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NO LONGER HIDING BEHIND ARCTIC ICE -- AN UNMANNED AIRCRAFT SYSTEM FOR THE CANADIAN ARCTIC

Maj C.F. Palmer

JCSP 43

Exercise Solo Flight

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EXERCISE *SOLO FLIGHT* – EXERCICE *SOLO FLIGHT*

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Maj C.F. Palmer

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INTRODUCTION

Interest in the Arctic Region has gained greater momentum since the end of the cold war, to the extent that in the 1990's an exclusive intergovernmental forum called the Arctic Council was designed to "...promote cooperation, coordination, and interaction..."¹ among the many Arctic States. As the Arctic Region gains further international interest and attention due to environmental changes, the Canadian Government needs to consider its future role in this part of the world. As a permanent member of the Arctic Council, the Canadian Government not only has a responsibility in maintaining a spirit of cooperation with its Arctic partners, but also has a responsibility as a leader in this circumpolar community. As international communities gain more awareness of the Arctic's previously inaccessible untapped potential concerning natural mineral resources, significant fuel reserves, and new commercial transport passageways, Canada can no longer hide behind a wall of Arctic ice. Canada must accept its greater responsibility as a major player in the Arctic Region, and seek the capabilities necessary to protect its national security interests. Canada must also realize that Arctic security is a key component to Canadian security, and that as a responsible authority it must maintain a robust capability to adequately monitor activities in the Canadian North, be they for commercial, tourism, environmental, economic, or other purposes.

Although the Canadian Government has invested in and made some progress in the security of its Arctic Region, there still exist critical capability gaps between its strategic and tactical Arctic intelligence, surveillance and reconnaissance (ISR) capabilities. This is a gap which must be filled to ensure Canadian security and

¹Arctic Council, "About us," last accessed 29 April 2017, <http://www.arctic-council.org/index.php/en/>.

sovereignty, in particular along the Northwest Passage (NWP) where there are large expanses of uninhabited territory and few safety and security capabilities readily available.

This paper will show that Canada has a severe capability gap in how it protects its sovereignty in the Arctic, and will suggest that this gap should be filled with a technological solution in the form of an Unmanned Aircraft System (UAS). This paper is written in three parts. The first part will discuss recent changes in the Arctic environment that are stimulating the Canadian Government to look hard at the problem of security and sovereignty in the Arctic and review the latest Government policy papers that pertain to the Arctic. The second part will discuss Arctic surveillance capabilities that the Canadian Government employs currently, and reveal that there currently is a severe capability gap in the area of *persistent surveillance* for the Arctic. The final part will describe the Canadian military's prior use of UAS technology, and discuss how the techniques employed to successfully procure those systems should be utilized to facilitate progress of the Joint Unmanned Surveillance and Target Acquisition System (JUSTAS) Program. This paper will be written by analyzing journal articles and literature from Canadian experts in the field of Canadian Arctic security and sovereignty, and will review current Canadian governmental security policy that concerns the Arctic.

THE CANADIAN ARCTIC DEFINED

The Arctic is significant to Canada in its size, potential, and remoteness. The Canadian Arctic comprises 76% of Canadian landmass, and is a part of all three Territories and the northern portions of four Provinces.² The Canadian Arctic land mass

²Robert M. Bone, *The Canadian North: Issues and Challenges* (Don Mills:Oxford University Press, 2012), 4.

is huge and complex, with the Arctic Archipelago alone covering 1.4 million square kilometers, and contains 94 major islands and over 36,000 minor islands.³ The Arctic has four seasons which varies in available daylight as you travel north. The North Pole, for example, is shrouded in complete darkness from late October to early March, whereas it is lit in continual sunlight from late March until late September.⁴ A demanding environment for any form of operations, be they scientific, military, or commercial, the average temperature in the Canadian Arctic in the winter months is less than -20C, with February seeing temperatures in the -50C range. The temperature averages around +5C during the summer months.⁵

There is now little doubt that climate change over the last few decades has had a pronounced effect on the Arctic. Satellite imagery from the 1980s and onwards has shown a gradual increase in the ice melt season, which is now three weeks longer than what was reported 35 years ago.⁶ This increased melt season results in less ice during the summer season, which means less ice is available to thicken during the winter season. Much like when you clear a spot on your driveway in wintertime, water, like asphalt, absorbs heat from the sun. Called the Albedo Effect,⁷ once cleared of snow and ice, this heat greatly accelerates the melting process in the surrounding areas. The Intergovernmental Panel on Climate Change predicts that this Albedo Effect process will

³Historica Canada, "Arctic Archipelago," last accessed 5 April 2017, <http://www.thecanadianencyclopedia.ca/en/article/Arctic-archipelago/>.

⁴ Pacific Marine Environmental Laboratory, "Arctic Zone," last accessed 2 May 2017, https://www.pmel.noaa.gov/Arctic-zone/gallery_np_seasons.html.

⁵ University of Guelph, "The Arctic Winter," last accessed 15 April 2017, http://www.Arctic.uoguelph.ca/cpe/environments/ climate/climte_present/temp/arc_winter.htm#.

⁶ National Geographic, "Arctic Ice is Shrinking," last accessed 3 April 2017, <http://ngm.nationalgeographic.com/2016/01/Arctic-ice-shrinking-graphic-environment-text>.

⁷ Earth and Space Research, "Albedo Definition," last accessed 15 April 2017, <https://www.esr.org/outreach/glossary/albedo.html>.

likely result in an ice-free Arctic summer as early as 2040.⁸ This melting is not only affecting the Canadian Arctic. For the first time in 2009 commercial ships were able to pass through the Russian North Sea Route unaccompanied by icebreakers from Vladivostok to the Netherlands.⁹ This accelerated reduction in Arctic ice has gripped international attention. In their article *The Geopolitics of Arctic Melt*, authors Charles Ebinger and Evie Zambetakis state that "... climate change has catapulted the Arctic into the center of geopolitics, as melting Arctic ice transforms the region from one of primarily scientific interest into a maelstrom of competing commercial, national security and environmental concerns...."¹⁰

For the purpose of this paper this international focus in the Arctic can be consolidated into two main themes: economic (for example, new access to hydrocarbon reserves), and commercial (for example, access to new maritime commercial trade routes). The amount of available oil and fuel reserves in the Arctic is significant. According to a U.S. Geological Survey (USGS) in 2008, the Arctic Region holds approximately 240 billion barrels of untouched oil and natural gas.¹¹ Some Arctic nations have commenced major projects to extract oil and natural gas in their northern area, including Norway, Iceland and Russia.¹² The advantage of a Northwest Passage (NWP) available for maritime commercial shipping is significant. The NWP route can offer a

⁸ Intergovernmental Panel on Climate Change, "Climate Change 2013: The Physical Science Basis," last accessed 20 April 2017, <http://www.ipcc.ch/report/ar5/wg1/>.

⁹ Climatewire, "First commercial ships taking Russia's Northeast Passage," last accessed 20 April 2017, <https://www.eenews.net/climatewire/2009/08/25/stories/81736>.

¹⁰ Charles Ebinger and Evie Zambetakis, *The Geopolitics of Arctic Melt*, last accessed 20 April 2017, https://www.brookings.edu/wp-content/uploads/2016/06/11_arctic_melt_ebinger_zambetakis.pdf.

¹¹ D. L. Gautier *et al.*, "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle," U.S. Geological Survey, USGS Fact Sheet 2008-3049, 2008.

¹² Ondrej Urban, "Future of the Arctic Oil Reserves," Stanford University, last accessed 21 April 2017, <http://large.stanford.edu/courses/2015/ph240/urban2/>.

reduction of about 4,000 nautical miles (nm) on voyages between Europe and Asia,¹³ although there still remains some debate as to whether the NWP will ever be a truly viable commercial trade route, due to the costs and complexities of traversing that part of the world.¹⁴ However, since the 1980's, voyages through the NWP have proven to be an annual event. Averaging less than ten voyages per year prior to the 1980's, the shipping frequency has grown to more than 20 per year in the last decade, with the Northwest Territory Government reporting 30 in 2013.¹⁵ As the NWP gains attention from a variety of players in numerous industries such as research, resource extraction, tourism, and commercial transit shipping, so too should the Canadian Government pay attention to this new trend.

Although the Arctic Council, which is currently comprised of eight states' (including Canada, Denmark, Finland, Iceland, Norway, Russia Federation, Sweden and USA)¹⁶ purpose is for "...promoting cooperation, coordination and interaction among the Arctic States..."¹⁷, not all States in the Arctic Region cooperate all the time, and there are still unresolved issues concerning territorial sovereignty. For example, the Canadian NWP remains a contested waterway between Canada and the United States (US). Canada has claimed that the NWP is internal waters and therefore has sovereign control over the NWP (for example, it could stop shipping through the NWP if so desired), whereas the

¹³Mondaq, "Canada: NORDREG now Mandatory Within the Northwest Passage," last accessed 21 April 2017, <http://www.mondaq.com/canada/x/114788/Marine+Shipping/NORDREG+now+Mandatory+Within+the+Northwest+Passage>.

¹⁴Ernie Regehr, "Arctic Maritime Domain Awareness: A domestic and strategic imperative," *Disarming Arctic Security*, the Simons Foundation, February 3, 2014, 3.

¹⁵ Government of Northwest Territories, "State of the Environment," last accessed 14 April 2017, <http://www.enr.gov.nt.ca/state-environment/73-trends-shipping-northwest-passage-and-beaufort-sea>.

¹⁶ Arctic Council, "About us," last accessed 29 April 2017, <http://www.arctic-council.org/index.php/en/>.

¹⁷ Arctic Council, "The Arctic Council Background," last accessed 17 April 2017, <http://www.arctic-council.org/index.php/en/about-us>.

US claims that the NWP is a strait that should remain open to international shipping.¹⁸

According to Ron Huebert, senior research fellow with the Centre for Military and Strategic Studies, in his co-written book entitled *Canada and the Changing Arctic*:

As long as Canada can show that it is serious about asserting proper control over the region and about safeguarding its security there, the Americans should respond by not pressing their position. In other words, American agreement not to challenge Canada would be exchanged for Canadian protection of the region.¹⁹

As such, the role of the Canadian sovereignty encompasses both security and protection. Protection is not only against military threats from other States, but includes protection against criminal activities, protection for tourists and travelers in the North (as seen with the recent 900 passenger *Crystal Serenity* NWP Arctic cruise completed in September 2016),²⁰ and protection against environmental disasters. As noted in Defence Research and Development Canada (DRDC) Northern Watch Program, as greater numbers of humans flock to the North, there is an increased requirement for surveillance to ensure that conditions of safety, security, and sovereignty are maintained.²¹ In his article *The Canadian Armed Forces in the Arctic: Purpose, Capabilities, and Requirements*, author Adam Lajeunesse describes the role of the military in the Arctic as “defending sovereignty consists of exercising *effective* control in response to specific needs and interests in Canadian territory and internal waters. This entails focused efforts

¹⁸ Franklyn Griffiths, Rob Huebert and P. Whitney Lackenbauer, *Canada and the Changing Arctic: Sovereignty, Security and Stewardship* (Waterloo: Wilfred Laurier University Press, 2011), 46-47.

¹⁹ *Ibid.*, 47.

²⁰ US News, "Thanks to Melting Ice, Cruise Ship Travels Northwest Passage," last accessed 28 April 2017, <https://www.usnews.com/news/news/articles/2016-09-09/giant-cruise-ship-makes-historic-voyage-in-melting-arctic>.

²¹ Garry J. Heard, Bruce McArthur, and Gary Inglis, "Overview of the technical results of the Northern Watch Project," last accessed 20 April 2017, cradpdf.drdc.rddc.gc.ca/PDFS/unc253/p804761_A1b.pdf.

to monitor northern activity and respond to *unconventional* security situations.”²²

There remains little doubt that the Government of Canada sees the Arctic as a national interest, made evident in certain themes and messaging that exist in policy documentation that remains consistent regardless of what political party is in power. These themes, if summarized quickly, is the requirement of the government to exercise sovereignty (control) in the Arctic through key capabilities including continual surveillance and conspicuous presence. This was best reiterated during a Report of the Standing Senate Committee on Fisheries and Oceans in December 2009:

A primary concern for Canada is that ships transiting the Northwest Passage recognize Canadian sovereignty and comply fully with the Canadian regulations. The evidence previously heard by the Committee (last year) suggested that, without Canada taking adequate control measures with respect to unauthorized shipping activity, the Passage risks becoming progressively “internationalized” and subject to right-of-transit passage.²³

The responsibility for sovereignty does not fall solely within the purview of the military, and in fact, sovereignty is upheld through a comprehensive whole-of-government approach at the federal, provincial/territorial and municipal levels. Former CDS General Natynczyk made it very clear in his speech to the Standing Senate Committee on National Security and Defence in 2010 that the military plays a very important role in “...supporting the success of others” in the North.²⁴ For example, aeronautical search and rescue (SAR) in the Arctic Region is within scope of the

²² Canadian Global Affaires Institute, “The Canadian Armed Forces in the Arctic: Purpose, Capabilities, and Requirements,” last accessed 20 April 2017, http://www.cgai.ca/canadian_armed_forces_in_the_Arctic.

²³ Canadian Senate Report of the Standing Senate Committee on Fisheries and Oceans, “Controlling Canada’s Arctic Waters: Role Of The Canadian Coast Guard,” last accessed 15 April 2017, <https://sencanada.ca/content/sen/committee/402/fish/rep/rep07dec09-e.pdf>.

²⁴ Parliament of Canada, “Proceedings of the Standing Senate Committee on National Security and Defence Issue 5 - Evidence - Meeting of June 7, 2010,” last accessed 20 April 2017, <https://sencanada.ca/en/Content/SEN/Committee/403/defe/05evb-e>.

Department of National Defence (DND), whereas maritime SAR is within scope of the Canadian Coast Guard (CCG) through the Department of Fisheries and Oceans (DFO). While sovereignty patrolling and surveillance in the Arctic is within the purview of the military, the Canadian Border Control Agency is responsible for dealing with border issues (i.e. activities concerning crossing Canada's borders) and the Royal Canadian Mounted Police and other police forces are responsible for dealing with criminal activities within Canadian territory. The following are recaps of capstone documents that outline the Canadian Government's interests in the Arctic.

The Statement on Canada's Arctic Foreign Policy was produced under Prime Minister Stephen Harper in 2010. Although this is labeled as a foreign policy, it includes strong wording in the realm of domestic policy. This policy reveals four pillars for Canada to advance its international and domestic interests: "... exercising sovereignty; promoting economic and social development; protecting our environmental heritage; and improving and devolving Northern governance."²⁵ In addition, this same policy states that "...Canada is committed to exercising the full extent of its sovereignty, sovereign rights and jurisdiction in the region."²⁶ As the term *sovereignty* is featured throughout the document, the term should be afforded some clarification. According to Rob Huebert, "...sovereignty comes down to the issue of control within a specific geographic area by a specific body."²⁷ Sovereignty can be claimed if there is a defined territory (which is accepted by the international community), a recognized governance system exists, and

²⁵Global Affaires Canada, "Statement On Canada's Arctic Foreign Policy," last accessed 23 April 2017, http://www.international.gc.ca/arctic-arctique/arctic_policy-canada-politique_arctique.aspx?lang=eng.

²⁶*Ibid.*,

²⁷Franklyn Griffiths, Rob Huebert and P. Whitney Lackenbauer, *Canada and the Changing Arctic: Sovereignty, Security and Stewardship* (Waterloo:Wilfred Laurier University Press, 2011), 19.

that people inhabit the defined territory.²⁸ Rob Huebert is quick to point out in his book that there still remain some contentious issues and friction pertaining to how the certain parts of the Arctic Region territory, in particular the NWP and continental shelf, is defined and delineated between competing Arctic States.

The Canadian Government published its *Canada First Defence Strategy* in 2008, a strategy that remains extant as of the writing of this paper and is still active on the Government of Canada website. This strategy proposed to “... continue rebuilding the Canadian Forces into the state-of-the-art military that Canada needs...”²⁹ and listed six core missions. The Arctic is featured prominently throughout the document including in the first core mission, where the strategy states: “[the military will] conduct daily domestic and continental operations, including in the Arctic and through NORAD.”³⁰ This strategy recognizes the importance of investing in Arctic sovereignty activities and capabilities in light of potential illegal activities in the North spurred on by the changing weather patterns, namely an increase in shipping, resource exploration and tourism. It states explicitly that military’s role is to: “...ensure the *constant* monitoring of Canada’s territory and air and maritime approaches, including in the Arctic, in order to detect threats to Canadian security as early as possible.”³¹

Most recently in 2016, the Minister of National Defence published the *Report on Plans and Priorities* for the Department and Canadian Armed Forces. Again the Arctic is featured prominently in this publication, where it states: “Protecting Canada’s sovereignty and the security of Canadians is the Canadian Armed Forces’ first

²⁸Franklyn Griffiths, Rob Huebert and P. Whitney Lackenbauer, *Canada and the Changing Arctic: Sovereignty, Security and Stewardship* (Waterloo:Wilfred Laurier University Press, 2011), 14.

²⁹National Defence and the Canadian Armed Forces, “Canada First Defence Strategy,” last accessed 20 April 2017, <http://www.forces.gc.ca/en/about/canada-first-defence-strategy.page>.

³⁰*Ibid.*,

³¹*Ibid.*,

responsibility. As such, there will be a renewed focus on surveillance and control of Canadian territory and approaches, particularly our Arctic regions.” This same report further identifies a requirement for an expression of military power as a component of national sovereignty “...through constant monitoring and conspicuous presence of military forces in Canadian territory, including the Arctic...”³²

CURRENT STATE OF ARCTIC SURVEILLANCE

At present there is a collage of capabilities that the Canadian Government employs in the Arctic to survey maritime approaches to the Northwest Passage and generate maritime domain awareness. Some of the capabilities are imposed by international and national laws (regulatory), some are technological in nature, and some are less-than technological (physical) in nature. Although many of the capabilities are complementary in nature, they all have limitations that reveal gaps in the Arctic surveillance systems as a whole, in particular concerning maritime security. The following section will describe some of the major platforms that the whole-of-government currently employs in the Arctic for surveillance and reveal that there are critical capability gaps in Canada’s ability to provide persistent surveillance in the north.

Regulatory

Under international regulations set out by the International Maritime Organization, all ships over 300 tons, and passenger ships of all sizes, must make use of self-reporting identification systems. The commonly used system is called Long Range

³² National Defence and the Canadian Armed Forces, “Department of National Defence and the Canadian Armed Forces 2016-17 Report on Plans and Priorities,” last accessed 15 April 2017, <http://www.forces.gc.ca/en/about-reports-pubs-report-plan-priorities/2016-index.page>.

Identification and Tracking (LRIT).³³ The Canadian Coast Guard (CCG) manages the LRIT data center, and the data is shared with other government departments through the DND-managed Maritime Operations Centers (MSOCs), located on the Atlantic and Pacific coasts and the Great Lakes³⁴. In addition to LRIT, vessels use a radio system called Automatic Identification System (AIS) which report similar info as the LRIT but also share critical information with other ships and pass information to remote collection sites. According to Ernie Regehr, Senior Fellow in Defence Policy and Arctic Security, in his Simons Foundation article *Disarming Arctic Security*, Canada employs only one AIS remote collection site in the Arctic, and recognizes there are “major reporting gaps in the North”.³⁵

Canada has mandated that all vessels that report under the LRIT and AIS must report a sailing plan prior to entering Canadian northern waters through a system called NORDREG. The objectives of this system are “...the enhancement of safety and movement of traffic, the strengthening of Canadian sovereignty in Arctic waters and the prevention of pollution of Arctic waters.”³⁶ Although these regulatory and automated reporting systems play a large part in tracking these vessels entering Canadian waters, they do little to account for their actions when in Canadian waters. For example, if a ship were to illegally dump waste in the Arctic sea by accident or otherwise, the regulations do little to prevent this from not being reported or appropriately attended to.

³³ International Maritime Organization, “Long-range identification and tracking (LRIT),” last accessed 20 April 2017, <http://www.imo.org/en/OurWork/Safety/Navigation/Pages/LRIT.aspx>.

³⁴ Transport Canada, “Horizontal initiative: Marine Security,” last accessed 15 April 2017, <https://www.tc.gc.ca/eng/corporate-services/planning-dpr-2013-14-1188.html>.

³⁵ Ernie Regehr, “Arctic Maritime Domain Awareness: A domestic and strategic imperative,” *Disarming Arctic Security*, the Simons Foundation, February 3, 2014, 3.

³⁶ Mondaq, “Canada: NORDREG now Mandatory Within the Northwest Passage,” last accessed 21 April 2017, <http://www.mondaq.com/canada/x/114788/Marine+Shipping/NORDREG+now+Mandatory+Within+the+Northwest+Passage>.

Technological

RADARSAT 2 was launched in 2007, and was adopted by DND to conduct surveillance of Canadian coastline and the Arctic.³⁷ It is a Canadian Space Agency controlled space based Synthetic Aperture Radar (SAR) satellite capability that detects the movement of ships greater than 20 meters in length, reports this information to one of three ground receiver sites, and then relays this information to the MSOCs. RADARSAT has a distinct advantage of detecting vessels regardless of weather conditions, day or night³⁸ and can be fine-tuned to resolve an object up to one meter.³⁹

Although the RADARSAT is effective at identifying shipping activities in the Arctic, the RADARSAT system, due to its orbit pattern, cannot adequately achieve *persistent* surveillance and situational awareness. The satellite orbits the earth approximately 14 times per day, resulting in an updated image once every 100 minutes. In a life or death emergency situation in the Arctic, the RADARSAT system may not offer timely situational awareness. In the article *Risk management using Remote Sensing Data : Moving From Scientific To Operational Applications*, RADARSAT 2 and similar technologies are seen as a complementary technology, not a primary technology, where it states “Whenever possible, radar acquisitions should always be activated at the same time as optical acquisitions in an emergency situation.”⁴⁰ In other words, although RADARSAT can detect and identify a problem area in the Arctic, additional sensor

³⁷ Wikipedia, “RADARSAT-2,” last accessed 10 April 2017, <https://en.wikipedia.org/wiki/Radarsat-2>.

³⁸ Canadian Space Agency, “Maritime Surveillance,” last accessed 20 April 2017, <http://www.asc-csa.gc.ca/eng/satellites/radarsat/maritime.asp>.

³⁹ Canadian Space Agency, “Satellite Characteristics,” last accessed 20 April 2017, <http://www.asc-csa.gc.ca/eng/satellites/radarsat/radarsat-tableau.asp>.

⁴⁰ F.Sarti, J.Inglada, R.Landry and T. Pultz, *Risk management using Remote Sensing data : moving from scientific to operational applications*, last accessed 21 April 2017, <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.15.6765&rep=rep1&type=pdf>.

solutions must be used for detailed analysis.

Another technological solution, currently being trialed by Defence Research Development Canada (DRDC), is the Northern Watch Technology Development Project (NWTDP). This system is an unmanned but remotely operated underwater and above water sensor array initiative intended to monitor designated key Arctic chokepoints for maritime traffic. The project's goal was to "...develop and demonstrate a capability to conduct up to 365 days, 24/7 persistent local area surveillance of air, maritime surface, and sub-surface objects in the Canadian Arctic."⁴¹ Although the system has been in development for eight years and has gained favorable attention by DND,⁴² DRDC recognized in their document *Overview of the Technical Results of the Northern Watch Project* released in June 2016 that the system is not yet ready, and there was significant work to be done for the system to operate long-term in an 'unmanned' state for an extended period of time.⁴³ Although the system could potentially discover vessels penetrating the NWP at choke points, as a fixed sensor capability it does not offer a capability to survey vessels traveling along the NWP route. To do so would require substantial investment to install numerous systems to cover approximately 900nm of the NWP.⁴⁴

⁴¹ Garry J. Heard, Bruce McArthur, and Gary Inglis, "Overview of the technical results of the Northern Watch Project," last accessed 20 April 2017, cradpdf.drddc.gc.ca/PDFS/unc253/p804761_A1b.pdf

⁴² Paul Bryce, *NATO Association of Canada, Global Technologies for Defence and Security*, "Eyes on the Arctic: The Role of Radar and Drones," August 5 2016, last accessed 10 April 2017, <http://natoassociation.ca/eyes-on-the-arctic-the-role-of-radar-and-drones/>.

⁴³ Garry J. Heard, Bruce McArthur, and Gary Inglis, "Overview of the technical results of the Northern Watch Project," last accessed 20 April 2017, cradpdf.drddc.gc.ca/PDFS/unc253/p804761_A1b.pdf.

⁴⁴ Encyclopedia Britannica, "Northwest Passage," last accessed 27 April 2017, <https://www.britannica.com/place/Northwest-Passage-trade-route>.

Physical

For the purpose of this paper *physical* means include all traditional ‘manned’ ways of detecting and surveying activity in the Arctic. This includes people, aircraft, and maritime vessels. One of the more prominent activities the government has undertaken is conducting joint operations with the Canadian Rangers in the North through its Operation (Op) NANOOK and Op NUNALIVUT series of activities. These operations have been conducted on a yearly basis since 2007 with a stated objective of asserting Canada’s sovereignty over its northernmost regions⁴⁵. Typically employing more than 500 soldiers, the operations have focused on whole-of-government emergency response scenarios and to prove that the military maintains an ability to operate effectively in the harsh Arctic environment. It has been debated whether operations such as Op NANOOK are still useful, in light of lessening interest in the activities by the newly elected Liberal Government. However, John Higginbotham, a senior fellow and the Arctic lead for the Center for International Governance Innovation, stated in an interview that “whether or not the Prime Minister is there, [Nanook] is invaluable in keeping the Canadian forces focused on sea, air and land dimensions of operations in the Arctic.”⁴⁶ Deliberate operations such as the Op NANOOK series of operations, however, are not akin to rapid response. It takes upwards of a year for the government and military to plan for and execute these operations.

As stated in Ernie Regehr’s *Disarming Arctic Security* article, “By some accounts,

⁴⁵ National Defence and the Canadian Armed Forces, “Operation NANOOK,” last accessed 20 April 2017, <http://www.forces.gc.ca/en/operations-canada-north-america-recurring/op-nanook.page>.

⁴⁶ High North News, “Analysis: Is Operation Nanook Still Relevant in Canada,” last accessed 16 April 2017, <http://www.highnorthnews.com/analysis-is-operation-nanook-still-relevant-in-canada/>.

the Canadian Navy is largely absent from the Arctic.”⁴⁷ This is not entirely true. The Royal Canadian Navy (RCN) does offer a capability to operate in the Arctic under open-water conditions as seen during Op NANOOK, and the RCN is currently procuring a new fleet of Arctic Offshore Patrol Ships planned for delivery in 2018 which can operate in “some ice conditions”.⁴⁸ This same article, however, correctly adds that the focus for Canadian maritime presence comes from the CCG, not the military. This article points out that the heavy ice breaking capabilities of the CCG required in the Arctic is very limited in numbers (two are currently available), the ships are not actually stationed (or staged) in the Arctic, and the ships are ageing. Although there is a project underway to replace the ageing heavy icebreakers as early as 2020, interim measures have been proposed to mitigate mechanical failures of its existing fleet.⁴⁹ The CCG’s medium icebreakers are capable of two-season operations (summer/fall) whereas its light icebreaker capability is capable of only summer operations.

The Department of Fisheries and Oceans (DFO) has very limited Arctic surveillance capabilities. The DFO does not possess integrally owned aircraft for surveillance, and it relies on DND to provide a guaranteed number of annual surveillance hours through their CP-140 Aurora aircraft platform, and supplements this capability with a lease agreement for three Beechcraft King Air B200.⁵⁰ The Beechcraft platforms offer a

⁴⁷Ernie Regehr, “Arctic Maritime Domain Awareness: A domestic and strategic imperative,” *Disarming Arctic Security*, the Simons Foundation, February 3, 2014, 7.

⁴⁸National Post, “Naval Officers learn how to handle ice-filled waters in anticipation of new Arctic patrol ships,” last accessed 1 May 2017, news.nationalpost.com/news/canada/naval-officers-learn-how-to-handle-ice-filled-waters-in-anticipation-of-new-arctic-patrol-ships.

⁴⁹ National Post, “Canadian Coast Guard may be forced to lease icebreakers as aging fleet increasingly at risk of breakdowns,” last accessed 15 April 2017, <http://news.nationalpost.com/news/canada/canadian-coast-guard-may-be-forced-to-lease-icebreakers-as-aging-fleet-increasingly-at-risk-of-breakdowns>.

⁵⁰ Fisheries and Oceans Canada, “Fisheries and Oceans Canada Air Surveillance Program,” last accessed 26 April 2017, http://www.dfo-mpo.gc.ca/international/media/bk_air-surveillance-aerien-eng.htm.

200 mile, 360° search radar, a forward-looking infrared system, telephoto video cameras, and a night time illumination system. Two aircraft are located on the east coast, whereas one is located on the west coast. The operating range is approximately 2000 nm, and is not wholly suitable for traveling the distances required to operate effectively in the Arctic.⁵¹ For example, the distance from its location in Halifax to an emergency response along the NWP in Resolute is approximately 2,300 nm, therefore this aircraft would have to refuel in Iqaluit en-route. The distance from Iqaluit to Resolute is approximately 1000 nm, which means that the aircraft could not offer any form of persistent surveillance prior to having to return to Iqaluit for refueling.

Similar to the DFO, Transport Canada has three aircraft used for surveillance in a program called the National Aerial Surveillance Program (NASP). NASP's listed objectives are the Enforcement of Domestic Laws & Regulations, Deterrence, Emergency Response, Ice Reconnaissance and Enhancing Marine Domain Awareness.⁵² Transport Canada employs three Dash-8 aircraft and their platforms offer side-looking airborne radar, infrared/ultraviolet line scanner, digital camera systems and AIS. Similar to the aircraft employed by the DFO, the Dash-8's maximum range is approximately 2000nm⁵³, and suffers the same limitations for conducting persistent surveillance in the Arctic.

The Canadian Armed Forces employ CP-140s as its primary aerial surveillance platform. The 11 purchased in the 1980s were originally intended for anti-submarine warfare. Numerous enhancements to its detection and surveillance capabilities have made it a very capable multi-role C4ISR and search and rescue platform. With a range of

⁵¹ *Ibid.*

⁵² Transport Canada, "Transport Canada's National Aerial Surveillance Program (NASP)," last accessed 25 April 2017, www.arctic-council.org/eppr/wp-content/uploads/2011/06/NASP_EPPR2.pdf.

⁵³ Bombardier, "Dash-8 Performance," last accessed 26 April 2017, https://www2.bombardier.com/Used_Aircraft/en/Q_DashPerformance.jsp.

4,500nm and an average endurance of 12 hours,⁵⁴ this aircraft can leave Halifax and patrol the entirety of the NWP from Dundas Harbor (eastern entry point into NWP) to Sachs Harbor (western exit point of NWP) without refueling. Although an excellent airframe that has received extensive upgrades, the aircraft suffers from two limiting factors– the limited number of aircraft available to conduct the numerous operations demanded of them, including expeditionary operations, and the crew itself, due to fatigue when operating over extended periods of time.

As can be seen, there are numerous systems available to reach and survey the Arctic, however no systems currently employed by the Canadian Government offer an ability to provide *persistent* surveillance. The next section will discuss Canada’s experience with UAS and discuss how this technology can offer a persistent surveillance capability for the Canadian Arctic.

CANADIAN ARMED FORCES PAST EXPERIENCES WITH UAS

A UAS capability for the Arctic offers many benefits that traditional aeronautical ISR platforms do not. Dr. Daniel Bruntstetter, the Associate Professor of Political Science at the School of Social Sciences (University of California), describes several distinct advantages that UAS has over piloted aircraft in his article *Drones: The Future of Warfare?* The advantages to employing UAS include a great persistent surveillance capability (upwards of 24/7 surveillance), the employment of very precise technology to identify and track targets, and the elimination of risks to pilots and aircrews. All this

⁵⁴ Royal Canadian Air Force, “CP-140 Aurora,” last accessed 20 April 2017, <http://www.rcf-arc.forces.gc.ca/en/aircraft-current/cp-140.page>.

allows for better decision making.⁵⁵ His article also includes several disadvantages to UAS, including the fact that UAS needs a “clear view from the skies”, therefore Arctic weather could seriously impede surveillance performance. In addition, UAS requires constant manning: “...drones require sustained human presence: at the in-region bases from which they are launched, at the remote bases from which they are piloted...”⁵⁶ In fact, the US Air Force is now struggling with a problem of UAS pilot retention due to an endlessly demanding workload and few prospects for advancement.⁵⁷ However, there is little doubt that a UAS capability will certainly fill the persistent surveillance capability gap in the Canadian Arctic. Best summarized in the RCAF Journal article *Will JUSTAS Prevail? Procuring a UAS Capability for Canada*: “Low-intensity, time-consuming, persistent surveillance over the frigid expanse of Canada’s sparsely populated Arctic territory lends itself well to unmanned overflights, which would prevent the need for a pilot to be placed in harm’s way.”⁵⁸

Canada has a long history with UAS, both as an innovator and as a user of this technology. Throughout the 1960’s, 1970’s and 1980’s Canada developed numerous UAS capabilities including the CL-89 surveillance drone, CL-327 Sentinel⁵⁹ helicopter styled surveillance drone (1977) and target drones.⁶⁰ More recently the CAF has gained

⁵⁵ E-International Relations, “Drones: The Future of Warfare?,” last accessed 27 April 2017, <http://www.e-ir.info/2012/04/10/drones-the-future-of-warfare/>.

⁵⁶ *Ibid.*.

⁵⁷ Gizmodo, “Nobody Wants to Fly Air Force Drones Because It's a Dead End Job,” last accessed 16 April 2017, <http://gizmodo.com/nobody-wants-to-fly-air-force-drones-because-its-a-dea-1179733596>.

⁵⁸ Danny Garrett-Rempel, “Will JUSTAS Prevail? Procuring a UAS Capability for Canada,” *RCAF Journal* 4, no1 (Winter 2015): 19.

⁵⁹ Federation of American Scientists, “CL-227 Sentinel,” last accessed 28 April 2017, <https://fas.org/man/dod-101/sys/ac/row/cl-327.htm>.

⁶⁰ RCAF Journal, “Can Unmanned Aircraft Systems Meet Canadian Air Power Needs?,” last accessed 28 April 2017, <http://www.rcaf-arc.forces.gc.ca/en/cf-aerospace-warfare-centre/elibrary/journal/2016-vol5-iss3-04-can-unmanned-aircraft-systems-meet-canadian-air-power-needs.page>.

experience employing surveillance drones during expeditionary operations. The French manufactured CU-161 SPERWER were purchased off-the-shelf in 2003 for use in Afghanistan,⁶¹ and in 2009 the Israeli manufactured CU-170 Heron UAV was ‘fast-track’⁶² procured by CAF for use in Afghanistan as a SPERWER replacement.⁶³ The US-manufactured ScanEagle was quickly procured by the CAF in 2009 for counterterrorism and maritime security operations for Op ARTEMIS,⁶⁴ and most recently the CAF purchased the RQ-21A Blackjack UAS systems (a successor to the ScanEagle) to be operated by the Canadian Army for tactical intelligence, surveillance and reconnaissance.⁶⁵

The Royal Canadian Airforce (RCAF) led Joint Unmanned Surveillance and Target Acquisition System (JUSTAS) Program was generated in 2000 to ‘facilitate Canada’s process of procuring its own cutting-edge UAS capability’.⁶⁶ Envisioned as a two-phased implementation, the program would first cover both overland surveillance, and then a “domestic maritime surveillance and patrols over the arctic” medium altitude long endurance (MALE) capability.⁶⁷ The program has yet to deliver any capabilities based on these phases, even with full sponsorship by the then Prime Minister Steven

⁶¹NATO Association, “After a Decade Canada has Drones,” last accessed 20 April 2017, <http://natoassociation.ca/after-a-decade-canada-has-drones/>.

⁶² Financial Post, “Military fast-tracking plan to lease aerial drones,” last accessed 28 April 2017, <http://www.financialpost.com/m/military+fast+tracking+plan+lease+aerial+drones/295985/story.html>.

⁶³ CBC, “Canada to acquire attack drones: air chief,” last accessed 28 April 2017, <http://www.cbc.ca/news/world/canada-to-acquire-attack-drones-air-chief-1.841372>.

⁶⁴ NATO Association, “Drones: The Best Defence Canada Doesn’t Have,” last accessed 29 April 2017, <http://natoassociation.ca/drones-the-best-defence-canada-doesnt-have-part-i-long-awaited-justas/>.

⁶⁵ FlightGlobal, “Canada becomes first export customer for Blackjack UAV,” last accessed 29 April 2017, <https://www.flightglobal.com/news/articles/canada-becomes-first-export-customer-for-blackjack-u-428899/>.

⁶⁶Danny Garrett-Rempel, “Will JUSTAS Prevail? Procuring a UAS Capability for Canada,” *RCAF Journal* 4, no1 (Winter 2015): 19.

⁶⁷ *Ibid.*, p23

Harper, who had publicly announced a new “Drone Squadron” for the CAF.⁶⁸

There are two factors at play as to why the JUSTAS Program has not been successful: inadequate requirement identification and lack of funding. According to defence critic and reporter David Pugliese, the JUSTAS program has been consistently plagued with delays caused in part by unclear objectives and lack of program oversight.⁶⁹ In addition, indications are that a MALE UAS system could be cost-prohibitive, as some cost estimates are in the 1+ billion dollar range over the entire lifecycle of the platform.⁷⁰ Although a request for interest (RFI)⁷¹ was promulgated by the Program in 2016 to “... utilize the feedback from Industry to develop detailed cost estimates and refine planning documents leading towards Definition Phase funding approval”⁷², according to David Pugliese, indications are that the CAF will not see the technology in place prior to 2023.⁷³

Notwithstanding the difficulties the JUSTAS Program has had in delivering a capability, there has been a growing interest from industry in providing the CAF a UAS capability for the Canadian Arctic. Northrop Grumman has indicated interest in demonstrating a modified UAS solution called Polar Hawk (based on their Global Hawk

⁶⁸ Ottawa Citizen, “Plan to buy Drones Dogged with Problems,” last accessed 20 April 2017, <http://ottawacitizen.com/news/national/plan-to-buy-drones-for-canadian-military-dogged-by-problems-audit-shows>.

⁶⁹ *Ibid.*

⁷⁰ Defence News, “Canada Restarts Attempt to buy Drones,” last accessed 29 April 2017, <http://www.defensenews.com/story/defense/air-space/isr/2015/05/16/canada-restarts-attempt-to-buy-drones/27242059/>.

⁷¹ Nestor Arellano, “Armed Drones to Play Greater Role in Air Force,” *Vanguard Canada*, last accessed 18 April 2017, <http://www.vanguardcanada.com/2016/01/19/armed-drones-to-play-greater-role-in-air-force/>.

⁷² Unmanned Systems Canada, “The Canadian Government releases Request for Information for the DND Joint Unmanned Surveillance and Target Acquisition System (JUSTAS),” last accessed 28 April 2017, <https://www.unmannedsystems.ca/the-canadian-government-releases-request-for-information-for-the-dnd-joint-unmanned-surveillance-and-target-acquisition-system-justas/>.

⁷³ Ottawa Citizen, “RCAF Hopes to Have drones Flying by 2023,” last accessed 25 April 2017, <http://ottawacitizen.com/news/national/rcaf-hopes-to-have-drones-flying-by-2023>.

system), and General Atomics is assured their Predator B series of UAS would be very effective for Arctic persistent surveillance.⁷⁴ Both of these systems offer long endurance capabilities suitable for the expanses of the Canadian Arctic, and efforts have been made to test their capabilities in the north as far as 85 degrees latitude.⁷⁵

Although there the CAF has recently gained valuable operational and procurement experience with UAS, and there is an operational need for a UAS capability for persistent surveillance of the Canadian Arctic, the JUSTAS Program has continued to fail at delivering any capabilities. In order to facilitate the procurement of UAS, the CAF can utilize its recent procurement successes, namely by leveraging an operational focus for this capability and adopting a cyclical style project strategy. The following section will provide initial details to a strategy which may allow JUSTAS to finally get off the ground.

First, all the successful UAS procurements were conducted as Urgent Operational Requirement (UOR) linked directly to expeditionary operations. A UOR is defined in the Department of National Defence Project Approval Directive (PAD) as “... the term given to any operational requirement for equipment or construction that requires faster approval, implementation and delivery to the operational commander than the standard approval and acquisition procedures provide.”⁷⁶ All requirements for prior UAS capabilities were fed into the CAF procurement system *bottom-up* from the deployed operators at the ‘pointy-end’, and the procurements were conducted relatively quickly

⁷⁴ Canadian Military Journal, “JUSTAS and Project Epsilon: Integrated Intelligence, Surveillance, and Reconnaissance of the Canadian Arctic,” last accessed 24 April 2017, http://www.journal.forces.gc.ca/vo11/no4/24-bond-eng.asp#_edn30.

⁷⁵ New Atlas, “Global Hawk UAS gears up for Arctic duty,” last accessed 24 April 2017, <http://newatlas.com/polar-hawk-uas/22908/>.

⁷⁶ Canada, Department of National Defence, Project Approval Directive (PAD) 2015.

based on urgent operational requirements. To take a play book directly from Afghanistan, in order to be successful the CAF needs to ‘sell’ the Canadian Arctic to the Government as an expeditionary operation that requires its own unique set of capabilities. Vignettes or storyboards should be produced and approved by the appropriate Operational Commander (such as Commander Canada Joint Operations Command or Commander Joint Task Force North) which clearly integrates UAS with existing technologies (such as RADARSAT), using safety of life at sea (SOLAS) or similar examples to bring the operational requirement to the forefront.

Second, all of the successful UAS procurements in the past decade have focused on smaller tactical form-factor platforms that were not weaponized.⁷⁷ In order for JUSTAS to be palatable in the eyes of the government and the Canadian public for operating in the Arctic above Canadian soil, the JUSTAS Program needs to dispel any rhetoric concerning weaponization.⁷⁸ The JUSTAS Program should focus on educating the government and public on the benefits and capabilities of a larger UAS required to persistently survey the large expanses of the Canadian Arctic. The public should be informed of the uniqueness of the Arctic, the expected future increase in numbers of vessels traveling the NWP, the dangers, costs and inefficiencies of using manned aircraft to conduct this type of operation, and the benefits of this technology for conducting this form of surveillance. Similar to vignettes, the public needs to be informed of the virtues of data that can be collected from a UAS, which can lead to faster remediation of

⁷⁷ RCAF Journal, “Can Unmanned Aircraft Systems Meet Canadian Air Power Needs?,” last accessed 28 April 2017, <http://www.rcaf-arc.forces.gc.ca/en/cf-aerospace-warfare-centre/elibrary/journal/2016-vol5-iss3-04-can-unmanned-aircraft-systems-meet-canadian-air-power-needs.page>.

⁷⁸ Vice News, “The Canadian Air Force Is Looking to Buy Weaponized Drones,” last accessed 26 April 2017, <https://news.vice.com/article/the-canadian-air-force-is-looking-to-buy-weaponized-drones>.

environmental emergencies, or an ability to generate precise situational awareness about a vessel that requires assistance, which may save lives.

Finally, all of the prior UAS were affordable due to their relatively short service life (approximately three to five years). The JUSTAS Program is cost prohibitive due to the CAF's requirement to justify lifecycle costs in maintaining platforms for 20+ years. As the UAS is a relatively nascent technology, there will be significant changes over subsequent years as the technology improves. The RCAF should pursue a flexible iterative approach, described in the PAD as a *Cyclical Project*,⁷⁹ whereby a UAS is leased, not purchased, for a limited duration of time. As recently reported by The Economist, as UAS technology matures and competition grows, the cost of this technology will only become cheaper.⁸⁰ A Cyclical Project approach will allow for continual upgrades and changes to platforms and sensor technology, and not lock the CAF into a costly long-term commitment to supporting a specific airframe.

CONCLUSION

Climate change is affecting the way people look at the Arctic Region as a potential location for new natural resources, fossil fuels, tourism and expedited commercial shipping. As international interest in the Arctic Region grows as a potential resource hub and transportation highway, so too should the Canadian Government grow its capabilities to meet any potential security or safety threat. This is no small task, however, for the area to be monitored and controlled is expansive, sparsely inhabited and dangerous. The Canadian Government should seek to leverage the experience the CAF

⁷⁹ Canada, Department of National Defence, Project Approval Directive (PAD) 2015.

⁸⁰ The Economist, "Up in the air," last accessed 24 April 2017, <http://www.economist.com/news/special-report/21599524-drones-will-change-warand-more-up-air>.

has garnered over the past decade through expeditionary operations to prove a UAS system to conduct persistent surveillance which would greatly enhance the RADARSAT system currently being employed to provide strategic oversight of the North.

The JUSTAS Program has not yielded any significant results since the year 2000 due to high costs and unclear objectives. A revision of the UAS procurement strategy needs to be implemented which emphasizes the operational requirement to the government and public (which should be appropriately described by an Operational Commander), that communicates the benefits of UAS for Arctic surveillance. Furthermore, there are more affordable project strategies that can be employed to leverage this nascent technology. To fail in the mission of protecting Canadian in the Arctic has great consequences, including Canadian sovereign claims to the NWP. A UAS persistent surveillance capability will allow Canada to look beyond the wall of Arctic ice.

Bibliography

Books and Journal Articles

Bone, M. Robert. *The Canadian North: Issues and Challenges*. Don Mills: Oxford University Press, 2012.

Canada. Department of National Defence. Project Approval Directive (PAD) 2015

Griffiths, Franklyn, Rob Huebert and P. Whitney Lackenbauer, *Canada and the Changing Arctic: Sovereignty, Security and Stewardship*. Waterloo: Wilfred Laurier University Press, 2011.

Garrett-Rempel, Danny. "Will JUSTAS Prevail? Procuring a UAS Capability for Canada." *RCAF Journal* 4, no1 (Winter 2015).

Zallen, B. Scott. *On Thin Ice: The Inuit, The State, and the Challenge of Arctic Sovereignty*. Plymouth: Lexington Books, 2009.

Websites and Web Articles

Arctic Council. "About us." Last accessed 29 April 2017. <http://www.arctic-council.org/index.php/en/>.

Arctic Council. "The Arctic Council Backgrounder." Last accessed 17 April 2017. <http://www.arctic-council.org/index.php/en/about-us>.

Bombardier. "Dash-8 Performance." Last accessed 26 April 2017. https://www2.bombardier.com/Used_Aircraft/en/Q_DashPerformance.jsp.

Bryce, Paul. *NATO Association of Canada. Global Technologies for Defence and Security*. "Eyes on the Arctic: The Role of Radar and Drones." August 5 2016. Last accessed 10 April 2017. <http://natoassociation.ca/eyes-on-the-arctic-the-role-of-radar-and-drones/>.

Canadian Global Affaires Institute. "The Canadian Armed Forces in the Arctic: Purpose, Capabilities, and Requirements." Last accessed 20 April 2017. http://www.cgai.ca/canadian_armed_forces_in_the_Arctic.

Canadian Military Journal. "JUSTAS and Project Epsilon: Integrated Intelligence, Surveillance, and Reconnaissance of the Canadian Arctic." Last accessed 24 April 2017. http://www.journal.forces.gc.ca/vol11/no4/24-bond-eng.asp#_edn30.

Canadian Senate Report of the Standing Senate Committee on Fisheries and Oceans. "Controlling Canada's Arctic Waters: Role Of The Canadian Coast Guard." Last

- accessed 15 April 2017.
<https://sencanada.ca/content/sen/committee/402/fish/rep/rep07dec09-e.pdf>.
- CBC. "Canada to acquire attack drones: air chief. Last accessed 28 April 2017.
<http://www.cbc.ca/news/world/canada-to-acquire-attack-drones-air-chief-1.841372>.
- Charles Ebinger and Evie Zabetakis. *The Geopolitics of Arctic Melt*. Last accessed 20 April 2017. https://www.brookings.edu/wp-content/uploads/2016/06/11_arctic_melt_ebinger_zambetakis.pdf.
- Climatewire. "First commercial ships taking Russia's Northeast Passage." Last accessed 20 April 2017. <https://www.eenews.net/climatewire/2009/08/25/stories/81736>.
- Earth and Space Research. "Albedo Definition." Last accessed 15 April 2017.
<https://www.esr.org/outreach/glossary/albedo.html>.
- E-International Relations. "Drones: The Future of Warfare?." Last accessed 27 April 2017. <http://www.e-ir.info/2012/04/10/drones-the-future-of-warfare/>.
- Encyclopedia Britannica. "Northwest Passage." Last accessed 27 April 2017.
<https://www.britannica.com/place/Northwest-Passage-trade-route>.
- Federation of American Scientists. "CL-227 Sentinel." Last accessed 28 April 2017.
<https://fas.org/man/dod-101/sys/ac/row/cl-327.htm>
- Financial Post. "Military fast-tracking plan to lease aerial drones." Last accessed 28 April 2017. <http://www.financialpost.com/m/military+fast+tracking+plan+lease+aerial+drones/295985/story.html>.
- Fisheries and Oceans Canada. "Fisheries and Oceans Canada Air Surveillance Program." Last accessed 26 April 2017. http://www.dfo-mpo.gc.ca/international/media/bk_air-surveillance-aerien-eng.htm.
- FlightGlobal. "Canada becomes first export customer for Blackjack UAV." Last accessed 29 April 2017. <https://www.flightglobal.com/news/articles/canada-becomes-first-export-customer-for-blackjack-u-428899/>.
- Gautier, D.L. "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle." U.S. Geological Survey. USGS Fact Sheet 2008-3049. 2008.
- Gizmodo. "Nobody Wants to Fly Air Force Drones Because It's a Dead End Job." Last accessed 16 April 2017. <http://gizmodo.com/nobody-wants-to-fly-air-force-drones-because-its-a-dea-1179733596>.

- Global Affaires Canada. "Statement On Canada's Arctic Foreign Policy." Last accessed 23 April 2017. http://www.international.gc.ca/arctic-arctique/arctic_policy-canada-politique_arctique.aspx?lang=eng.
- Government of Northwest Territories. "State of the Environment." Last accessed 14 April 2017. <http://www.enr.gov.nt.ca/state-environment/73-trends-shipping-northwest-passage-and-beaufort-sea>.
- Heard, Garry, Bruce McArthur, and Gary Inglis. "Overview of the technical results of the Northern Watch Project." Last accessed 20 April 2017. [cradpdf.drdc.rddc.gc.ca/PDFS/unc253/p804761_A1b.pdf](http://www.cradpdf.drdc.rddc.gc.ca/PDFS/unc253/p804761_A1b.pdf).
- High North News. "Analysis: Is Operation Nanook Still Relevant in Canada." Last accessed 16 April 2017. <http://www.highnorthnews.com/analysis-is-operation-nanook-still-relevant-in-canada/>.
- Historica Canada. "Arctic Archipelago" Last accessed 5 April 2017. <http://www.thecanadianencyclopedia.ca/en/article/Arctic-archipelago/>.
- Intergovernmental Panel on Climate Change. "Climate Change 2013: The Physical Science Basis." Last accessed 20 April 2017. <http://www.ipcc.ch/report/ar5/wg1/>.
- International Maritime Organization. "Long-range identification and tracking (LRIT)." Last accessed 20 April 2017. <http://www.imo.org/en/OurWork/Safety/Navigation/Pages/LRIT.aspx>.
- Mondaq. "Canada: NORDREG now Mandatory Within the Northwest Passage." Last accessed 21 April 2017. <http://www.mondaq.com/canada/x/114788/Marine+Shipping/NORDREG+now+Mandatory+Within+the+Northwest+ Passage>.
- National Defence and the Canadian Armed Forces. "Canada First Defence Strategy." Last accessed 20 April 2017. <http://www.forces.gc.ca/en/about/canada-first-defence-strategy.page>.
- National Defence and the Canadian Armed Forces. "Department of National Defence and the Canadian Armed Forces 2016-17 Report on Plans and Priorities." Last accessed 15 April 2017. <http://www.forces.gc.ca/en/about-reports-pubs-report-plan-priorities/2016-index.page>.
- National Defence and the Canadian Armed Forces. "Operation NANOOK." Last accessed 20 April 2017. <http://www.forces.gc.ca/en/operations-canada-north-america-recurring/op-nanook.page>.
- National Geographic. "Arctic Ice is Shrinking." Last accessed 3 April 2017.

<http://ngm.nationalgeographic.com/2016/01/Arctic-ice-shrinking-graphic-environment-text>.

NATO Association. "After a Decade Canada has Drones." Last accessed 20 April 2017. <http://natoassociation.ca/after-a-decade-canada-has-drones/>.

NATO Association. "Drones: The Best Defence Canada Doesn't Have." Last accessed 29 April 2017. <http://natoassociation.ca/drones-the-best-defence-canada-doesnt-have-part-i-long-awaited-justas/>.

New Atlas. "Global Hawk UAS gears up for Arctic duty." Last accessed 24 April 2017. <http://newatlas.com/polar-hawk-uas/22908/>.

Ondrej Urban. "Future of the Arctic Oil Reserves." Stanford University. Last accessed 21 April 2017. <http://large.stanford.edu/courses/2015/ph240/urban2/>.

Pacific Marine Environmental Laboratory. "Arctic Zone." Last accessed 2 May 2017, https://www.pmel.noaa.gov/Arctic-zone/gallery_np_seasons.html.

Parliament of Canada. "Proceedings of the Standing Senate Committee on National Security and Defence Issue 5 - Evidence - Meeting of June 7, 2010." Last accessed 20 April 2017. <https://sencanada.ca/en/Content/SEN/Committee/403/defe/05evb-e>.

RCAF Journal. "Can Unmanned Aircraft Systems Meet Canadian Air Power Needs?." Last accessed 28 April 2017. <http://www.rcaf-arc.forces.gc.ca/en/cf-aerospace-warfare-centre/elibrary/journal/2016-vol5-iss3-04-can-unmanned-aircraft-systems-meet-canadian-air-power-needs.page>.

Royal Canadian Air Force. "CP-140 Aurora." Last accessed 20 April 2017. <http://www.rcaf-arc.forces.gc.ca/en/aircraft-current/cp-140.page>.

Sarti, F, J. Inglada, R. Landry and T. Pultz. Risk management using Remote Sensing data : moving from scientific to operational applications. Last accessed 21 April 2017. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.15.6765&rep=rep1&type=pdf>.

The Economist. "Up in the air." Last accessed 24 April 2017. <http://www.economist.com/news/special-report/21599524-drones-will-change-warand-more-up-air>.

Transport Canada. "Horizontal initiative: Marine Security." Last accessed 15 April 2017. <https://www.tc.gc.ca/eng/corporate-services/planning -dpr-2013-14-1188.html>.

Transport Canada. "Transport Canada's National Aerial Surveillance Program (NASP)." Last accessed 25 April 2017. www.arctic-council.org/eppr/wp-

content/uploads/2011/06/NASP_EPPR2.pdf.

US News. "Thanks to Melting Ice, Cruise Ship Travels Northwest Passage." Last accessed 28 April 2017. <https://www.usnews.com/news/news/articles/2016-09-09/giant-cruise-ship-makes-historic-voyage-in-melting-arctic>.

University of Guelph. "The Arctic Winter." Last accessed 15 April 2017. http://www.Arctic.uoguelph.ca/cpe/environments/climate/climate_present/temp/arc_winter.htm#.

Vice News. "The Canadian Air Force Is Looking to Buy Weaponized Drones." Last accessed 26 April 2017. <https://news.vice.com/article/the-canadian-air-force-is-looking-to-buy-weaponized-drones>.