanks to miniaturization of their components and developments in autopilot technology. Third, they can be controlled remotely using widely available cellular data networks.[95]

This chapter will examine the evolution of the sUAS threat. It will go through chronological examples of six types of sUAS users: innocent users, ignorant users, activists, criminals, insurgents, and terrorists. All of these categories will show the growing capabilities of sUAS, while the latter categories will also show the growing intent of non-state actors to employ them offensively. It should be noted that this paper will only examine non-state actors. Nation states often possess much more advanced technology and are beyond the scope of this paper. It should also become clear that the incidents discussed are a fairly new phenomenon. There are very few examples prior to 2013, about the time that capable sUAS started to become cheap and widely available. To conclude, this chapter will review some of the military and academic literature available to understand how views of the threat have evolved. The aim of this chapter

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[94]Dennis 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.

[95]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), 11-12.

is to show that the advent of mass produced, low-cost, and easily piloted small UAS has resulted in an increased potential for malicious use of these systems, both against civilian targets at home and against Canadian interests abroad.

Defining Threats and Risks

Prior to delving into specific actors, it is important to establish a clear definition of threats and risks. A 2016 study of hostile UAS by the Remote Control Project (hosted by the Oxford Research Group and under the auspices of the civil society intelligence group Open Briefing) provides a clear, concise definition as shown in Figure 3.1. A threat is an actor possessing both capability and intent to attack. A risk is a function of a threat, a vulnerability, the likelihood of the threat attacking the vulnerability, and the potential impact of the attack.[96]

Threat = Capability x Intent
Risk = Likelihood (Threat + Vulnerability) x Impact

Figure 3.1 - Threat and Risk

Source: Abbot *et al, Hostile drones: Supplementary risk assessment,* 7.

Innocent Users

There are many sUAS users who pose no threat as they have no intent to cause any harm. They follow all regulations and are safe operators. However, it is useful to examine some of these users as they demonstrate the potential capabilities that a malicious actor could harness.

One of the first examples of such a user is New Zealand engineer Bruce Simpson. In 2003 he started a project to build a homemade cruise missile in his garage for less than $5,000, much of which he documented online (Figure 3.2). Simpson was careful not to provide enough information for his plan to be copied. His stated goal was “not to provide terrorists or other

[96]C. Abbott *et al*. *Hostile Drones: Supplementary Risk Assessment* (London: Oxford Research Group, 2016), 7.

nefarious types with the plans for a working cruise missile but to prove the point that nations need to be prepared for this type of sophisticated attack from within their own borders." Simpson came under pressure from the New Zealand government to halt his efforts, although it is unclear whether they were successful. His website, last updated in 2004, states that he completed the first missile, had it taken to a location that even he did not know, and was well on his way to completing a second missile.[97] Simpson is an example of a user who had no intent of causing damage, but demonstrated what capabilities existed. An important point however, is that in 2003, a fair amount of technical expertise was required to construct an airborne weapon. It would have been much easier for law enforcement to track known experts or critical components of a potential missile.

Figure 3.2 - Bruce Simpson with one of his homemade cruise missiles

Source: Simpson, "Cruise Missile Construction Diary"

Today, not only are off-the-shelf sUAS very capable, but there exist vast resources to help hobbyists to modify them or build their own sUAS. DIY Drones is a massive online community started by the former editor of *Wired* magazine. Their website contains extensive forums, guides, and software for building and modifying UAS.[98] His related company 3D

[97]Bruce Simpson, "A DIY Cruise Missile: Watch me build one for under $5,000," last accessed 31 January 2016, http://www.interestingprojects.com/cruisemissile/.
[98]DIY Drones, "DIY Drones," last accessed 25 March 2016, http://diydrones.com/.

Robotics sells UAS and components.[99] Canada Drones is a similar company based in Toronto, and there are many others worldwide.[100] U.S. based Game of Drones sells hardened components specifically tailored to the robot fighting community. One of their products is the Hiro Action-Sports airframe, which they advertise as an "indestructible airframe," available for less than $100 (Figure 3.3).[101] According to their website,

> We have stomped on it, thrown it into walls and through windows, dropped it from hundreds of feet, flown through fire, landed on water and crashed literally hundreds of times. And we also shot it several times at close range with a 12 gauge shotgun loaded with heavy dove ammo, and the airframe was little more than scuffed and was up and flying within 5 minutes with a new motor and fresh zip-ties.[102]

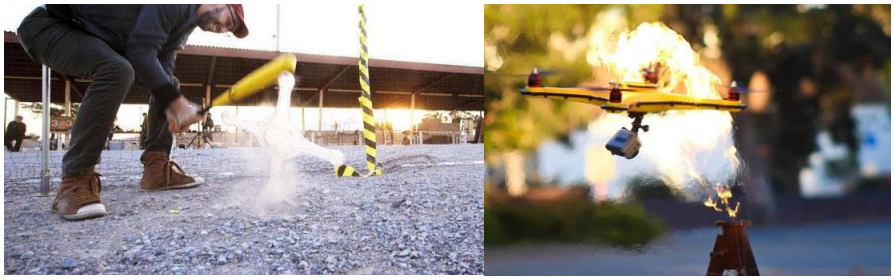

Figure 3.3 – Hiro sUAS "indestructible airframe"

Source: Game of Drones, http://www.gameofdrones.com/

Other hobbyist resources are specifically tailored to releasing toy weapons from sUAS. For example, the Qanum RTR Bomb System sells for about $10 (Figure 3.4). It can be mounted

[99]3D Robotics, "3DR | Shop Drone & UAV Technology – 3DR," last accessed 25 March 2016, https://store.3dr.com/.
[100]Canada Drones, "Canada Drones, Your Canadian source for UAV gear," last accessed 25 March 2015, http://www.canadadrones.com/.
[101]Game of Drones. "FAQs – Game of Drones." Last accessed 22 December 2015, http://www.gameofdrones.com/faqs/.
[102]*Ibid.*

on any model aircraft and allows remote release of a hollow projectile which can be filled with a small payload.[103]

Figure 3.4 - Qanum RTR Bomb System

Source: VanHemert, "Remote Control Bomb System Tests Your Powers of Restraint," *Gizmodo.*

The Burrito Bomber previously discussed uses this system with some modifications.[104] The software, which generates a GPS waypoint and automatically flies the Burrito Bomber to its target and releases the payload, is publically shared on the internet by its creators.[105]

There have been several other examples of weapons being mounted to sUAS. In May 2015, three Canadian men mounted two Roman candle fireworks to an off-the-shelf sUAS and chased each other around (Figure 3.5). While they had no intention of hurting anyone else, their

[103]Hobby King, "Quanum RTR Bomb System 1/6 scale Plug-n-Drop," last accessed 27 December 2015, http://www.hobbyking.com/hobbyking/store/uh_viewitem.asp?idproduct=10624&aff=800324.
[104]Darwin Aerospace, "Burrito Bomber: The world's first airborne Mexican food delivery system," last accessed 27 December 2015, http://www.darwinaerospace.com/burritobomber.
[105]*Ibid.*

YouTube video did prompt a TC investigation.[106] Incidentally, in the video they appear to score at least one direct hit.[107]

Figure 3.5 - Canadian men chase each other with a Roman candle equipped sUAS

Source: Feibel, "Transport Canada investigates viral Ottawa 'drone attack' video," *Ottawa Citizen.*

Two months later, in July 2015, U.S. teenager Austin Haughwout implemented a similar but much more serious idea. He mounted and fired a handgun from a quadcopter as part of a university project (Figure 3.6). His YouTube video sparked some controversy, particularly since the FAA later determined that he had broken no laws. As a police officer in his Connecticut town put it, "It appears to be a case of technology surpassing current legislation."[108]

[106]Adam Feibel, "Transport Canada investigates viral Ottawa 'drone attack' video," *Ottawa Citizen*, 21 May 2015, last accessed 31 January 2016, http://ottawacitizen.com/news/local-news/transport-canada-investigates-viral-ottawa-drone-attack-video.
[107]*Ibid.*
[108]Michael Martinez, "Handgun-firing drone appears legal in video, but FAA, police probe further," *CNN*, 21 July 2015, last accessed 30 September 2015, http://www.cnn.com/2015/07/21/us/gun-drone-connecticut/.

Figure 3.6 - Handgun being fired from a quadcopter

Source: Martinez, "Handgun-firing drone appears legal in video, but FAA, police probe further," *CNN*.

The same youth re-ignited the controversy in December 2015 with another weaponized sUAS. This latest model was a flame throwing octocopter, which he used to mockingly roast a turkey (Figure 3.7).[109]

[109]Yoni Heisler, "Drone with attached flamethrower roasts a turkey in this crazy video," *BGR*, 9 December 2015.

Figure 3.7 - Austin Haughwout's second weaponized sUAS

Source: Heisler, "Drone with attached flamethrower roasts a turkey in this crazy video," *BGR*, 9 December 2015.

In fact, complete sUAS with mounted weapons are even being sold directly. The South African company Desert Wolf sells a sUAS called the Skunk Riot Control Copter (Figure 3.8). The controversial octocopter carries pepper spray and 4,000 paintballs or other non-lethal ammunition, which it fires from 4 barrels at up to 20 round per second each, for a total rate of fire of 80 projectiles per second. It also includes speakers, strobe lights, and a bright eye-safe laser to temporarily blind targets.[110] The company claims it offers a preferable option to riot police carrying lethal munitions, citing a 2012 incident in Marikana, South Africa where police shot and killed 34 striking miners. In 2014 they sold 25 vehicles to an unnamed international mining company and claimed to have interest from others.[111]

[110]Desert Wolf, "Desert Wolf – Skunk Riot Control Copter," last accessed 2 February 2016, http://www.desert-wolf.com/dw/products/unmanned-aerial-systems/skunk-riot-control-copter.html.
[111]C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* (London: Oxford Research Group, 2016), 13.

Figure 3.8 - The Skunk Riot Control Copter

Source: Desert Wolf, "Desert Wolf – Skunk Riot Control Copter."

These examples illustrate just how far the capability available to lay users has evolved since Bruce Simpson starting building his cruise missile in 2003. The resources to build, modify, or buy sUAS with hardened components, weapon systems, and the necessary software, while not necessarily legal around the world, are now readily available to motivated users.

Ignorant Users

The next category of sUAS users is those who bear no ill intentions, but nevertheless manage to cause harm or create danger to the public. It is important to study these users, as they not only demonstrate capabilities that malicious users could exploit, but they can also cause significant damage themselves. Todd Humphreys, professor at the University of Texas at Austin, is a UAS expert and was called to testify before Congress on sUAS threats in March 2015. He put it succinctly:

> The great majority of . . . incidents will be accidental, such as the flyaway UAV that crashed on the White House grounds in January. But in the early stages of a

> UAV incursion, it will be impossible to distinguish the accidental from the intentional, the benign from the malicious.[112]

There have been three principle types of such incidents: flying sUAS near restricted areas or people, crashing sUAS by accident, and causing near-misses with manned aircraft.

For the first type, there have been several examples over the last few years of sUAS being flown over sports stadiums without permission, often causing serious concern to law enforcement. For example, a sUAV had police scrambling in August 2014 when it overflew the 93,000 spectators at the University of Texas Longhorns football season opener.[113] A similar incident occurred at a Carolina Panthers football game the same month.[114] sUAVs have been flown over several Major League Baseball games, prompting the league to seek out radar systems to detect them.[115] A soccer game between Serbia and Albania turned into a riot when a sUAV carrying an Albanian flag was flown over the crowd in Belgrade.[116] These incidents have also included sUAVs flying near important people. In August 2015, the FAA revealed that an

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[112]House of Representatives, Committee on Homeland Security, Subcommittee on Oversight and Management Efficiency, *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 2.

[113]"Police Detain UT Student For Flying Drone Over Longhorns, UNT Game," *CBS*, 1 September 2014, last accessed 20 December 2015, http://dfw.cbslocal.com/2014/09/01/police-arrest-ut-student-for-flying-drone-over-longhorns-unt-game/.

[114]Mark Washburn, "Drone buzzes Panthers-Chiefs game and police pounce," *The Charlotte Observer*, 26 August 2014, last accessed 25 March 2016, http://www.charlotteobserver.com/news/local/article9156713.html.

[115]Michael Schmidt and Michael Shear, "Drones Spotted, but Not Halted, Raise Concerns," *The New York Times*, 29 January 2015, last accessed 26 December 2015, http://www.nytimes.com/2015/01/30/us/for-super-bowl-and-big-games-drone-flyovers-are-rising-concern.html?_r=1.

[116]Corey 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.

unauthorized sUAV had flown near President Obama while he was playing golf, the third such incident that year.[117]

The second type of unsafe sUAS incidents are accidental crashes. These have at times been quite serious, and have been reported with increasing frequency. In 2003 a fourteen year old girl was killed when a model airplane went out of control and struck her in the head.[118] In 2006, a Belgian UAV supporting UN operations in Congo crashed in Kinshasa, killing one civilian and injuring two others.[119] An octocopter crashed into a crowd at a bull running event in Virginia in August 2013, injuring several spectators.[120] In September 2013 a man was decapitated when he lost control of his large remote control helicopter.[121] An athlete was injured during an Australian triathlon in April 2014 when a sUAV hit her head.[122] A baby was injured when a quadcopter crashed in Pasadena, California in September 2015.[123] These incidents have become so frequent that one Florida lawyer has set up a website specifically soliciting clients who have been injured by drones.[124]

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[117]Kellan 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/.

[118]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): 9; David Sapsted, "Girl, 14, killed by model plane after near-misses," *The Telegraph*, 18 November 2003, last accessed 7 May 2016, http://www.telegraph.co.uk/news/uknews/1447013/Girl-14-killed-by-model-plane-after-near-misses.html.

[119]Eddy Isango, "Drone Crash in Congo Kills 1, Injures 2," *The Washington Post*, 3 October 2006, last accessed 7 May 2016, http://www.washingtonpost.com/wp-dyn/content/article/2006/10/03/AR2006100300778.html.

[120]Martin Well, "Drone crashes into Virginia bull run crowd," *The Washington Post*, 26 August 2013, last accessed 25 March 2016, https://www.washingtonpost.com/local/drone-crashes-into-virginia-bull-run-crowd/2013/08/26/424e0b9e-0e00-11e3-85b6-d27422650fd5_story.html.

[121]Kirstan Conley, "Toy helicopter slices off top of man's head," *New York Post*, 5 September 2013, last accessed 25 March 2016, http://nypost.com/2013/09/05/man-decapitated-by-remote-controlled-toy-helicopter/.

[122]"Australian triathlete injured after drone crash," *BBC News*, 7 April 2014, last accessed 25 March 2016, http://www.bbc.co.uk/news/technology-26921504.

[123]Daniel Victor, "F.A.A. Opens Inquiry After Baby Hurt in Drone Crash," *The New York Times*, 23 September 2015, last accessed 25 March 2016, http://www.nytimes.com/2015/09/23/business/drone-crash-injures-baby-highlighting-faa-concerns.html?_r=0.

[124]DroneInjuriesLawyer.com, "Drone Injuries Lawyer Blog," last accessed 25 March 2016, http://www.droneinjurieslawyer.com/.

There have been a host of other high profile crashes recently, although in these cases no one was injured. In September 2013 a quadcopter crashed into a New York building, almost hitting a pedestrian when it came down.[125] In June 2014 a sUAV crashed into a downtown Vancouver building.[126] A sUAV crashed into Yellowstone's pristine Grand Prismatic Spring in August 2014, despite a U.S. National Parks Service nationwide ban on UAS.[127] In September 2015 a sUAV crashed in an empty section of the stands at the U.S. Open tennis tournament.[128] The next month, a second sUAV went down near the White House.[129]

Of perhaps more concern than any of the above incidents has been the dramatic rise in near mid-air collisions between sUAVs and manned aircraft. The FAA processed 1,133 UAS incident reports in 2015, up from only 238 the year prior.[130] These incidents 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."[131] The situation has been similar in Canada, with TC conducting over 50 investigations since 2010 into "reckless and negligent" UAS use.[132] These included incidents such as sUAVs interfering with landings at Vancouver and Toronto international

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[125]Zeke Miller, "What You Need To Know About Flying Drones In Washington, DC," *Time*, 6 May 2014.
[126]Jason Proctor and Bal Brach, "Drone crash prompts Vancouver to review film industry use," 11 June 2014, last accessed 8 December 2015, http://www.cbc.ca/news/canada/british-columbia/drone-crash-prompts-vancouver-to-review-film-industry-use-1.2671977.
[127]Kelsey Atherton, "Can Birds Be Trained To Bring Down Drones?" *Popular Science*, 5 December 2014.
[128]Barb Darrow, "Drone crash lands at U.S. Open," *Fortune*, 4 September 2015.
[129]Kristen Holmes, "Man detained outside White House for trying to fly drone," *CNN*, 15 May 2015, last accessed 25 March 2016, http://www.cnn.com/2015/05/14/politics/white-house-drone-arrest/.
[130]Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule . . .*, 78597.
[131]*Ibid.*
[132]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles . . .*, 3.

airports, despite TC regulations prohibiting operations within 9 km of an airport.[133] They also included interfering with wildfire fighting efforts in B.C., grounding aircraft for hours until the operators could be located.[134] Similar incidents have been occurring in Europe as well. In 2015 six aircraft in the UK narrowly missed "catastrophic collisions," including two Airbus A320 aircraft who both missed sUAVs by less than 50 feet while landing at London's Heathrow airport.[135] On April 17, 2016, an sUAV actually struck a British Airways Airbus A320 on approach to Heathrow, although the aircraft landed safely.[136]

While discussing malicious use of sUAS, one British study opined that "by virtue of either their kinetic energy alone or their ability to function as mechanical bird strikes, drones pose a significant threat to commercial airliners."[137] Fears of such an attack prompted the U.S. Department of Homeland Security to issue a warning in August 2015 after three sUAVs were sighted within three days at John F. Kennedy International Airport in New York.[138]

In fact, collisions with sUAVs could be significantly worse than most bird strikes. As Canadian aviation lawyer Lee Mauro points out, aircraft "are not tested for a 75 pound carbon

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[133]Lorenda Reddekopp and Genevieve Tomney, "Drones creating hazards over airports," *CBC News*, 14 August 2014, last accessed 8 December 2015, http://www.cbc.ca/news/canada/toronto/drones-creating-hazards-over-airports-1.2736878.

[134]Farrah Merali, "Drone operators blast 'irresponsible and selfish' flight that grounded firefighters," *CBC News*, 18 August 2015, last accessed 19 December 2015, http://www.cbc.ca/news/canada/british-columbia/drone-operators-blast-irresponsible-and-selfish-flight-that-grounded-firefighters-1.3193540; Stephanie Mercier, "B.C. fires: West Kelowna firefighters' efforts interfered with by drones," *CBC News*, 1 August 2015, last accessed 19 December 2015, http://www.cbc.ca/news/canada/british-columbia/b-c-fires-west-kelowna-firefighters-efforts-interfered-with-by-drones-1.3177010.

[135]Corey 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.

[136]"'Drone' hits British Airways plane approaching Heathrow Airport," *BBC News*, 17 April 2016, last accessed 7 May 2016, http://www.bbc.co.uk/news/uk-36067591.

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

[138]Kellan Howell, "Drones over JFK airport prompts federal terror alert," *Washing Times*, 4 August 2015. Last accessed 6 December 2015, http://www.washingtontimes.com/news/2015/aug/4/terrorist-alert-issued-following-third-drone-sight/.

fibre drone flying into the engine or the windscreen."[139] This is a slight exaggeration, as the maximum size of a sUAV (without SFOC) in Canada and the U.S. is 55 pounds.[140] There do not appear to be any comprehensive studies on the effects of UAS impacts on manned aircraft, but some rough estimates have been made. Lacher and Maroney looked at the kinetic energy required to kill a person on the ground in a direct collision, and concluded that sUAVs less than 1.5 pounds would pose no risk.[141] The same methodology was used by the FAA's UAS Registration Task Force, who recommended that the FAA not require registration of sUAVs less than 0.55 pounds.[142] Again, their primary concern was a sUAV crashing and injuring a person on the ground. For risk to aircraft, it is reasonable to compare sUAV size to birds. U.S. Airways Flight 1549, which crash landed in the Hudson River in January 2009, struck a flock of Canada geese.[143] The average weight of an adult Canada goose is between 5.8 to 10.7 pounds.[144] Assuming that the solid parts of a sUAV would do at least as much damage as the body of a goose (acknowledging that no studies have shown this to be the case), it is therefore reasonable to assume that many sUAVs up to the 55 pound limit could do significant damage to an aircraft, particularly if it were to impact a vulnerable component like an engine.

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[139]"Drone seen flying in path of landing planes at Vancouver airport," *CBC News*, 1 July 2014, last accessed 8 December 2015, http://www.cbc.ca/news/canada/british-columbia/drone-seen-flying-in-path-of-landing-planes-at-vancouver-airport-1.2693601.

[140]Transport Canada, *Advisory Circular 600-004: Guidance Material for Operating Unmanned Air Vehicle Systems under an Exemption* (Ottawa: Transport Canada, 27 November 2014).

[141]Andrew Lacher and David Maroney, *A New Paradigm for Small UAS* (The MITRE Corporation, 2012), 12.

[142]Federal Aviation Administration, "Unmanned Aircraft Systems Registration Task Force Aviation Rulemaking Committee: Task Force Recommendations Final Report," 21 November 2015, 6-10.

[143]"Canada geese brought Flight1549 down, NTSB says," *CNN*, 12 February 2009, last accessed 25 March 2016, http://www.cnn.com/2009/US/02/12/hudson.plane.geese/.

[144]*Ibid.*

There is also a growing concern of sUAVs colliding with each other, causing harm when they crash.[145] The possibility seems legitimate, particular over urban areas with the growing numbers of recreational sUAS and multitude of plans for sUAS delivery services.

Users who crash their sUAVs into people, buildings, and manned aircraft do not meet the definition of a threat since they harbour no ill-intent. However, they can cause significant harm and certainly serve to illustrate what more sinister operators could do.

Activists

Activists, much like the last two categories of sUAS operators, do not usually intend to cause harm, but use sUAS to attract attention to political issues. They primarily serve to illustrate potential threats and vulnerabilities, although they are not necessarily well-intentioned. Bruce Simpson, the New Zealand cruise missile builder, could also fall in this category. There have been three high profile incidents of activists using sUAS, all since 2013.

The first incident occurred in September 2013. A member of the German Pirate Party, protesting government surveillance and UAS programs, flew a quadcopter sUAS a few feet from German Chancellor Angela Merkel and Defense Minister Thomas de Maizere during a campaign rally (Figure 3.9). The sUAV was unarmed and crashed shortly after appearing. The sUAS operator was briefly held by police then released.[146]

[145]National 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.
[146]Sean Gallagher, "German chancellor's drone "attack" shows the threat of weaponized UAVs," *ARS Technica*, 18 September 2013.

Figure 3.9 – A Parrot AR sUAV operated by the German Pirate Party hovers in front of Chancellor Merkel

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

The next string of incidents occurred in France over the fall of 2014 and spring of 2015. Between October and November 2014, sUAS were spotted flying over 13 French nuclear power stations. The flights were mostly at night, and on one evening five incursions occurred within six hours around the country. Of developed nations, France is the most dependent on nuclear power and flight with 5 km of nuclear stations is strictly forbidden. Three people were arrested as they were about to launch a sUAS near one station in November 2014, but authorities believe they were copycats of the original perpetrators. The masterminds were never caught. It is widely speculated that they were anti-nuclear protestors, although French authorities did not rule out the possibility that the flights were reconnaissance or rehearsals for a more nefarious purpose. After

the first ten incidents, France dispatched special teams to the nuclear stations with authority to shoot down any intruding sUAVs. They were unable to stop a further three incursions.[147]

Similar incidents continued in France over the months that followed. According to Bernard Cazeneuve, the French interior minister, 60 sUAS incursions occurred of various restricted airspaces between October 2014 and March 2015. In total there were overflights of 17 nuclear stations, a nuclear submarine base, the Elysée Palace, the Eiffel Tower, and the U.S. embassy in Paris. On one night in March, there were ten sUAV sighting around Paris including over the offices of Charlie Hebdo magazine, which had been attacked in January. The motives of the incursions are unknown.[148]

The third example occurred in Japan in April 2015. Yasuo Yamamoto, an anti-nuclear energy protester, landed a sUAV on the roof of the Japanese prime minister's office. Prime Minister Shinzo Abe was not there, but Yamamoto had the sUAV loaded with an ominous payload – a small package of radioactive caesium. The package did not contain enough material to be harmful and Yamamoto turned himself in to police.[149]

These examples serve to illustrate the accessibility of restricted sites to sUAS. As will be discussed in Chapter 5, most current defences of sensitive sites are optimized for threats on the ground or larger threats from the air. sUAS present unique challenges in terms of detection and engagement.

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[147]John 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.

[148]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.

[149]"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.

Criminals

A wide range of criminals have taken advantage of the advent of sUAS. Their motives range from smuggling to murder. For the purposes of this paper, they are distinguished from insurgents and terrorists in that they have no intent to do indiscriminate physical harm. These are also clearly uses of sUAS that the Government of Canada (GoC) has a duty to prevent.

An increasingly common criminal use of sUAS is to smuggle contraband into prisons. Some examples include smuggling drugs into a U.K. prison in 2009, cell phones into a Brazilian prison in 2012, drugs into a Hull, Quebec prison in 2013, tobacco into a Georgia prison in 2013, and drugs into an Australian prison in 2014.[150] Again these examples illustrate the ability of sUAS to penetrate restricted airspace.

Since at least 2010, or earlier, Mexican drug cartels have been using sUAS to smuggle drugs across the U.S. border. The U.S. Drug Enforcement Agency (DEA) intercepted about 150 sUAVs between 2012 and 2014, each carrying an average of 13 kilograms of cocaine and other drugs for a total of about two tons. These cartels are also developing custom made UAS capable of carrying larger payloads.[151]

The most sinister example of the criminal use of sUAS was an assassination plot which was broken up in Germany in September 2013, less than a week before the incident with Chancellor Merkel. The suspects were right-wing extremists, and their plan was to use explosives mounted on sUAVs to murder political opponents.[152]

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[150]Marc 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.
[151]Camilo Giraldo, "Mexico's Cartels Building Custom-Made Narco Drones: DEA," *Insight Crime*, 11 July 2014.
[152]"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.

Insurgents

There is a long history of insurgents, particularly in the Middle East, using UAS. This often involved support from an actual or presumed nation state, as in the case of Hamas and Hezbollah. Increasingly, evidence is growing of insurgents using off-the-shelf sUAS. They typically use them for intelligence, surveillance, and reconnaissance (ISR) or for attack as flying improvised explosive devices (IEDs).

One of the earliest examples of insurgents attempting to exploit sUAS was discovered in August 2002. A Columbian raid on a Revolutionary Armed Forces of Columbia (FARC) camp found nine remote controlled airplanes, although their intended use remains unclear.[153]

Hamas and Hezbollah have been using UAS since at least 2004 with the support of Iran. Hezbollah made incursions into Israeli airspace in 2004 and 2005 using Iranian built UAS. During the 2006 Lebanon war, Hezbollah sent multiple UAS against Israeli forces, some of which were laden with explosives. In July 2006 they managed to hit an Israeli warship, setting it on fire and leaving four sailors missing. Israel managed to shoot down at least one UAS carrying about 30kg of explosives. Israel announced in 2010 that both Hamas and Hezbollah were in possession of UAS capable of flying over 300km, and in 2012 claimed to have destroyed a Hamas UAS development facility. In 2013 Israel intercepted a Hezbollah UAS 140 miles inside Israeli airspace near the Dimona nuclear plant. Later that year, Palestinian security forces captured Hamas members who were about to fly armed UAS into Israel.[154]

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[153]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; C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets . . .*, 12.

[154]Gettinger, 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.

Figure 3.10 - A purportedly armed Hamas UAS

Source: Gettinger and Michel, "A Brief History of Hamas and Hezbollah's Drones," 14 July 2014.

In September 2014, Hezbollah launched its most advanced UAS attack to date against Syrian rebels. They claim the attack killed 23 fighters and was followed by a ground offensive.[155]

UAS are being used by both sides in the conflict in eastern Ukraine. Donetsk People's Republic militias are reported to have advanced Russian built UAS, while Ukrainian forces have been using modified off-the-shelf sUAS.[156] Ukrainian forces, apparently poorly funded, have been crowd funding online to procure the equipment.[157]

The most recent insurgent group to use off-the-shelf sUAS is the Islamic State of Iraq and the Levant (ISIL). In August 2014 they published a video online from a DJI Phantom quadcopter conducting reconnaissance of the Tabqa airfield in northern Syria. ISIL later seized the airfield.

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[155]Adiv Sterman, "Hezbollah drones wreak havoc on Syrian rebel bases," *The Times of Israel*, 21 September 2014, last accessed 25 March 2016, http://www.timesofisrael.com/hezbollah-drones-wreak-havoc-on-syrian-rebel-bases/.
[156]Patrick Tucker, "In Ukraine, Tomorrow's Drone War Is Alive Today," *Defense One*, 9 March 2015.
[157]People's Project, "First People's Drones – People's Project.com," last accessed 24 December 2015, http://www.peoplesproject.com/en/bpla/.

Sightings of ISIL sUAVs were reported in Fallujah, Iraq and prior to an attack on the Baiji oil refinery complex in Iraq.[158] In December 2015 Kurdish fighters shot down an explosive-laden sUAV that ISIL was trying to use as a flying IED (Figure 3.11).[159]

Figure 3.11 - A downed sUAS reportedly rigged with explosives by ISIL

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

These recent examples show that not only are sUAS becoming more capable, but that malicious actors are increasingly intent on using them for harm.

Terrorists

Ten days prior to the first quadcopter crashing on the White House lawn, the DHS held a summit a few miles away to discuss "the potential use of hobbyist drones as weapons of terror or assassination."[160] They discussed many of the examples already covered here, but also put on display a variety of off-the-shelf sUAS they had rigged as simulated flying IEDs. The example

[158]Brian Barrett, "When Good Drones Go Bad," *Wired,* 18 January 2016.
[159]David Hambling, "ISIS Is Reportedly Packing Drones With Explosives Now," *Popular Mechanics,* 16 December 2015.
[160]Kevin Poulsen, "Why The US Government Is Terrified Of Hobbyist Drones," *Wired,* 5 February 2015

shown in Figure 3.12 is a similar model to the one that crashed by the White House.[161] This last type of sUAS user is the principle purpose of this paper, as they potentially possess the capability and intent to do harm to Canada. There have been several documented examples of terrorist attempts to conduct sUAS attacks, but none have been successful to date.

Figure 3.12 - A DJI Phantom 2 rigged with a mock explosive payload

Source: Poulsen, "Why the U.S. Government is Terrified of Hobbyist Drones," *Wired*, 5 February 2015.

Prior to sUAS being widely available, several terrorist groups considered UAS attacks. The Japanese group Aum Shinrikyo, who carried out the sarin gas attack in Tokyo in 1995, considered using UAS for their attack.[162] Osama Bin Laden considered using sUAS to assassinate U.S. President George W. Bush and other heads of state at the G-8 Summit in 2001.[163] However, in these cases it appears that the technical complexity of such attacks, at the time, led these groups to discard the idea.

[161]*Ibid.*
[162]Eugene Miasnikov, *Threat of Terrorism Using Unmanned Aerial Vehicles: Technical Aspects . . .*, 25.
[163]*Ibid.*

Christopher Paul, a resident of Worthington, Ohio, pled guilty in 2008 to plotting terrorist attacks. The al-Qaeda affiliate intended to load explosives on remote controlled boats and a remote controlled helicopter and attack targets in the U.S. and Europe.[164]

The first credible terrorist attempt to use actual UAS for an attack by an American citizen was in 2011. Rezwan Ferdaus planned to launch three remote controlled airplanes, modified to use automatic GPS navigation and loaded with C-4 explosives, to hit the Pentagon and the Capitol building. He planned to follow the initial attack with a ground assault. His plot was foiled by the Federal Bureau of Investigation (FBI).[165]

The next noteworthy plot was in Spain in 2012. Three al-Qaeda members planned to attack a shopping mall and a joint US-Spanish naval base near Gibraltar. Based on evidence collected at one of their residences, officials believe their plan was to fly explosive-laden remote control aircraft as part of the attack.[166]

Another terrorist attack using sUAS was broken up in Germany in June 2013, only a few months before the incident with Chancellor Merkel. Several Islamist extremists were arrested after it was discovered that they planned to use sUAS to conduct an attack in Europe.[167]

The latest confirmed plot to use explosive-laden sUAVs was broken up by the FBI in April 2014. El Mehdi Semladi Fahti, a Moroccan national living in the U.S. illegally after his

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[164]Paul Cruickshank and Tim Lister, "Analysis: Model planes as weapons of terror," *CNN*, 29 September 2011, last accessed 25 March 2016, http://www.cnn.com/2011/09/29/opinion/model-plane-attack/.

[165]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.

[166]Soeren Kern, "Al Qaeda in Spain," *Gatestone Institute*, 15 August 2012.

[167]Jeevan 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.

visa had expired, planned to use a modified sUAS to fly explosives into a school in Boston and a federal building in Hartford.[168]

Since that time, there have been several warnings issued by various governments of imminent attacks. In March 2014, the RCMP issued a warning that "critical Canadian facilities" were vulnerable to terrorist attacks using sUAS. They cited "at least 13 cases between 1995 and 2013" of terrorist plans to conduct attacks using remote controlled aircraft. These included loading them with explosives and dispersing chemical or biological agents.[169] In July 2014, British counter-terrorism officials asked members of the British Model Flying Association to be on the lookout for suspicious behaviour.[170] Three months later, the New York Police department announced they were concerned about a terrorist sUAS attack.[171] U.K. officials revealed in July 2015 that they were concerned about ISIL launching a terrorist attack using sUAS. One advisor to the British Cabinet said: "There is a genuine threat from Islamists wishing to deliver high explosives by drone to crowded areas. The effects could be devastating."[172] An anonymous counter-terrorism source told the British *Mirror* that ISIL "is obsessed with re-creating the horror of 9-11 and believes this may be possible by launching a multi-drone attack on large numbers of

[168]Michael Mayko, "FBI: Drone-like toy planes in bomb plot," *CT Post*, 7 April 2014, last accessed 26 March 2016, http://www.ctpost.com/local/article/FBI-Drone-like-toy-planes-in-bomb-plot-5383658.php.
[169]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.
[170]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.
[171]"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/.
[172]Chris 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.

people in a synchronised attack."[173] Most recently, the U.S. DHS sent a warning to law enforcement agencies in August 2015 to watch for signs of a terrorist sUAS attack.[174]

Perception of the Threat

At this point it is worth reviewing experts' views on the sUAS threat, particularly in terms of terrorism. There has not been unanimous agreement that sUAS present a real threat, although views have increasingly shifted in this direction. Many of these experts propose concepts for defensive measures, which will discussed later in Chapter 5.

One of the first studies to examine the possibility of a terrorist UAS attack was published by Dennis Gormley of the Center for Nonproliferation Studies at the Monterey Institute of International Studies in 2003. Prompted in part by Bruce Simpson's homemade cruise missile, he assessed the possibility of a terrorist using a cruise missile or UAS. In doing so, he examined both the capability and motivation required at the time. He examined two scenarios in detail: first, a terrorist organization converting an anti-ship cruise missile, and second, converting a small airplane to be flown automatically. He determined that both options were possible, but unlikely based on the technical skills and testing required. Further, both options would have required several years to develop, leaving potential terrorists vulnerable to discovery. At the time, the major challenge was implementing an automatic flight management system.[175]

The next significant study on the subject was published in 2005 by Eugene Miasnikov of the Center for Arms Control, Energy and Environmental Studies at the Moscow Institute of Physics and Technology. His study, conducted again while commercial UAS technology was

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[173]*Ibid.*
[174]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/.
[175]Dennis Gormley, "UAVs and Cruise Missiles as Possible Terrorist Weapons," in *New Challenges in Missile Proliferation, Missile Defense, and Space Security . . .*, 3-8.

nascent, focussed on the threat of terrorists using UAS against Russia. He first examined possible terrorist uses of UAS, including delivering weapons of mass destruction (WMD). He concluded that this was possible, and that even conventional explosives could be very effective.[176] In particular he discussed the increased effects of fragmentation explosives in large crowds. He pointed out that in a 2003 incident in Moscow, such a device was detonated at ground level, but much of the crowd was shielded by the victims closest to the bomb. This would not be the case if the weapon were to be used at a modest height.[177] He then laid out a wide range of reasons that UAS would appeal to terrorists including access to difficult targets, covertness, cost effectiveness, accuracy, and psychological effect.[178] Miasnikov went on to argue that terrorists would prioritize simplicity and visibility over effectiveness, and in this sense were more likely to use small UAS vice larger ones with better payloads.[179] He discussed several types of UAS, including military, civilian, private airplanes converted to UAS, and homemade or commercial model airplanes, as well as possible methods of control and payload delivery. Lastly, he discussed issues with defending against an sUAS threat. He concluded that homemade sUAS posed the greatest potential threat, and that terrorist use of sUAS was plausible.[180]

In 2008 Jackson, Frelinger, Lostumbo, and Button published another study for the Defence Threat Reduction Agency at the RAND corporation's National Defence Research Institute. The focus of their study was the threat posed by UAS and cruise missiles to U.S. homeland. Their aim was to "bound the problem" by examining the likelihood of terrorists

[176]Eugene Miasnikov, *Threat of Terrorism Using Unmanned Aerial Vehicles: Technical Aspects . . .*, 23.
[177]*Ibid.*, 8.
[178]*Ibid.*, 4.
[179]*Ibid.*, 9.
[180]*Ibid.*, 23.

choosing one of these forms of attack, in order to help determine where to invest finite homeland defence resources.[181] They described the challenge:

> Assessing how such weapons could be used in attacks in the United States is also difficult, because there is also an almost infinite number of targets within the homeland that are vulnerable from the air and therefore represent possible sites to attack. For such a challenge as thinking about how to respond to the potential use of these weapons or the design of defensive approaches, an unbounded problem becomes intractable: The resource requirements of protecting everything quickly become staggering. This challenge is further complicated because such weapons represent only one from a variety of attack options an adversary could choose to use. Before the country invests in a wide array of cruise-missile or other air-defense assets for the nation, the problem needs to be bounded so that scarce resources can be focused productively.[182]

To perform their assessment, Jackson *et al* looked at the problem from the terrorist point of view, and assessed their alternative methods of attack. They determined that UAS attacks were advantageous for five scenarios:

1. attack over perimeter defenses
2. attack over national borders
3. carry out multiple simultaneous attacks
4. conduct an attack campaign (a series of attacks over time)
5. attack area targets with unconventional weapons.[183]

Their conclusion, however, was that UAS attacks "do not appear to have major advantages over other ways of carrying out operations against similar targets, although they cannot be dismissed outright as a potential threat."[184] They point out that "greater complexity, technological uncertainty, and higher costs and risks" made it more of a "niche threat," with simpler options available in most cases.[185]

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[181]B.A. Jackson *et al*, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles . . .*, iii.
[182]*Ibid.*, iv.
[183]*Ibid.*, xv.
[184]*Ibid.*, xv-xvi.
[185]*Ibid.*, 58.

The following year, Lele and Mishra published a study of UAS terrorism in the Journal of Defence Studies. Lele was at the Institute for Defence Studies and Analyses, New Delhi, while Mishra was at Jawarharlal Nehru University, New Delhi. Their study concentrated on the threat to India. They examined evidence of terrorist attempts to employ UAS between 1995 and 2004 as well as other forms of aerial terrorism between 2000 and 2008. They concluded that UAS pose a plausible threat but that a more in depth risk assessment was needed.[186]

In 2011 Major Gaub, U.S. Army, published a monograph on the subject of UAS threats from the School of Advanced Military Studies at the United States Army Command and General Staff College. He argued that there was an increasing threat from both state and non-state actors using UAS against deployed U.S. military forces. He pointed out the threat posed by states such as Iran and Russia as well as other actors such as Hezbollah.[187] In particular he noted that during Operation Iraqi Freedom that "Patriot batteries were unable to intercept low-flying threats, including two ultra-lights that flew over U.S. troops while they moved north through Iraq."[188] He also discussed the possible threat of UAS swarms.[189] Gaub concluded that UAS posed a real threat to deployed U.S. forces and that steps needed to be taken to address them.[190]

The same year, another study was presented at the European Conference on Information Warfare and Security. Researchers Beaudoin, Gademer, Avanthey, Germain, and Vittori were all members of the Laboratoire d'Acquisition et Traitement des Images et du Signal at the École D'Ingénieurs du Monde Numérique in Paris. Their study, building on a 2010 study by the same

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[186]Ajay Lele and A. Mishra, "Aerial Terrorism and the Threat from Unmanned Aerial Vehicles," *Journal of Defence Studies* 3, no. 3 (July 2009): 63-64.
[187]Darin Gaub, "The Children of Aphrodite: The Proliferation and Threat of Unmanned Aerial Vehicles in the Twenty-First Century" (Monograph, School of Advanced Military Studies, United States Army Command and General Staff College, 2011), 16-17.
[188]*Ibid.*, 32.
[189]*Ibid.*, 32-33.
[190]*Ibid.*, 49-51.

group, examined the threat of sUAS swarms to conduct terrorist attacks. They highlighted two growing capabilities of sUAS: "the increasing level of automation of these systems and their new capacity for collaboration."[191] They defined five levels of automation, and pointed out that while the highest levels were still the purview of laboratories, higher levels of UAS automation were becoming cheaper and more accessible to the public.[192] They further defined four levels of cooperation between sUAS operating in a group: isolated individuals, groups of individuals, teams of sUAS, and swarms of sUAS. In particular they discuss the advantage of swarms, where sUAS act with no leader but rather based on simple rules similar to shoals of fish or flocks of birds.[193] They concluded that such a threat was plausible and would be difficult to counter.[194]

At this point, however, there was certainly not a general agreement that terrorist sUAS posed a credible threat. After the arrest of Ferdaus in 2011 for his plot to launch explosive-laden sUAS at the Pentagon and Capitol building, several experts spoke out about the possibility. Rick Nelson of the Center for Strategic and International Studies pointed out that Ferdaus' sUAVs would have had to "hit a window or other vulnerable area to maximize damage," a difficult feat based on his plan.[195] James Crippin, director of the Western Forensic Law Enforcement Training Center, pointed out that while Ferdaus may have had enough C-4 explosives to do serious damage, controlling the timing of the explosion would have been very difficult.[196] Greg Hahn, the technical director of the Academy of Model Aeronautics pointed out that Ferdaus likely

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[191]Laurent 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*, 2.
[192]*Ibid.*, 2-3.
[193]*Ibid.*, 3-5.
[194]*Ibid.*, 7-8.
[195]"Model Airplanes a New Terrorist Weapon? Experts Say They Pose Little Threat," *Fox News*, 30 September 2011, last accessed 22 December 2015, http://www.foxnews.com/us/2011/09/29/could-model-airplanes-be-next-terrorist-weapon.html.
[196]*Ibid.*

wouldn't have been able to control the specific model aircraft he acquired with his planned payload.[197]

A public debate was again sparked in 2012 when President Obama signed the FAA Modernization and Reform Act of 2012, which directed the FAA to integrate UAS into the U.S. NAS.[198] In an Op-Ed to the Los Angeles Times, John Villasenor, senior fellow at the Brookings Institution and electrical engineering professor at the University of California in Los Angeles (UCLA), argued that terrorist use of UAS had "received too little attention."[199] He brought forward the example of the AeroVironment Switchblade sUAS, two of which fit in a soldier's backpack. The Switchblade only has a few minutes time of flight, but carries a camera and a small explosive.[200] Villasenor argued that although terrorists didn't currently have that capability, it was a matter "of when and not if."[201] He went on to cite several examples of terrorist groups investigating UAS, concluding that the proposed UAS regulations were too lax, in particular with respect to model aircraft.[202] However, Villasenor's opinion was not universally accepted. A counter piece by Shadowproof magazine managing editor Kevin Gosztola called Villasenor's views "hysterical and improbable."[203]

While the less technical, opinion based debate continued in the media, more academic studies continued to less fanfare. In 2013, Klaas Jan de Kraker and Rob van de Wiel of TNO Defence Research presented an analysis of sUAS threats. Their research was sparked by a 2010

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[197]*Ibid.*
[198]United 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. 73.
[199]John 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.
[200]AeroVironment, "Switchblade: UAS Advanced Development Center," last accessed 20 December 2015, https://www.avinc.com/uas/adc/switchblade/.
[201]John 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.
[202]*Ibid.*
[203]Kevin Gosztola, "And The 'Terrorists Might Use Drones' Myth Was Born," *Shadowproof*, 27 March 2012.

prank crash of a model aircraft into the Netherlands' House of Parliament and by the Ferdaus incident. They examined four scenarios: an attack on a stadium by a gun-carrying UAS, an attack on a VIP behind bulletproof glass, a chemical attack on a military compound, and a swarm attack on an airbase. They pointed out that sUAS were very difficult to detect, and even when they are detected, they are difficult to identify as hostile in time to react. They measured the radar cross section (RCS) of several sUAS and found them to be about the size of birds. Jan de Kraker and van de Wiel's conclusion was that sUAS "could be stealthy, accurate, and potentially deadly weapons, and the probability of their use is rapidly increasing."[204]

The RAND Corporation published another study on UAS threats in 2014 by Davis, McNerney, Chow, Hamilton, Harting, and Byman. Based on increasing proliferation of UAS and technological advancements (particularly with respect to GPS), they re-examined the threats to U.S. security. The focus of their study was larger armed UAS, which they concluded were still the exclusive purview of nation states, most of which are U.S. allies. They did acknowledge that "it is also plausible, though not necessarily likely, that a substate group might employ armed UAVs to create a significant psychological effect."[205]

Another 2014 study was conducted by the Birmingham Policy Commission for the University of Birmingham. The study had a very broad scope, exploring UAS issues confronting the UK government from military use to civil integration. As a small part of their report, they discussed non-state actors using UAS as weapons. By 2014 it was becoming clear that many of the technologies that had been difficult to acquire a decade earlier were becoming widespread. "In the wrong hands, RPA could become a dangerous and destabilizing delivery system. We

[204]Sean Gallagher, "German chancellor's drone "attack" shows the threat of weaponized UAVs," *ARS Technica*, 18 September 2013.
[205]Lynn Davis *et al*, *Armed and Dangerous? UAVs and U.S. Security* (Santa Monica: RAND Corporation, 2014), 1.

doubt how far the proliferation of the various enabling technologies . . . can be controlled."[206] They pointed out that even without explosives, UAS could be used to take down vulnerable targets like airliners.[207] They also pointed out that the UK government took the threat seriously, deploying counter-UAS systems during the 2012 Olympics.[208]

A third study in 2014 was written by Bryan Card, a student at the University of Texas at El Paso. Based on the rapid growth of commercial UAS, and in particular by the emergence of Amazon's sUAS delivery program, Card opined that UAS were becoming "more attractive and accessible to terrorists as a delivery method for their attacks."[209] To demonstrate the ease of controlling sUAS remotely, Card cited experiments conducted by MIT Professor Missy Cummings. In her experiments, Cummings set up a sUAS in Cambridge, Massachusetts to be controlled from Seattle, Washington over the internet. The controller used software on an iPhone, and to demonstrate the ease of control Cummings let random passersby control the sUAS.[210] Card also cited a 2011 experiment where an sUAS "tracked human targets by locking in on their cellphone signals."[211] Card further pointed out that "terrorists can build UAVs today for under $10,000, which is well within the costs of historical terrorist attacks."[212] He also discussed previous terrorist intentions to use UAS and the difficulties in intercepting them. As with the Birmingham study, Card concluded that "it would be nearly impossible to cease the proliferation of this technology," and that the U.S. government needed to address the threat.[213]

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[206]Birmingham Policy Commission, *The Security Impact of Drones: Challenges and Opportunities for the UK . . .*, 12.
[207]*Ibid.*, 75.
[208]*Ibid.*, 74.
[209]Bryan Card, "The Commercialization of UAVs: How Terrorists Will Be Able to Utilize UAVs to Attack the United States" . . ., 1.
[210]*Ibid.*, 11-12.
[211]*Ibid.*, 15.
[212]*Ibid.*, 16.
[213]*Ibid.*, *26*.

While the academic literature appears to have started taking the sUAS threat seriously by 2014, the public conversation remained very much split. For example, after the NYPD announced they were concerned about the sUAS threat, John Surico, a freelance journalist, published a counter argument in Vice magazine. Surico argued that the NYPD was blowing the threat out of proportion. He interviewed Cummings, who pointed out that it would be difficult to weaponize sUAS, mostly due to their small payloads.[214]

The next serious examination of the sUAS threat was a congressional subcommittee hearing in March 2015. Sparked by several incidents, including the White House crash, the Merkel incident, the Paris intrusions, and the Ferdaus plot, the purpose was to determine the implications of sUAS on the DHS and other law enforcement agencies in the U.S.[215] The subcommittee heard from four experts.

The first expert was Todd Humphreys, an engineering professor and UAS expert from the University of Texas at Austin. Humphreys cited the intrusion of a sUAV at the Longhorn football season opener in 2014 as a prime example of a security breach. Humphreys acknowledged that most such incidents will likely be accidental and benign. However, he pointed out that

> . . . the distressing truth is that even consumer-grade UAVs can be rigged to carry out potent attacks against which our defenses will be either only weakly effective or so militarized that the defenses themselves will pose a threat to the surrounding civil infrastructure.[216]

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[214]John Surico, "Why Is the NYPD Waging a Shadow Drone War?" *Vice*, 4 November 2014.
[215]House 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, 1-2.
[216]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 2.

Humphreys went on to highlight the key change that had allowed the threat to materialize: "never before have highly-capable UAVs been so inexpensive and widely available."[217] He went on to point out that very simple measures could be taken to counter accidental intruders and intentional but unsophisticated intruders. However, against an intentional, sophisticated intruder Humphreys painted a disturbing picture of a possible attack. He further explained that the instructions, hardware, and software necessary to modify a sUAS were becoming easily available. Finally, he pointed out that for a terrorist, the "threshold for a successful attack is low."[218]

The next expert interviewed was MGen (retired) Frederick Roggero, President and CEO of Resilient Solutions, a counter-UAS company. Roggero also pointed out the rapidly increasing sUAS capabilities available to the public. He argued that "for less than $1,000 one could purchase a system that would allow you to conduct traditional 'air force' missions, at limited, but still effective, levels of success."[219]

The third person to testify was Chief Richard Beary, President of the International Association of Chiefs of Police. Beary made similar arguments about the possible threat of terrorist or criminal sUAS use. He also highlighted the "lack of clear guidance and best practices" among law enforcement agencies.[220] In particular, he noted that it was unclear what law enforcement could (or should) do to identify UAS operators or stop unsafe operations.[221]

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[217]*Ibid.*
[218]*Ibid,* 3.
[219]House of Representatives. Committee on Homeland Security. Subcommittee on Oversight and Management Efficiency. *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Frederick Roggero, Security Issues & Possible Solutions For Homeland Security and Law Enforcement*, 18 March 2015, 2.
[220]House of Representatives. Committee on Homeland Security. Subcommittee on Oversight and Management Efficiency. *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Statement of Chief Richard Beary, President of the International Association of Chiefs of Police*, 18 March 2015, 2.
[221]*Ibid.*

The last expert to testify was Gregory McNeal, Professor of Law and Public Policy at Pepperdine University. While acknowledging the possibility of a threat, McNeal argued that prior to expending funds on sUAS countermeasures, DHS should conduct a "comprehensive risk assessment to identify the probability, magnitude of harm, benefits of security measures, and cost of those measures."[222] He went on to argue the importance of "distinguishing between possible threats and probable threats" in order to avoid "fear based appeals focused on worst-case scenarios."[223] Citing the 2008 RAND report, he highlighted the need for a thorough risk assessment to include both the probability of a successful attack and the losses sustained in such an attack.[224] He also suggested that any spending should be preceded by a cost-benefit analysis.[225]

Later that year, a comprehensive study was published by Professors Ryan Wallace of Polk State College and Jon Loffi of Oklahoma State University in the International Journal of Aviation, Aeronautics, and Aerospace. The purpose of their study was to determine possible uses of UAS by criminals and terrorists and to explore defensive strategies.[226] Citing the wide array of examples available by late 2015, they argued that "the nefarious aspects of UAS have moved from concept to reality."[227] They further pointed out that there was "currently no cohesive defense strategy in which to systematically counter UAS threats."[228] In a thorough analysis they broke down the potential threat into several categories: nuisance, airspace interference,

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[222]House of Representatives. Committee on Homeland Security. Subcommittee on Oversight and Management Efficiency. *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Testimony by Gregory McNeal*, 18 March 2015, 1.
[223]*Ibid.*
[224]*Ibid*, 2.
[225]*Ibid*, 3.
[226]Ryan Wallace and Jon Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," . . .: 2.
[227]*Ibid.*, 4.
[228]*Ibid.*, 2.

surveillance, reconnaissance, kinetic/kamikaze, smuggling, non-lethal weapons, projectile weapons, chemical weapons, biological weapons, radiological/nuclear weapons, IED/explosive weapons, and electronic attack.[229] For all threat categories, they presented examples illustrating the viability of the threat. They concluded that "the threat is real. . . . The threat is not exaggerated or hyped."[230]

The latest study available was the 2016 analysis by the Remote Control Project authors Abbott, Clarke, Hathorn, and Hickie. Their study looked at the hostile use of UAS, unmanned ground vehicles (UGVs) and unmanned maritime vehicles (UMVs) against targets in the UK. They included a thorough review of most incidents to that point, as well as examining the "capabilities of over 200 current and upcoming aerial, ground and marine systems."[231] The study went on to produce an actual risk assessment for British targets. They looked at six categories of users: lone wolf, terrorist organizations, insurgent groups, organised crime groups, activists, and corporations. They then assessed the risk of each group to use different types of unmanned vehicles to either conduct an attack or conduct ISR. Overall, they concluded that attacks from the air were the most likely. Further, they concluded that "the overall risk from the hostile use of drones by non-state actors against British targets is assessed to be medium, though the threat from terrorist organisations and insurgent groups is assessed as high."[232]

Threat to Canada

Much of the evidence presented above did not specifically address the threat to Canada. It is valid to ask whether these examples can be extrapolated to indicate a credible threat to this country.

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[229]*Ibid.*, 6.
[230]*Ibid.*, 22.
[231]C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* . . ., 2.
[232]C. Abbott *et al*. *Hostile Drones: Supplementary Risk Assessment* . . ., 1.

First, the innocent, ignorant, and activist sUAS users primarily serve to demonstrate capability. The demonstrated capabilities are equally valid in the Canadian context, since Canada has similar regulations to most of the countries discussed, particularly the U.S. Further, the small size of sUAS mean that any threat capability developed in the U.S. could easily be brought across the border into Canada.

In terms of sUAVs crashing into people, buildings, or manned aircraft, the evidence shows that the threat is as valid in Canada as elsewhere. For example, the 2014 crash of a sUAV into a downtown Vancouver building is similar to other such incidents in the U.S.[233] TC's statistics show that sUAV near misses with manned aircraft in Canada are a significant rising concern.

Insurgent use of commercial sUAS should also be a concern to Canada. While these users do not pose a direct threat to the country, they pose a potential threat to Canadians abroad, particularly military or other government personnel.

Assessing the threat of a terrorist sUAS attack in Canada is difficult to do accurately in an unclassified paper. However, the 2014 RCMP warning about facility vulnerability to sUAS attacks highlights that Canadian law enforcement is seriously considering the threat.[234] Canada has experienced several planned or actual terror attacks since 2001, including the "Toronto 18" and Via Rail plots and the attacks of Martin Couture-Rouleau and Michael Zehaf-Bibeau.[235]

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[233]Jason Proctor and Bal Brach, "Drone crash prompts Vancouver to review film industry use," 11 June 2014, last accessed 8 December 2015, http://www.cbc.ca/news/canada/british-columbia/drone-crash-prompts-vancouver-to-review-film-industry-use-1.2671977.

[234]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.

[235]Evan Solomon, "Ottawa gunman Michael Zehaf-Bibeau was shot 31 times, police report to reveal," *CBC* News, 1 June 2015, last accessed 7 May 2016, http://www.cbc.ca/news/politics/ottawa-gunman-michael-zehaf-bibeau-was-shot-31-times-police-report-to-reveal-1.3096073; René Bruemmer, "From typical teen to jihadist: How Martin Couture-Rouleau became radicalized after converting to Islam," *National* Post, 9 November 2014, last accessed 7

Further, al-Qaeda and ISIL have both called for attacks in the country.[236] As sUAS are becoming an increasingly attractive mode of attack, it follows that Canada should prepare for the possibility of a terrorist sUAS plot.

Summary

The threat posed by hostile use of sUAS has clearly evolved in the last decade. While public opinion of the possibility of an attack is by no means unanimous, there has been a marked shift in the conclusions of more rigorous military and academic studies. The cost and availability of sUAS that are very easy to operate has changed dramatically, in particular since about 2013. The increasing capabilities of sUAS, combined with a clear desire of non-state actors to employ them maliciously, mean that sUAS must be considered a credible threat to Canada.

May 2016, http://news.nationalpost.com/news/canada/from-typical-teen-to-jihadist-how-martin-couture-rouleau-became-radicalized-after-converting-to-islam; "2 Via Rail terror plotters sentenced to life in prison," *CBC* News, 23 September 2015, last accessed 7 May 2016, http://www.cbc.ca/news/canada/toronto/via-rail-terror-sentences-1.3240050; Isabel Teotonio, "Toronto 18," *Toronto Star,* last accessed 7 May 2016, http://www3.thestar.com/static/toronto18/.

[236]Anthony Furey, "ISIS magazine calls for attacks on Canada," *Toronto Sun,* 22 November 2015, last accessed 7 May 2016, http://www.torontosun.com/2015/11/22/isis-magazine-calls-for-attacks-on-canada; Ben Makuch, "Jihadists Are Calling for New Attacks in Canada, Some on Oil and Media Companies," *Vice*, 21 January 2015.

CHAPTER 4 – CURRENT POLICIES

Given the potential threat posed by hostile sUAS, it is fair to ask what steps Canada and the rest of the world are taking to address the issue. This chapter will examine the policies of several countries, concentrating in particular on the U.S. and Canada. The intent here is not to provide an in-depth analysis of all facets of these countries' civil UAS policies. Rather, the goal is to parse out some factors that relate directly to malicious use of sUAS. After examining the status of current policies, this chapter will then also briefly discuss the current and potential roles of various Canadian government agencies. The aim of this chapter is to show that Canada's UAS policies, while progressive in addressing regulatory issues and commercial needs, are lagging the rest of the world in acknowledging potential security threats.

Overview

There is significant variation in national UAS policies around the world. Table 4.1 presents a sampling of worldwide policies as of 2014. It indicates which countries had regulations in place or in preparation for within visual line of sight (WVLOS) or beyond visual line of sight (BVLOS) civil operations. Blank cells indicate that no regulations were in place or in preparation.

Table 4.1 - Sampling of Worldwide UAS Regulations

	Regulations in Place (2014)		**Regulations in Preparation (2014)**	
Country	**WVLOS**	**BVLOS**	**WVLOS**	**BVLOS**
Australia	Yes	Yes		
Austria	<150 kg			
Brazil			Yes	
Belgium			<150 kg	
Bulgaria				
Canada	<25 kg			<25 kg
Columbia	Yes	Yes		
Croatia				
Cyprus				
Czech Republic	<150 kg	<150 kg		

Denmark	<150 kg			
Estonia				
Finland			<150 kg	
France	<25 kg	<25 kg	<150 kg	<150 kg
Germany	<25 kg			
Greece				
Hungary			<150 kg	
Iceland				
Ireland	<20 kg			
Italy	<25 kg			
Israel	Yes	Yes		
Japan	Yes		Yes	
Latvia				
Lithuania	<25 kg			
Luxembourg				
Malta			<150 kg	
Netherlands	<25 kg		<150 kg	
New Zealand			Yes	
Norway				
Poland	<150 kg	<150 kg		
Portugal				
Romania	<25 kg			
Russia			Yes	
Slovakia				
Slovenia				
South Africa			Yes	
South Korea	Yes			
Spain			<25 kg	
Sweden	<150 kg			
Switzerland				
Turkey			Yes	Yes
Ukraine	Yes		Yes	
U.K.	<20 kg			
U.S.			Yes	Yes

Sources: Bailie, Meredith, and Roughley, *Canadian Civil UAS 2014* and Van Blyenburgh, "Civil RPAS Regulation and Certification," 5 March 2014.

This table is a specific sampling gathered by Van Blyenburgh and updated by Bailie, Meredith, and Roughley. Some other countries, not included above, illustrate the extremes of

worldwide policy. For example, Kenya and Abu Dhabi have completely banned civil UAS, while UAS remain largely unregulated in most parts of South America.[237]

Europe

UAS regulation in Europe is somewhat complicated. Currently, European regulations are largely determined by individual nations. However, the European Union plans to centralize regulation of civil aviation, including civil UAS, through the European Aviation Safety Agency (EASA).[238] The plan for UAS regulation is contained in the 2013 European RPAS Roadmap, a product of the European RPAS Steering Group. This group is chaired by two director-generals from the European Commission and is comprised of a slew of European agencies, associations, and interest groups.[239] The important point to note is that the RPAS Roadmap acknowledges and addresses, albeit vaguely, the risk of UAS being "used as weapons against other airspace users or targets on the ground."[240]

Three European countries have taken specific steps to mitigate a perceived sUAS threat: Germany, France and the U.K. All three countries held counter UAS trials in 2015.[241] Several French companies are developing counter sUAS technologies while the French Ministry of Defence has openly voiced concerns about sUAS swarms, and are reportedly considering "a

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[237]Dickens Olewe, "Kenya: Ban On Civilians' Use of Drones Kills Innovation," *All Africa*, 9 July 2015, last accessed 26 March 2016, http://allafrica.com/stories/201507090611.html; Anwar Ahmad, "Sale of recreational drones banned in Abu Dhabi," *The National*, 11 March 2015, last accessed 26 March 2016, http://www.thenational.ae/uae/sale-of-recreational-drones-banned-in-abu-dhabi; Diego Cupolo, "Drone Use Soars in Latin America, Remains Widely Unregulated," *Upside Down World*, 19 December 2013, last accessed 26 March 2016, http://upsidedownworld.org/main/international-archives-60/4615-drone-use-soars-in-latin-america-remains-widely-unregulated-.

[238]Ballirano, Francesco P, "EASA Set to Become the FAA of Europe and Regulate Use of UAVs," *Droneblog* (blog), 29 June 2015, last accessed 30 September 2015, http://droneblog.com/2015/06/29/easa-set-to-become-the-faa-of-europe-and-regulate-use-of-uavs/.

[239]European RPAS Steering Group, *Roadmap for the integration of civil Remotely-Piloted Aircraft Systems into the European Aviation System: Final report from the European RPAS Steering Group*, June 2013, 4.

[240]*Ibid.*, 12.

[241]Andrew Chuter, "Mini Drones Spark Heightened Interest in Countering Threat," *Defense News*, 4 August 2015, last accessed 26 March 2016, http://www.defensenews.com/story/defense/air-space/strike/2015/06/20/small-drones-raise-interest--combating-threat/28977373/.

cyber-based capability to counter the devices when needed."[242] The U.K. has been taking the threat seriously since at least 2012. The Royal Air Force deployed integrated counter-sUAS systems (described in more detail in Chapter 5) to protect the 2012 London Olympics, the 2013 G8 Summit in Scotland, the 2014 NATO Summit in Wales, and the 2015 Remembrance Sunday events in London.[243] The U.K. government plans to continue deploying these systems to major events in the future.[244]

Pacific

At least three Pacific nations are specifically addressing the sUAS threat. South Korea, through the Korean Advanced Institute of Science and Technology, is developing teams of sUAS interceptors and unmanned ground vehicles (UGVs).[245] There has also been extensive testing of integrated counter sUAS systems along the Korean demilitarised zone.[246] Japan has actually deployed squads of net-carrying sUAS interceptors to protect key buildings in Tokyo.[247] In Australia, the association of Australian Certified UAV Operators (ACUO) called for "the establishment of a regional counter unmanned aerial systems initiative" including yearly counter-UAS exercises.[248]

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[242]Brooks Tigner, "France seeks new counter-UAV capability," *Janes*, 20 January 2016.

[243]House of Representatives . . . *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Frederick Roggero, Security Issues & Possible Solutions For Homeland Security and Law Enforcement*, 18 March 2015, 2; Corey 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.

[244]*Ibid.*

[245]Kelsey Atherton, "South Korea Gets Ready For Drone-On-Drone Warfare With North Korea," *Popular Science*, 2 April 2015.

[246]Blighter Surveillance Systems. "Anti-UAV Defence System (AUDS) Unveiled by Tri of British Technology Companies," 19 May 2015.

[247]"Drone squad to be launched by Tokyo police," *BBC News*, 11 December 2015, last accessed 2 January 2016, http://www.bbc.co.uk/news/technology-35070818.

[248]Australian 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.

United States

The U.S. FAA has been undergoing an airspace modernization program, specifically with regards to UAS, since President Obama signed the FAA Modernization and Reform Act of 2012. The keystone document guiding the process is the *Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap: First Edition – 2013*. However, much like TC in Canada, issues of national security are not the FAA's primary mandate. The 2013 roadmap does contain a short paragraph highlighting that UAS integration in the NAS will carry "certain national security implications," but simply states that the FAA will be proactive in working with "relevant United States Government departments and agencies."[249] For example, when asked by the Attorney General of Mississippi in February 2015 about the use of UAS in hunting, the FAA simply responded that with the "installation of a weapon, camera, whatever . . . if safe operation is not implicated, we don't really have an interest."[250] Further, by their own admission, the FAA is not manned to enforce its regulations on the sheer number of UAS users in the U.S.[251] In January 2015 the FAA released a memo to local law enforcement agencies across the country, summarizing UAS legislation, providing guidance on what to do with infractions, and ultimately requesting help dealing with UAS infractions.[252]

The FAA has, however, taken several important measures to address safety and security. For example, they have been widely publicizing "No Drone Zones" around restricted areas and

[249]Federal Aviation Administration, "Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap: First Edition – 2013," 12.
[250]Nelson, Steven, "FAA Wants Local Cops To Be Drone Police," *U.S. News & World Report*, 24 February 2015, last accessed 26 December 2015, http://www.usnews.com/news/articles/2015/02/24/faa-wants-local-cops-to-be-drone-police.
[251]*Ibid.*
[252]Federal Aviation Administration, "Law Enforcement Guidance For Suspected Unauthorized UAS Operations," 8 January 2015.

events, such as Washington, D.C., and the 2016 Superbowl.[253] Another important measure was the implementation of sUAS registration beginning in December 2016. The legislation passed requires users to register any sUAS over 0.55 lbs that they intend to fly outdoors.[254] According to the FAA, "UAS pose new security and privacy challenges and must be traceable in the event of an incident."[255] The legislation applies to all users, including modellers and hobbyists and requires users to mark a registration number on their sUAS as well as carry the registration with them.[256] It does not require users to take any specific training or pass any sort of knowledge test.[257]

The FAA also launched a series of "Focus Area Pathfinder" programs to address specific problem areas with UAS integration in the NAS.[258] Some of these tackle regulatory issues, while others address key safety issues such as the low level airspace plan to deconflict manned and unmanned traffic in an increasingly dense traffic environment. It is expected that these measures will be key to promoting the U.S. UAS industry while maintaining adequate public safety with regards to well-intentioned users. Spurred by a "steep increase in reports of small unmanned aircraft in close proximity to runways," the FAA added a Pathfinder program in October 2015, in partnership with CACI International, to evaluate sUAS detection technology.[259] The CACI product in question is in fact an integrated counter-sUAS system.[260]

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[253]Federal Aviation Administration, "No Drone Zone," last accessed 20 December 2015, https://www.faa.gov/uas/no_drone_zone/.
[254]Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule . . .*, 78595.
[255]Federal Aviation Administration, "UAS Registration Q&A," last accessed 3 January 2016, https://www.faa.gov/uas/registration/faqs/.
[256]*Ibid.*
[257]*Ibid.*
[258]Federal Aviation Administration, "Focus Area Pathfinders," 6 May 2015, last accessed 8 December 2015, https://www.faa.gov/uas/legislative_programs/pathfinders/.
[259]Federal Aviation Administration, "FAA Expands Unmanned Aircraft Pathfinder Efforts," 7 October 2015.
[260]CACI International Inc, "SkyTracker – Overview," last accessed 8 December 2015, http://www.caci.com/skytracker/index.shtml.

While U.S. national security is not the mandate of the FAA, it is certainly the mandate of the DHS and Department of Defense (DoD). The congressional hearing discussed in Chapter 3, as part of the Committee on Homeland Security, was specifically aimed to help DHS develop a "cohesive strategy to address these issues."[261] The DoD has been looking at counter-UAS technology since at least 2004.[262] They run two annual exercises: Black Dart, which focuses on emerging counter-UAS technology, and Blue Knight, which focuses on counter-UAS tactics, techniques, and procedures (TTPs).[263] As part of another program, a 2014 DoD request for information (RFI) solicited technology demonstrations of "chemical and/or biological detection capabilities on UAS platforms and countering commercial UAS with chemical and/or biological weapons of mass destruction payloads."[264]

While the FAA has struggled to define its role in countering a sUAS attack, the U.S. government as a whole is clearly taking the threat seriously. One final example is the "Preserving American Privacy Act," a bipartisan piece of legislation proposed in Congress in March 2015. This legislation, reintroduced after failing to pass during the previous session of Congress, is aimed to address two concerns with UAS: breeches of privacy and weaponization. With respect to weaponization, the act proposed to ban civilians and law enforcements agencies from mounting firearms to UAS.[265]

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[261]House of Representatives, . . . *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Statement of Subcommittee Chairman Scott Perry*, 18 March 2015, 2.

[262]Ryan Faith, "Inside 'Black Dart,' the US Military's War On Drones," *Vice*, 28 October 2014.

[263]"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.

[264]Federal Business Opportunities, "RFI – THUNDERSTORM Technology Demonstration – RRTO-2014-11-26-RFI-Spiral-15 (Archived) – Federal Business Opportunities: Opportunities," last accessed 24 December 2015, https://www.fbo.gov/index?s=opportunity&mode=form&id=c744e5f86221696d0ea2ae42957e4a9c&tab=core&_cview=0.

[265]Steven Nelson, "Weaponized, Peeping Drone Ban Proposed in Congress," *U.S. News & World Report*, 17 March 2015, last accessed 26 December 2015, http://www.usnews.com/news/articles/2015/03/17/weaponized-peeping-drone-ban-proposed-in-congress.

Canada

In Canada, TC is the principal agency regulating the use of UAS. It has fairly robust procedures in place for WVLOS operation of recreational, developmental, and commercial UAS. For recreational operations of sUAS less than 35 kg no permit nor any permission is required, although regulations are in place that all users must follow. For commercial or research with sUAS less than 25 kg, very few restrictions apply. For other operations, with a few exceptions, TC requires users to apply for an SFOC.[266] The general process is illustrated in Figure 4.1. Note that TC intends to make 25 kg a universal delineation future regulations, with no differentiation between recreational, commercial, and research purposes.[267]

[266]Transport Canada, "Flying an unmanned aircraft for work or research," last accessed 30 September 2015, http://www.tc.gc.ca/eng/civilaviation/standards/standards-4179.html; Transport Canada, "Flying an unmanned aircraft recreationally," last accessed 30 September 2015, http://www.tc.gc.ca/eng/civilaviation/standards/general-recavi-uav-2265.htm?WT.mc_id=21zwi.

[267]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles*, . . ., 9.

Figure 4.1 - Transport Canada UAS Regulation Flow Chart

Source: Transport Canada, "Flying an unmanned aircraft?," last accessed 19 March 2016

TC also has plans to modernize its UAS regulations. According to their May 2015 *Notice of Proposed Ammendment: Unmanned Air Vehicles,* TC will make several advances in 2016 including introducing marking and registration for sUAS, addressing licensing and training issues for operators, and creating robust flight rules.[268] TC also has a longer term plan to fully integrate UAS in Canada, including BVLOS operations.[269]

[268] *Ibid.,* 1.
[269] *Ibid.*

Canada's UAS regulations have been praised as relatively permissive, helping Canadian UAS companies gain an edge over international competitors.[270] Relative to the U.S., this has certainly been the case, at least historically. Some have argued that the SFOC clearance process for UAS larger than 25 kg and for commercial UAS is too cumbersome, and can take 2-3 months to be issued.[271] However, the process is often faster, with an average wait of about 15 days in 2012-2013.[272] This compares quite favourably with the FAA's equivalent clearance, known as a 333 exemption, which takes about 1-6 months with about a 2 month average wait. Amazon's testing in British Columbia is often cited as an example of this, and several other similar cases exist.[273] Amazon waited over a year for a 333 exemption, by which time it was no longer applicable to the technology they were testing. Their SFOC to test in Canada, by contrast, took only three weeks.[274]

However, relative to the rest of the world, Canada is by no means the most progressive country when it comes to UAS policies. As shown in Table 4.1, several countries already have policies in place to allow BVLOS UAS operations, such as Australia, Columbia, the Czech Republic, France, Israel, and Poland. According to a 2013 guide put together by the Drone

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[270]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014* (Ottawa: National Research Council Canada, 2015), 2; Mike Hager, "Canadian airspace is friendly to U.S. drones," *The Globe and Mail*, 30 March 2015, last accessed 31 January 2016, http://www.theglobeandmail.com/news/british-columbia/amazon-testing-delivery-drones-in-bc/article23693387/; Omar El Akkad and Kelly Cryderman, "Canadian technology and the flight of the drones," *The Globe and Mail*, 7 April 2014, last accessed 19 December 2015, http://www.theglobeandmail.com/technology/tech-news/canadian-technology-and-the-flight-of-the-drones/article17849259/; Evan Mitsui, "Commercial drones have 'endless' uses under Canada's laws," *CBC News*, 12 November 2013, last accessed 19 December 2015, http://www.cbc.ca/news/technology/commercial-drones-could-have-endless-uses-under-canada-s-laws-1.1386300.

[271]Stewart Baillie, Keith Meredith, and Dave Roughley, *Canadian Civil UAS 2014* (Ottawa: National Research Council Canada, 2015), 15.

[272]*Ibid.*

[273]Chris Costello, "A Look at the 333 Exemption Process," *Dronelife News*, 9 September 2015, last accessed 26 March 2016, http://dronelife.com/2015/09/09/a-look-at-the-333-exemption-process/.

[274]Chung, Emily, "Amazon tests delivery drones at secret site in Canada – here's why," *CBC News*, 31 March 2015, last accessed 30 September 2015, http://www.cbc.ca/news/technology/amazon-tests-delivery-drones-at-a-secret-site-in-canada-here-s-why-1.3015425.

Journalism Program at the University of Missouri, Canada scored a mere 2 out of 5 "UAV-Friendly Rating."[275]

Furthermore, the U.S. is rapidly becoming more progressive when it comes to UAS regulations. Although one of Canada's points of pride has been its four UAS testing facilities, the FAA has now established six UAS testing sites and a UAS centre of excellence.[276] The FAA, along with the National Aeronautics and Space Administration (NASA) and Google, have also been spearheading the creation of a low level air traffic system for UAS and manned aircraft below 500 feet above ground level.[277] The FAA also led TC in introducing sUAS registration.[278] While TC makes efforts to maintain alignment with the FAA, it seems that the FAA is now leading the way in terms of UAS integration in North America.

While TC has been leading UAS policy development in Canada, they have no specific mandate for national security. Their role is specific to safety: "Transport Canada develops and enforces safety regulations and standards; tests and promotes safety technologies; and is introducing safety management systems as a reliable and cost-effective way to prevent and manage safety risks in all modes of transportation."[279] TC did launch a "national safety awareness campaign" in October 2014, but this was focused on non-malicious users.[280] This is

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[275]Zach Garcia, "What Flies When it Comes to Drone Laws Across the Globe," *University of Missouri Drone Journalism Program*, 19 April 2013.

[276]Federal Aviation Administration, "Press Release – FAA Selects Mississippi State University Team As Center of Excellence for Unmanned Aircraft Systems," 8 May 2015; Federal Aviation Administration, "Test Sites," last accessed 3 January 2016, https://www.faa.gov/uas/legislative_programs/test_sites/.

[277]National 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.

[278]Department of Transportation, *Federal Register Vol. 80 No. 241 Registration and Marking Requirements for Small Unmanned Aircraft; Final Rule . . .*, 78595.

[279]Transport Canada, "Our Role – Transport Canada," last accessed 26 March 2016, https://www.tc.gc.ca/eng/safety-our-role.htm.

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

very similar to the situation in the U.S. with the FAA, DHS, and DoD. If Canada is going to develop a coherent sUAS security strategy, it will need to involve more than just TC.

There are several agencies in Canada who could potentially have roles to play in the development of such a strategy. Probably the most important would be DHS' Canadian equivalent, Public Safety Canada (PSC). Their mandate is "to keep Canadians safe from a range of risks such as natural disasters, crime and terrorism."[281] Of Public Safety's five agencies, four of them would be critical to any realistic counter-sUAS plan: Canada Border Services Agency (CBSA), the Royal Canadian Mounted Police (RCMP), the Canadian Security Intelligence Service (CSIS), and Correctional Service Canada (CSC).[282] Of course, any realistic plan would need to balance economic development, and would therefore necessitate the involvement of Innovation, Science, and Economic Development Canada. Their role is "to foster a growing, competitive and knowledge-based Canadian economy."[283] Lastly, the Department of National Defence (DND) would be another essential stakeholder, for two reasons. First, DND will have a need to protect its forces abroad from sUAS threats. Ensuring a coherent strategy between DND's force protection needs and any potential homeland counter-sUAS plan would be essential to the efficiency and effectiveness of both. Second, DND, in particular through its commitments to the North American Aerospace Defence Command (NORAD), has a responsibility to protect Canadians from airborne threats. The mission of the Canadian NORAD Region (CANR) is "to provide aerospace surveillance, identification, control and warning for the defence of Canada and

[281]Public Safety Canada, "About Public Safety Canada," last accessed 26 March 2016, https://www.publicsafety.gc.ca/cnt/bt/index-eng.aspx.
[282]*Ibid.*
[283]Innovation, Science and Economic Development Canada, "About us – Innovation, Science and Economic Development Canada," last accessed 26 March 2016, https://www.ic.gc.ca/eic/site/icgc.nsf/eng/h_07017.html.

North America."[284] More specifically, the post 9/11 Operation Noble Eagle charges NORAD with defending Canada and the U.S. from an internal attack.[285] While this has typically entailed guarding against another such event involving a large aircraft, it is not entirely clear whether there is a specific size threshold, or not, at which a hostile UAS would be CANR's problem or PSC.

The point here is clear: in developing a counter-sUAS strategy the GoC must ensure that all appropriate stakeholders are involved to ensure a balanced, efficient, and effective plan. Further, such a plan should be developed soon, as Canada is starting to lag the rest of the world both in terms of addressing UAS development and UAS security.

[284]North American Aerospace Defense Command, "Canadian NORAD Region," last accessed 30 September 2015, http://www.norad.mil/AboutNORAD/CanadianNORADRegion.aspx.
[285]*Ibid.*

CHAPTER 5 – SUAS DEFENCES

Accepting that a potential hostile sUAS threat exists, and that the Government of Canada (GoC) has a duty to create a balanced counter-sUAS strategy, the next question is: what can be done to prevent an attack? This chapter will explore some of the available technologies and expert opinions on what could, and should, be done to defend against malicious sUAS operators.

Prior to delving into sUAS defences, it is important to again emphasize the importance of the sUAS industry and of a balanced approach. In his testimony before the U.S. Congress, Dr. Humphreys put it:

> What can be done? First, it is important to take stock of what should not be done. Imposing restrictions on small UAVs beyond the sensible restrictions the Federal Aviation Administration recently proposed would not significantly reduce the threat of rogue UAVs yet would shackle the emerging commercial UAV industry.[286]

Humphreys went on to note the potential collateral damage issues involved with many sUAS defences, including some kinetic and electronic warfare (EW) options. In their conclusion, Jackson *et al* also put it succinctly:

> While seductive, large investments to defend against these air threats at the point of attack, particularly in the homeland, can distract from other more-productive defense investments that are focused on preventing attacks before they occur or in recovering evidence and performing forensics after an attack. Cruise-missile defences would be costly; each system could defend only a small amount of territory, and even effective defensive performance within those areas would be exposed to operational challenges. In an era in which a stated goal of U.S. adversaries is to damage the American economy and cause the United States to devote increasing amounts of its resources to defenses, ensuring that the government does not overspend to mitigate individual threats must be considered

[286]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 3.

> at the same time as trying to ensure that the nation is appropriately protected against terrorist and other asymmetric threats.[287]

It should be noted that this paper, while using some specific examples of systems, is by no means a comprehensive review of the currently available counter-sUAS systems. For the interested reader, Birch *et al* published an excellent market survey of systems.[288]

Academic Studies

Most of the studies discussed in Chapter 3 contain discussions and recommendation about possible counter-sUAS strategies. This chapter will attempt to synthesize these ideas, along with noting some other emerging technologies. In general, many ideas related to sUAS defences are common. sUAS are difficult to detect and identify. They are difficult to engage without incurring excessive costs or collateral damage, both of greater magnitude than simply allowing an attack to occur.

The points of disagreement tend to be about what exactly should be done, specifically whether it is worth attempting active point defence at sensitive sites or whether it is better to focus on prevention. Broadly speaking, earlier studies such as Miansikov and Jackson *et al* tend to advocate for a focus on prevention through avenues such as law enforcement.[289] This is in part due to a lack of counter-sUAS technology at the time. Miansikov's paper from 2005 concludes: "All this suggests that once a terrorist mini-UAV has been launched, it will be practically

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[287]B.A. Jackson *et al*, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles . . .*, 100.

[288]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* (Albuquerque: Sandia National Laboratories, 2015), 3.

[289]Eugene Miasnikov, *Threat of Terrorism Using Unmanned Aerial Vehicles: Technical Aspects . . .*, 23; B.A. Jackson *et al*, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles . . .*, 99.

impossible to defend against. Thus, the main accent of dealing with this threat needs to be on measures to prevent the attack during its preparation stages."[290]

Newer studies tend to highlight that defending against attacks is possible, mostly due to a surge in counter-sUAS technology development, which will be discussed in this Chapter. Almost invariable, however, they all agree that prevention remains the most important and cost-effective defence.[291]

Two very recent studies should also be noted at this point. They were not discussed in Chapter 3 since they deal only with defence strategies vice also assessing the probability of attack. The first, which could not be obtained prior to writing this paper, is a report by the NATO Industrial Advisory Group (NIAG), numbered SG-170 and titled *The Engagement of Low, Slow, and Small Aerial Targets by GBAD* [Ground Based Air Defences]. The report, which is referred to in other studies, examined detection, identification, and engagement of sUAS.[292] The second, which leans heavily on the NIAG report, is a survey of current counter-sUAS technologies published by Birch, Griffin, and Erdman of Sandia National Laboratories.[293] It is a thorough review of the state of counter-sUAS technology including the latest commercially available systems.

Layered Approach

All of the academic studies reviewed for this paper advocate some form of layered defence. The concept is straightforward. In addition to stopping an attack in progress, a coherent

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[290]Eugene Miasnikov, *Threat of Terrorism Using Unmanned Aerial Vehicles: Technical Aspects* . . ., 23.
[291]Ryan Wallace and Jon Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," . . .: 23-24; Bryan Card, "The Commercialization of UAVs: How Terrorists Will Be Able to Utilize UAVs to Attack the United States" . . ., 21-27; Birmingham Policy Commission, *The Security Impact of Drones: Challenges and Opportunities for the UK* . . ., 11-12; C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* . . ., 20.
[292]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 7.
[293]*Ibid.*

defence strategy should also include ways to prevent an attack from occurring, and should an attack occur, it should consider recovery and forensics to prevent further damage. This paper will examine eight layers: regulation, prevention, readiness, detection, identification, passive defence, active defence, and post-attack recovery and forensics. These will address three stages of an attack: preparation, execution, and exploitation. This is illustrated in Figure 5.1.

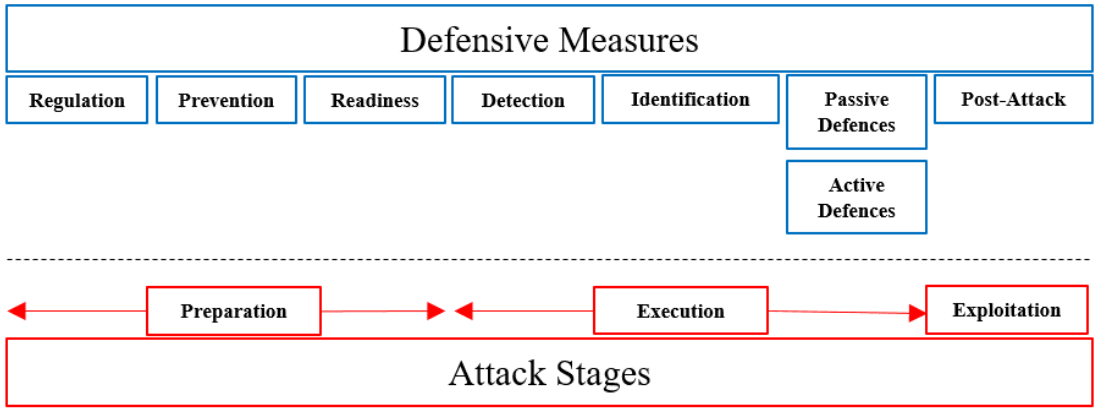

Figure 5.1 - Timeline of an Attack

Source: The author

Regulation

Effective regulation of sUAS operations accomplishes two goals. First, it decreases the chances of non-malicious users endangering the public. Second, by reducing the overall number of sUAS incidents, it helps to clear out the "noise," making suspicious or outright hostile actions much easier to detect.

sUAS registration is a good first step towards more effective regulation. It adds a degree of accountability to sUAS operations, ensuring that operators who cause accidents can be traced. It also allows governments to ensure that all sUAS operators have a minimum knowledge level.

This doesn't necessarily mean licensing all sUAS users, as some have suggested.[294] It could, however, mean a simple online test. At the very least it could ensure that users are aware that regulations exist and help them find them. sUAS registration could also help highlight potential malicious users during their preparation phase, as unmarked, unregistered sUAS could stand out. Although TC plans to implement a registration program similar to the FAA's, it still has not done so. Further, TC's plan, unlike the FAA's, is not to require model aircraft operators to register their aircraft.[295] This is an important gap. TC stated in their latest Notice of Proposed Amendments that they intended to leave model aircraft, possibly subject to a restriction on first person view (FPV) cameras, free of sUAS regulations, including registration.[296] This is due to the "proven safety record" of the Model Aeronautics Association of Canada (MAAC).[297] The emphasis on safety, versus security, highlights the issues discussed at the end of Chapter 4. To join the MAAC, all that is required is an online form.[298] While this is similar to the FAA's online registration, the important point is that the MAAC does not require users to mark their aircraft in any way.[299] This is important; of the historical examples given in Chapter 3, several of them planned to use modified remote control aircraft as opposed to off-the-shelf sUAS.

Abbott *et al* suggest some other regulatory countermeasures:

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[294]John 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; Chris Brown, "Drones have regulators, hobbyists on collision course: Canada's aviation overseers face their biggest challenge in generations," *CBC News*, 19 May 2014, last accessed 19 December 2015, http://www.cbc.ca/news/technology/drones-have-regulators-hobbyists-on-collision-course-1.2644232; C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* . . ., 15-16.

[295]Transport Canada, Canadian Aviation Regulations Advisory Council, *Notice of Proposed Amendment (NPA): Unmanned Air Vehicles* . . ., 11-12.

[296]*Ibid.*

[297]*Ibid.*

[298]Model Aeronautics Association of Canada, "MAAC Member Database," last accessed 26 March 2016, https://secure.maac.ca/members/en/join.php.

[299]Model Aeronautics Association of Canada, "MAAC Safety Code," last accessed 26 March 2016, http://www.maac.ca/en/safety_code.php.

> • Point of sale regulations, including identification requirements for the purchase and sale of drones above a certain level of capability.
> • Civil aviation rules and licensing regimes to regulate the use of drones, with harsh penalty regimes for flying near critical national infrastructure and sites of national security importance.
> • Manufacturing standards and restrictions for UAVs, including no-fly zones built in to firmware and limits on carrying capacity and controller range.[300]

They also note an interesting South African restriction prohibiting sUAS from being flown in "formation or swarm."[301] These would all be excellent ideas for TC to implement.

Prevention/Post-Attack

Most of the earlier studies of hostile sUAS suggested that prevention of attacks was the only real effective means of homeland defence, as discussed earlier. This includes intelligence and law enforcement activity to find potential hostile operators during their preparation stages. They also typically argued that post-attack forensics and recovery would be critical to preventing further attacks. Jackson *et al* suggest that "gathering information to help law enforcement identify potential supply chains or conducting forensics analysis . . . could improve security at a reasonable cost."[302] They further suggest:

> . . . explicitly adding activities involving remote controlled planes to lists of behavior for police to watch for, educating domestic sellers of these technologies to be on the lookout for and to report suspicious purchases, more-focused monitoring of the transfer of these technologies internationally, and forensics techniques specifically designed to mine for information the remnants of a UAV used in an attack.[303]

This element of defence cannot be overemphasized. Of all the confirmed terrorist attack attempts listed in Chapter 3, every one was foiled by law enforcement in the preparation stage.

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[300]C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets . . .*, 15.
[301]*Ibid.*, 16.
[302]B.A. Jackson *et al, Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles . . .*, 99.
[303]*Ibid.*, 75.

This was often due to good intelligence work and an emphasis on critical component purchases (usually explosives).

Readiness

In the event of an actual attack, it will be critical to make sure that any defenders are ready in terms of technology, training, and TTPs. To that end, the GoC should be striving to participate in some of the allied counter-UAS exercises that already exist. This should include the previously mentioned U.S. Blue Knight and Black Dart exercises, or any other potential counter-UAS exercise such as the one suggested by the Australian ACUO. Canada could also take advantage of its world-class airspace and ranges, such as the Cold Lake Air Weapons Range, to host an exercise and provide a valuable contribution of its own.

Detection

Detecting a sUAS is difficult. They are small, with small signatures, and often operate in cluttered background environments. The 2015 Sandia report studied the currently available sUAS detection technologies, with respect to three types of sUAS: a "glider made with radar transparent material" such as Styrofoam, a quadcopter, and a jet-turbine sUAS.[304] They assigned a generic colour of green, yellow, or red to good, mild, and poor detection performance respectively. Their results are shown in Figure 5.2.

[304]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 14.

Detection scheme	Glider	Quadcopter	Jet
Radar			
Passive optics (i.e., cameras)			
Active optics (i.e., LIDAR)			
Acoustics			
EM emissions			
B-field detection			

Figure 5.2 - sUAS Detection Ability Against 3 sUAS Types

Source: Birch, Griffin and Erdman, *UAS Detection, Classification and Neutralization: Market Survey 2015*

The study points out that "the lack of green indicators for all UAS types is supported by the findings of [NIAG Report SG-170], namely that multiple detection technologies must be integrated or fused into a single detection/classification architecture to ensure higher probability of detection."[305] They further quote the NIAG Report:

> The challenge for LSS [low, slow, and small] threat detection for current high frequency sensors is the false alarm plots and how to engage with the real LSS threats that are in the velocity domain of clutter or natural objects such as birds, 'angels' or ground vehicles. The combinations of sea and land clutter, climatic and atmospheric anomalies are compounded by the high number of real contacts varying from large qualities of birds to surface and air objects in a congested battle space.[306]

[305] *Ibid.*

[306] NATO Industrial Advisory Group, *Study SG-170: The Engagement of Low, Slow, and Small Aerial Targets by GBAD* (NATO: October 2012), quoted in Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 21.

Most of the currently available integrated counter-sUAS systems use some combination of different sensors. The next few sections will examine some sensor types in more detail.

Radar

The main challenge with radar detection of sUAS is their small RCS, particularly when compared to background clutter and birds. According to the Sandia study, the NIAG report measure the RCS of two commercially available sUAS to be -15dBm^2, and could be as low as -30dBm^2 if built with "RF transparent material" such as Styrofoam.[307] As a reference, this would vary from slightly larger RCS than a typical bird to well smaller.[308] Further, traditional air defence radars have difficulty detecting sUAS due to automatic filters that try to suppress display of birds and other clutter.[309] That being said, some experts believe that tailored radars provide the best sUAS detection based on detection range and scan rates, when compared to other systems.[310]

It should be noted that radars are relatively expensive systems. For example, the U.S. military spent over $2.5 billion developing the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS).[311] JLENS is a system of radar-carrying blimps intended to detect cruise missiles or larger UAS approaching the U.S. The scope of the program has been scaled down from 16 planned orbits of two blimps each to just two orbits.[312]

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[307]*Ibid.*
[308]Marcelo Miacci and Evandro Noharo, "Radar Cross Section Measurements (8-12 GHz) of Magnetic and Dielectric Microwave Absorbing Thin Sheets," *Revista de Fisica Aplicada e Instrumentacao* 15, no. 1 (December 2002): 24.
[309]NATO Industrial Advisory Group, *Study SG-170: The Engagement of Low, Slow, and Small Aerial Targets by GBAD* (NATO: October 2012), quoted in Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015 . . .*, 21.
[310]Joe Charlaff, "Analysis: Hostile UAVs … And The Defenses Against Them," *Homeland Security Today*, 8 September 2015.
[311]Patrick Tucker, "Drone-Hunting Blimp To Launch Over Washington," *Defense One*, 15 December 2014.
[312]*Ibid.*

Passive Radio Frequency (RF)

Passive RF detection means locating a sUAS, and often its operator, based on their own radio emissions. This is the only detection method capable of locating the sUAS operator, but of course relies on the operator directly controlling the sUAS via radio as opposed to using a cellular data network or preprogrammed waypoints. It also offers the advantage of being able to simultaneously detect and track multiple sUAS. Of course, if a sophisticated user operates their sUAS under radio silence, it would be invisible to passive RF detection.[313] These systems are generally "relatively inexpensive."[314]

Electro-Optical/Infrared (EO/IR)

EO/IR detection systems are essentially cameras, or arrays of cameras. Individual cameras are designed to operate in specific wavelengths, with specific bands offering different advantages and disadvantages. For example, visible wavelength cameras are cheap and offer high resolution to help with identification.[315] However, they are susceptible to camouflage, obscurants (smoke or weather), and require illumination at night.[316] IR cameras help reduce background clutter by highlighting heat sources and work well at night.[317] However, most sUAS have very low thermal signatures.[318] In general, EO/IR sensors are cheap but need to be set up in arrays with appropriate software in order to be effective without a human monitoring. While

[313]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures,* 18 March 2015, 5; Gabriel Birch *et al, UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 14.
[314]Gabriel Birch *et al, UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 14.
[315]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures,* 18 March 2015, 5; Gabriel Birch *et al, UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 13.
[316]Gabriel Birch *et al, UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 13.
[317]*Ibid.*
[318]*Ibid.*

some experts believe EO/IR detection would be the most effective against sUAS, it is not clear that the image recognition, clutter rejection, and camera array technology is currently available to provide reliable three-dimensional detection and tracking.[319]

Active Optical

Active optical systems refers to systems that include an active optical transmitter, typically a laser. Such systems include Light Detection and Ranging (LIDAR) and range gate imaging. These are not widely fielded, would be expensive, and would have scan rate limitations. However, they could potentially offer very accurate range measurements and better detection capability than passive EO/IR systems.[320]

Magnetic

Magnetic detection systems are also not widely fielded. They could potentially detect sUAS with large metal parts. However, most sUAS do not use many large metal parts and the technology is not well explored for the counter-sUAS role, particularly in urban environments.[321]

Acoustic

Acoustic counter-sUAS sensors rely on a network of microphones and a library of known sUAS sound signatures. These systems are surprisingly mature. For example, U.S. based DroneShield deployed their acoustic system, along with a series of net guns, to help enforce a sUAS ban at the 2015 Boston marathon.[322] They are also relatively inexpensive.[323] However,

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[319]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 5.
[320]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 13.
[321]*Ibid.*, 14.
[322]Kelsey Atherton, "Drone-Proofing the Boston Marathon," *Popular Science*, 21 April 2015
[323]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 4; Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 13.

their maximum detection range is limited (about 500 metres) and is affected by wind, they are highly dependent on having a good library of signatures, and they have issues with false alarms and spoofing in urban environments.[324] They are also unable to detect sUAS without motors running, such as a fixed-wing sUAS gliding to a target.[325]

Human Observers

Human observers, when alert, offer excellent detection ability and are able to initiate countermeasures. However, as Birch *et al* point out, they are expensive and have "demonstrably poor performance for long term monitoring in high consequence, low probability of event situations."[326]

Identification

Once a sUAS is detected, it must be identified. This means distinguishing it from clutter such as birds and identifying it as a threat. This is done using the detection technologies outlined above. Here is an important reason to employ multiple sensor types: while one sensor may have a higher probability of detection in a given environment, another sensor may be better suited to identify the target. Most, if not all, of the detection systems described above offer some ability to identify a target, although the success rate varies significantly based on the environment.

Passive Defences

Passive defences can be some of the most effective means of countering sUAS threats, particularly against less sophisticated operators. They are also often much cheaper than active

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[324]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 4; Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 14.

[325]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 4.

[326]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 14.

defences. There are two main types of passive defences: those based at a sensitive site or person, and those based in the sUAS itself.

Passive defences at a site include things such as barriers, catch nets, physical fencing, or even camouflage and hardening of facilities.[327] They also include simple measures like holding high-profile events indoors during elevated threat levels.[328]

The other form of passive defence is based within the sUAS itself, based on manufacturer imposed geofencing. Geofencing is essentially a built-in limitation on sUAS operation based on GPS location.[329] The massive sUAS manufacturer DJI implemented just such a system in April 2014 around airports. Their static geofencing logic starts tapering a sUAS' maximum altitude within five miles of an airport, and within 1.5 miles it forces the sUAS to land and won't allow it to take off. DJI added Washington, D.C. to the list of geofenced areas after the White House incident in January 2015, and in fact their first geofence was around Tiananmen Square. They have since expanded the geofencing program from 710 airports to 10,000, and have put restrictions on sUAS crossing certain international borders.[330]

Another idea being proposed is dynamic geofencing. This has been put forward as part of NASA's UAS Traffic Management (UTM) development program for the FAA's Pathfinder program. The idea would be to broadcast temporary restrictions, which would be received by

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[327]B.A. Jackson *et al*, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles . . .*, 80-81.

[328]Bryan Card, "The Commercialization of UAVs: How Terrorists Will Be Able to Utilize UAVs to Attack the United States" . . ., 25.

[329]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 2.

[330]Kevin Poulsen, "Why The US Government Is Terrified Of Hobbyist Drones," *Wired*, 5 February 2015.

sUAS internal software, preventing vehicle entry into certain areas. Such dynamic geofences could be used, for example, when fighting wildfires.[331]

Broader implementation of static geofencing and introduction of dynamic geofencing would certainly help reduce non-malicious users from creating hazards with their sUAS. Sophisticated, malicious operators, however, could potentially modify their sUAS to bypass these restrictions, particularly since so much sUAS modification guidance is available online.[332]

Active Defences

Active sUAS defences comprises a broad range of measures. Some of these would traditionally be considered kinetic or non-lethal, while others would not. Some traditional methods of air defence (AD) are discarded here as impractical for sUAS, such as interception with fighter aircraft.

Traditional Kinetic AD

Traditional AD systems, designed for intercepting larger targets such as fighters or surface-to-surface missiles (SSMs), have difficulties targeting sUAS. This is due to difficulty in detecting smaller, slower targets and also due to difficulties with weapons fuzing.[333] However, some systems have been specifically tailored for smaller targets, such as Lockheed Martin's Extended Area Protection and Survivability Integrated Demonstration (EAPS ID) Counter

[331]National 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.
[332]C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* . . ., 15.
[333]NATO Industrial Advisory Group, *Study SG-170: The Engagement of Low, Slow, and Small Aerial Targets by GBAD* . . . quoted in Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 18.

Rocket Artillery Mortar (C-RAM) system (Figure 5.3).[334] Israel used a Patriot missile with its Iron Dome system to shoot down a Hamas UAS in July 2014.[335]

Figure 5.3 - Lockheed Martin EAPS ID C-RAM system

Source: Lockheed Martin, "Extended Area Protection and Survivability"

These systems have three significant drawbacks. The first is cost. For example, Lockheed advertises their C-RAM system as being relatively cheap at just $16,000 per round.[336] Obviously this is well above the cost of almost any sUAS. The second is collateral damage, particularly in the domestic environment. Many experts warn that such systems would likely cause more damage intercepting a sUAS then allowing the attack to proceed.[337] For example, in the First Gulf War, U.S. Patriot missiles intercepting an Iraqi SCUD SSM created significant debris,

[334]Lockheed Martin, "Extended Area Protection and Survivability," Last accessed 22 December 2015, http://www.lockheedmartin.ca/us/products/eaps.html.
[335]Dan Gettinger, "What You Need to Know About Lasers," *Center for the Study of the Drone at Bard College,* 10 November 2014.
[336]Lockheed Martin, "Extended Area Protection and Survivability," Last accessed 22 December 2015, http://www.lockheedmartin.ca/us/products/eaps.html.
[337]NATO Industrial Advisory Group, *Study SG-170: The Engagement of Low, Slow, and Small Aerial Targets by GBAD* . . . quoted in Gabriel Birch *et al, UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 18; C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* . . ., 17; Ryan Wallace and Jon Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," . . .: 24; B.A. Jackson *et al, Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles* . . ., 79.

killing one and wounding 23 people.[338] The third disadvantage of these systems is that they can be overwhelmed by swarm attacks.[339]

Small Arms

Small arms can be very effective against sUAS, provided they can score a hit. Several sUAVs have been downed by shotguns. For example, a June 2013 video posted online showed a sUAV, operated by an activist during a protest, being shot down by Turkish police.[340] There have been several reported incidents in the U.S. of citizens using shotguns to shoot down sUAVs they believed were invading their privacy, including a New Jersey man in September 2014, a California man in June 2015, and a Kentucky man in July 2015.[341] Sniper rifles can also be effective, although it may be difficult to get a hit. One expert watched trained snipers take five or six shots to hit a moving sUAV.[342] However, a U.S. Marine sniper was able to successfully engage one at Black Dart in 2015, and there are also reports of a pro-Russian sniper in Ukraine disabling a Ukrainian UAS.[343] A sniper rifle may be overkill. According to one expert, even a hit with high-pressure water or a slingshot could potentially down a sUAV.[344] In fact, water cannons such as those used in anti-piracy applications have been suggested, but they have a limited range and currently no systems are integrated with automatic tracking and aiming.[345]

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[338]B.A. Jackson *et al*, *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles . . .*, 88.
[339]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015 . . .*, 18.
[340]Ryan Gallagher, "Video Reportedly Shows Drone Shot Down by Police at Turkish Protests," *Slate*, 24 June 2013.
[341]Cyrus Farivar, "Kentucky man shoots down drone hovering over his backyard," *ARS Technica*, 29 July 2015; Dan Gettinger, "Domestic Drone Threats," *Center for the Study of the Drone at Bard College*, 20 March 2015.
[342]Eric Limer, "How to Shoot Down a Drone," *Popular Mechanics*, 6 August 2015.
[343]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.
[344]Eric Limer, "How to Shoot Down a Drone," *Popular Mechanics*, 6 August 2015.
[345]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015 . . .*, 20.

The issue with some small arms is again collateral damage. Any kind of rifle round can come down with enough kinetic energy to kill a bystander.[346] However, several experts agree that a shotgun loaded with small birdshot is unlikely to cause any collateral damage due to the low terminal velocity of the pellets.[347] It would still be perfectly effective against a sUAV, as long as the range is not too great.[348] Non-lethal rounds are another option. The advantage of small arms is their low cost. As Wallace and Loffi put it, "a shotgun seems equally up to the task of engaging certain threat UAS platforms as more expensive developmental weapon systems."[349]

Lasers

Several countries have developed, and even deployed, anti-UAS lasers including Israel, China, and the U.S.[350] Lasers can be used to disable optical sensors on a sUAS (dazzling) in order to degrade end-game navigation (assuming the operator is not using GPS guidance).[351] They can also be used to physically destroy the sUAV, as shown in Figure 5.4. Lasers have two main advantages. First, they are almost impossible to counter once a target is acquired. Second,

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[346]Eric 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.

[347]*Ibid.*

[348]Eric Limer, "How to Shoot Down a Drone," *Popular Mechanics*, 6 August 2015.

[349]Ryan Wallace and Jon Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," . . .: 23.

[350]Gareth Jennings, "ADEX 2015: Rafael showcases Iron Beam C-RAM & C-UAV laser," *IHS Jane's Defence Weekly*, 19 October 2015; "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; Jordan Golson, "Army's New Laser Cannon Blasts Drones Out Of The Sky, Even In Fog," *Wired*, 5 September 2014; Sean Gallagher, "Navy will deploy first ship with laser weapon this summer," *ARS Technica*, 6 March 2014.

[351]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 18; Laurent Beaudoin, *et al*, "Potential Threats of UAS Swarms and the Countermeasure's Need," . . ., 6.

they are very cheap to operate, with estimates of about $1 per laser shot compared to about $1 million for a Patriot missile.[352]

However, lasers have several drawbacks. For one, they are expensive to buy and the technology is not very mature.[353] They are affected by bad weather, although Boeing's High Energy Laser Mobile Demonstrator (HEL MD) successfully engaged UAS in foggy conditions during tests in 2014.[354] The systems all currently have about the same engagement range – about 2km – and all take about 5-15 seconds or so to fully disable a UAS.[355] As Abbott *et al* point out, for a fast commercially available sUAS this could mean the sUAV travelling over 100 metres before being disabled, which could be unacceptable in an urban environment.[356]

[352]Dan Gettinger, "What You Need to Know About Lasers," *Center for the Study of the Drone at Bard College,* 10 November 2014.
[353]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 18-19; Ryan Wallace and Jon Loffi, "Examining Unmanned Aerial System Threats & Defenses: A Conceptual Analysis," . . .: 21-22.
[354]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 19; Jordan Golson, "Army's New Laser Cannon Blasts Drones Out Of The Sky, Even In Fog," *Wired,* 5 September 2014.
[355]Gareth Jennings, "ADEX 2015: Rafael showcases Iron Beam C-RAM & C-UAV laser," *IHS Jane's Defence Weekly*, 19 October 2015; "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; Jordan Golson, "Army's New Laser Cannon Blasts Drones Out Of The Sky, Even In Fog," *Wired*, 5 September 2014; Sean Gallagher, "Navy will deploy first ship with laser weapon this summer," *ARS Technica*, 6 March 2014.
[356]C. Abbott *et al*. *Hostile Drones: The Hostile Use of Drones by Non-State Actors Against British Targets* . . ., 18.

Figure 5.4 - The U.S. Navy's Laser Weapons System (LaWS) and a Successfully Destroyed Target UAS

Source: Mick, "Why the U.S. is Racing to Shoot Down Iranian UAVs With Lasers by Next Summer," *Daily Tech*, 9 April 2013.

Net Guns

A novel idea to take down sUAS with minimal collateral damage is to launch a net from the ground. The obvious drawback to this is the net gun's maximum range. The net guns DroneShield deployed to the 2015 Boston Marathon had a range of about 50 feet.[357]

Birds of Prey

In October 2014, a video surfaced of a hawk attacking, and downing, a quadcopter sUAV. Several experts initially dismissed the idea of training birds to take down sUAVs due to the risk of injury to the birds.[358] However, in February 2016 the Dutch National Police

[357]Carl Franzen, "The Anti-Drone Business Is About to Take Off," *Popular Mechanics*, 1 May 2015.
[358]Kelsey Atherton, "Can Birds Be Trained To Bring Down Drones?" *Popular Science*, 5 December 2014.

announced they were doing just that, with eagles.[359] While the idea is promising, it is still experimental.

Figure 5.5 - A Trained Eagle Attacking a sUAV in Holland

Source: "Eagle vs drone: Watch police video of bird taking down tech," *The Seattle Times*, 2 February 2016.

Interceptor sUAS

A surprising number of companies are developing sUAS designed to intercept and take down other sUAS, although the technology remains fairly immature.[360] They are also severely limited when the hostile sUAS is as fast, or faster, than the interceptor.[361] Nevertheless, several innovative examples have been demonstrated. The French Malou has developed net-carrying sUAS, while Rapere, another French company, is developing sUAS that dangle a wire to tangle rotary wing sUAV.[362] Dutch Delft Dynamics successfully mounted a net gun on a sUAV and

[359]"Eagle vs drone: Watch police video of bird taking down tech," *The Seattle Times*, 2 February 2016, last accessed 27 March 2016, http://www.seattletimes.com/nation-world/oddities/eagles-vs-drones-dutch-police-eye-birds-to-prey-on-drones/.
[360]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 8.
[361]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 20.
[362]Kelsey Atherton, "France Tests Kamikaze, Netted Interceptor Drones To Protect Nuclear Reactors," *Popular Science*, 10 February 2015.

used it to take down another sUAV.[363] The Tokyo police have actually deployed net-carrying sUAS to protect vital sites.[364]

Figure 5.6 - Malou Net Carrying Interceptor sUAS

Source: Moseman, "This Drone Interceptor Captures Your Pathetic Puny Drone With a Net," *Popular Mechanics,* 11 February 2015.

Hacking

One method of stopping unmodified sUAS with unencrypted command links is to hijack control of the vehicle. sUAS hacking competitions are becoming increasingly popular. A few hacking tools have already been demonstrated, such as SkyJack and Maldrone.[365] These tools enable a hacker to gain control of specific sUAS, and even to spread malware to other sUAS in range. This presents an obvious advantage against sUAS swarms.

[363]Delft Dynamics, "DroneCatcher catches drone," last accessed 22 December 2015, http://www.delftdynamics.nl/index.php/en/news-en/117-dronecatcher-catches-drone.
[364]"Drone squad to be launched by Tokyo police," *BBC News,* 11 December 2015, last accessed 2 January 2016, http://www.bbc.co.uk/news/technology-35070818.
[365]Kamkar, Samy. "Samy Kamkar – SkyJack: autonomous drone hacking." Last accessed 27 December 2015. http://samy.pl/skyjack/; Thomas Fox-Brewster, "Maldrone: Watch Malware That Wants To Spread Its Wings Kill A Drone Mid-Flight," *Forbes,* 27 January 2015.

The disadvantage of these hacking methods is that there are several ways to negate them. The command link could be encrypted using openly available software, or the sUAS could be operated autonomously based on pre-set waypoints.[366]

RF Jamming

RF jamming can be one of the most effective ways of stopping hostile sUAS. In particular, it offers the ability to easily engage multiple targets at once, which is critical to stopping a swarm attack.[367] Four types of counter-sUAS jamming are being developed: GPS spoofing, GPS denial, link denial, and high-power microwave (HPM)/high-power electromagnetic (HPEM).

GPS spoofing is an advanced jamming technique that tricks a receiver with a false position. It is difficult to do but has been demonstrated against sUAS.[368] Iran claims that it hijacked and stole a U.S. UAS in 2011 using a combination of hacking and GPS spoofing, although the authenticity of their claim is questionable.[369]

GPS denial is a much simpler technique. Noise jamming on GPS frequencies essentially denies any GPS signal, but unlike spoofing does not trick the receiver with a false position. Against many commercially available sUAS, this results in the aircraft stopping in midair or

[366]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 6.
[367]Laurent Beaudoin, *et al*, "Potential Threats of UAS Swarms and the Countermeasure's Need," . . ., 5-6.
[368]Andrew Roush, "Up in the Air," *Alcade*, 29 October 2014.
[369]Scott Peterson and Payam Faramarzi, "Exclusive: Iran hijacked US drone, says Iranian engineer," *Christian Science Monitor*, 15 December 2011; Adam Rawnsley, "Iran's Alleged Drone Hack: Tough, But Possible," *Wired*, 16 December 2011.

crashing.[370] However, other more sophisticated sUAS can revert to manual control or a less accurate inertial navigation system.[371]

Both types of GPS jamming have drawbacks. More expensive receivers can be designed with anti-jam features.[372] Further, there is a significant risk of unsafe collateral effects to other aircraft in the area, although this can be mitigated somewhat with directional jammers.[373]

Command link denial is similar to GPS denial. This type of jamming denies the sUAV the ability to receive RF commands. This again can be very effective against unsophisticated operators, but a more advanced sUAS can revert to preplanned waypoint navigation.[374]

HPM/HPEM weapons cause "temporary disruption to physical destruction of unprotected electronics."[375] The technology offers promise, but is still immature and has collateral damage concerns.[376]

Most RF jamming systems are fairly large, and are either fixed or vehicle mounted. At least one manufacturer, however, has built a rifle-sized sUAS jamming system. Battelle's DroneDefender weapon, shown in Figure 5.7, weighs less than ten pounds and claims to jam sUAS control systems, GPS, and radio detonation signals.

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[370]Kyle Mizokami, "You Don't Need to Shoot Down a Drone to Destroy It Anymore," *Popular Mechanics*, 8 October 2015; David Szondy, "Battelle's DroneDefender anti-drone beam gun grounds UAVs," *Gizmag*, 16 October 2015.
[371]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 8.
[372]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 19.
[373]House of Representatives . . ., *Unmanned Aerial System Threats: Exploring Security Implications and Mitigation Technologies: Todd Humphreys, Statement On The Security Threat Posed By Unmanned Aerial Systems And Possible Countermeasures*, 18 March 2015, 7.
[374]*Ibid.*, 8.
[375]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 19-20.
[376]*Ibid.*

Figure 5.7 - Battelle's DroneDefender Jamming System

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

Integrated Counter-sUAS Systems

Several companies have developed integrated counter-sUAS systems. These systems typically employ several detection and identification methods, combined with RF jamming countermeasures. Examples include CACI's Skytracker, which is being used as part of the FAA Pathfinder program, and the Blighter Surveillance Systems Anti-UAV Defence System (AUDS), which has been used by Britain on several occasions.[377] It should be noted that none of these systems are, to date, well proven. Birch *et al* conclude their market survey: "Systems exist in the commercial domain that likely solve a limited piece of the larger LSS [low, slow, and small] UAS problem, but no complete system appears to exist with evidence of acceptable performance."[378]

[377]CACI International Inc. "SkyTracker – Overview." Last accessed 8 December 2015. http://www.caci.com/skytracker/index.shtml; Blighter 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.
[378]Gabriel Birch *et al*, *UAS Detection, Classification and Neutralization: Market Survey 2015* . . ., 33.

Summary

This chapter laid out many examples of possible methods to counter a malicious sUAS operator during the various stages of an attack. While perhaps no single system has yet proven itself as a counter-sUAS panacea, many offer promise and, in combination, could be effective. The critical step that is missing, and beyond the scope of this paper, is to combine a realistic threat assessment with a cost benefit analysis to develop a plan of what should reasonably be done to defend ourselves.

CHAPTER 6 – CONCLUSION

Small UAS present fantastic possibilities for Canada. Millions of sUAS are flying worldwide, with numbers growing rapidly. Canada's three well established sUAS applications (law enforcement, precision agriculture, and media) will continue to grow while new applications such as surveying and infrastructure inspections show great promise. Canada has over 150 companies developing sUAS technology, taking advantage of testing facilities and a fairly efficient regulatory process. Economically, although Canada may not rival the U.S. in terms of military UAS development, experts still estimate the Canadian UAS industry will be worth well over $100 million over the next ten years. The myriad benefits of small UAS to Canada, both in terms of their many uses and in terms of the growing Canadian UAS industry, should drive policies that minimize restraints on commercial and recreational use.

However, the advent of mass produced, low-cost, and easily piloted small UAS has resulted in an increased potential for malicious use of these systems, both against civilian targets at home and against Canadian interests abroad. Already, incidents of sUAV crashes and near misses with manned aircraft are on the rise, including in Canada. sUAVs have shown the capability to carry guns, flamethrowers, and explosives. At the same time, sUAVs have been flown dangerously close to the leaders of Germany, Japan, and the United States as well as near sensitive locations such as nuclear sites and the White House. Disrupted plots in Germany and the U.S. have shown that terror groups are now considering sUAS delivery as a valid mode of attack. Insurgent groups in the Middle East are increasingly making use of the technology. Canada has been, and will continue to be, a target for terrorists and must prepare for the possibility of a sUAS attack.

The juxtaposition of these issues demands a balanced UAS policy that promotes development while ensuring safety and security. Canada needs to catch up to other countries that already permit BVLOS UAS operations and further streamline the SFOC process. At the same time, Canada must acknowledge the growing threat. Germany, France, the UK, Australia, South Korea, and the U.S. are all actively looking into counter-sUAS strategies. To date, Canada's UAS policies, while progressive in addressing regulatory issues and commercial needs, are lagging the rest of the world's acknowledgement of potential security threats.

Given the tremendous benefits but grave potential threats presented by sUAS, the Government of Canada must implement a domestic sUAS defence strategy that balances the need to promote expanded sUAS use with the need to ensure public safety. This strategy should be layered to include attack prevention, readiness measures, detection measures, passive and active defences, and post-attack forensics, while weighing cost and effort against threat severity and probability.

In order to proceed in a coherent manner, the Government of Canada should create an inter-agency task force to research and develop a counter-sUAS plan, based on a thorough risk assessment and cost-benefit analysis, to determine what needs to be defended, how to do so, and how much to spend. Some specific defensive measures should include a robust registration system as well as mandatory manufacturer-imposed geofencing. Canada should actively participate with the U.S. in developing a low-level airspace system that includes dynamic geofencing and other measures to prevent mid-air collisions. Potential terrorist targets such as sports stadiums should have basic, low-cost passive defences such as nets in place. Our most sensitive sites and people should be protected with more advanced counter-sUAS systems. At the

same time, Canada should be participating in U.S. and European exercises to remain up to speed on the latest counter-sUAS technology and TTPs.

It will never be possible to defend the entire country against every threat. However, a balanced sUAS strategy can minimize the risks of malicious and irresponsible sUAS use while encouraging the nascent Canadian industry to flourish.

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