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Airships in the Arctic: A Solution to "Too Much Geography"

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AIRSHIPS IN THE ARCTIC: A SOLUTION TO "TOO MUCH GEOGRAPHY"

By Lieutenant-Commander N.A. Normand

Abstract

Climate change is rapidly exacerbating the criticality of managing the Canadian Arctic region in an ethical and environmentally conscientious manner. Climate change disproportionately impacts the Arctic and will adversely impact transportation in the region. The author proposes a sustainment circuit of airships that could be used to support Canadian Armed Forces (CAF) activities in the Arctic. This circuit will connect to existing transportation nodes and lines of communication. CAF usage of this circuit will likely be intermittent, meaning the circuit will have surplus capacity to augment existing cargo delivery to the inhabitants of the region and can also be used to exert sovereignty over the region. This expression of sovereignty takes the form of the identification of regulatory non-compliance and will increase logistical connectivity.

What has worked in the past to connect the Arctic with the rest of the world is rapidly becoming untenable. This paper demonstrates that the speed, payload, and range of many conceptual and some prototypical platforms in industry could already add value to this problem set. Throughout this paper, the author has identified numerous platforms that could be used to develop this proof of concept. The cargo airship industry is still in an embryonic phase. There are numerous innovative solutions within industry that could be applied to the problem of a tenuously connected Arctic region. That region has many stakeholders outside of the CAF. More stakeholder engagement than is typically required for a new CAF platform and will need to include other governmental partners such as the RCMP, CBSA, and DFO. Additionally, it is of the utmost importance to socialize a proposed solution with the region's current inhabitants, with special attention paid to indigenous rights. Proceeding in a way that is uncollaborative with current inhabitants risks generating a misalignment of interests.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

"If some countries have too much history, we have too much geography"

--- William Lyon Mackenzie King - Canada's 10th Prime Minister

Canada's geography represents a significant challenge when it comes to transportation. Presently, 30% of Canada's landmass is accessible via low-cost conventional modes of transportation.[1] The remaining 70% is expensive and difficult to access because of the large geographical distances involved and extremely harsh prevailing climatic conditions. This 70% has been characterized as "an impoverished frontier that depends on seasonal ice roads for inland transport and annual sea lifts for communities on the coasts."[2] Furthermore, 90% of Canadians live within 160km of the US border.[3] This means that the majority of the population, and the transportation infrastructure that services that population, is clustered in the southernmost region of the country. National Defence is a public good that the Canadian Armed Forces (CAF) are mandated to perform on behalf of the government of Canada. National Defence is not limited to these southernmost regions of Canada despite the clustered population centres and transportation infrastructure. Because the CAF is tasked with defending the entirety of the nation, a solution is required so that the CAF can conduct operations in the region efficiently and in a manner that is sensitive to local demands. It is an implied task that the defence of Canada should involve maximal preservation of Canada. This would include preserving physical geographical features, ecosystems, and the country's inhabitants.

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[1] Barry Prentice. "Transport Canada 2030 strategic plan missing a key plank." *The Hill Times* (22 February 2021).
[2] Ibid.
[3] CBC News. "By the numbers" *CBC News* (12 May 2009): accessed 25 April 2021, https://www.cbc.ca/news/canada/by-the-numbers-1.801937.

Climate change has recently been linked to national security.[4] In March 2021, the US Government's National Intelligence Council released a multi-decade forecast called "Global Trends 2040".[5] This assessment is issued every four years and stated that "more extreme weather events would, especially in the 2030s, "disproportionately" affect poor and vulnerable populations, endangering their stability, health and livelihoods."[6] The report also characterized climate change as "a destabilizing force"[7] It then follows that in pursuing National Defence, the CAF must also try to avoid negatively impacting National Security by contributing to climate change. The region that has the poorest access to transportation infrastructure is Canada's Arctic. As will be shown in this paper, presently there are substantial areas of Canada that have little to no access to that transportation network. This paper will demonstrate how airships could be employed to perform sustainment functions for military operations with minimal environmental footprint. Furthermore, the sustainment solution proposed in this paper also has the potential to improve living conditions in the arctic by bringing down the cost to ship material to Canada's Arctic.

Transport Canada published their strategic plan that will support their vision for the future of transportation in Canada. Figure I illustrates the five themes associated with this strategic plan called Transportation 2030.

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[4] Olivia Gazis. "U.S. intelligence touts new emphasis on climate change, calling it an "urgent national security threat"" *CBS News*, (23 April 2021): accessed 25 April 2021, https://www.cbsnews.com/news/climate-change-national-security-threat-us-intelligence/.

[5] United States. "Global Trends 2040: A More Contested World." *National Intelligence Council*, (March 2021): accessed 25 April 2021 https://www.dni.gov/index.php/global-trends-home.

[6] Olivia Gazis. "U.S. intelligence touts new emphasis on climate change, calling it an "urgent national security threat"" *CBS News*, (23 April 2021): accessed 25 April 2021, https://www.cbsnews.com/news/climate-change-national-security-threat-us-intelligence/.

[7] Ibid.

Figure I – Transportation 2030
Source: Transport Canada, *Transportation 2030: Actions Focused Under Five Themes*[8]

[8] Canada. Transport Canada, *Transportation 2030*, accessed 25 April 2021, https://tc.canada.ca/en/corporate-services/transportation-2030-infographic.

Of particular interest to this paper are the third, fourth, and fifth themes. As will be shown through the chapters of this paper, airships could be used as a "green" and innovative transportation means. Airships could be used to aid in the establishment of world-leading marine corridors and potentially open trade corridors to global markets. This could be accomplished through the establishment of a sustainment circuit that sees between one and three hydrogen-fuelled, rigid-hulled airships that regularly transit the Arctic region. These airships could be diverted for any number of National Defence imperatives such as supporting Arctic operations/exercises; search and rescue activities; intelligence, surveillance, reconnaissance (ISR) activities; detection of regulatory non-compliance and/or illegal activities. A sustainment system that sees a circuit of airships transiting the arctic region providing sustainment and potentially ISR functions for the CAF will likely have surplus capacity. This capacity could be used to augment commercial shipping to the Arctic region. This means that these airships would be CAF platforms that are maximally used both to satisfy national defence imperatives and to increase the logistical connectivity of the Arctic. More items can be brought into the region where there is demand and products from the region can more easily make their way to the global market for sale. This presents an opportunity to both further National Defence and economic development objectives. Although airships have not been widely used since the First World War, technological developments, climate change pressures, and an increased focus on the living conditions of indigenous peoples within Canada has presented an opportunity for the CAF to use airships for the following functions: to provide sustainment to both domestic and expeditionary CAF operations; to exercise sovereignty over the Canadian Arctic region; and to increase visibility and situational awareness on activities within the Arctic region.

CHAPTER 1 – TECHNICAL ISSUES

Airships are lighter than air which means they generate lift as a result of the lighter than air gas that fills the envelope. Heavier than air aircraft such as helicopters and airplanes generate lift by moving a wing or rotor through the air. This movement takes energy which means heavier than air aircraft are inherently less efficient because not only does the heavier than air aircraft have to expend energy to generate lift, they also need to expend energy to move between destinations. Both lighter than air and heavier than air craft experience drag associated with moving between destinations. Lighter than air craft need only expend energy to overcome drag. Since lighter than air craft engines only need to "move the airship, not lift it, and since the airships were relatively slow even the parasitic drag component [is] small."[9] This means that although there is a speed tradeoff with airships in that they are significantly slower than heavier than air aircraft, the energy they use for propulsion is significantly more efficiently utilized than with heavier than air aircraft.

Hydrogen vs. Helium:

It is important to note that not all lifting gasses are created equal. There are two primary lifting gasses used in lighter than air craft: helium and hydrogen. Hydrogen is more efficient as a lifting gas. For example, a 6.5 million cubic ft. airship inflated with helium is necessary to do the work of a 5 million cubic ft. airship inflated with hydrogen.[10] That said, there is a hesitancy to use hydrogen as a lifting gas due to its flammability. Any conversation about airships often entails a discussion of the Hindenburg disaster. Figure 1.1 is an image of a German airship bearing a swastika burning as it crashes to the ground.

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[9] Walter O. Gordon, Chuck Holland, and Karen S. Wilhelm. "Back to the Future: Airships and the Revolution in Strategic Airlift." Air Force Journal of Logistics 29, no. 3 (Fall, 2005): 47

[10] Richard G. VanTreuren. *Airships vs. Submarines*. Edgewater, Florida: Atlantis Productions, 2009: 18.

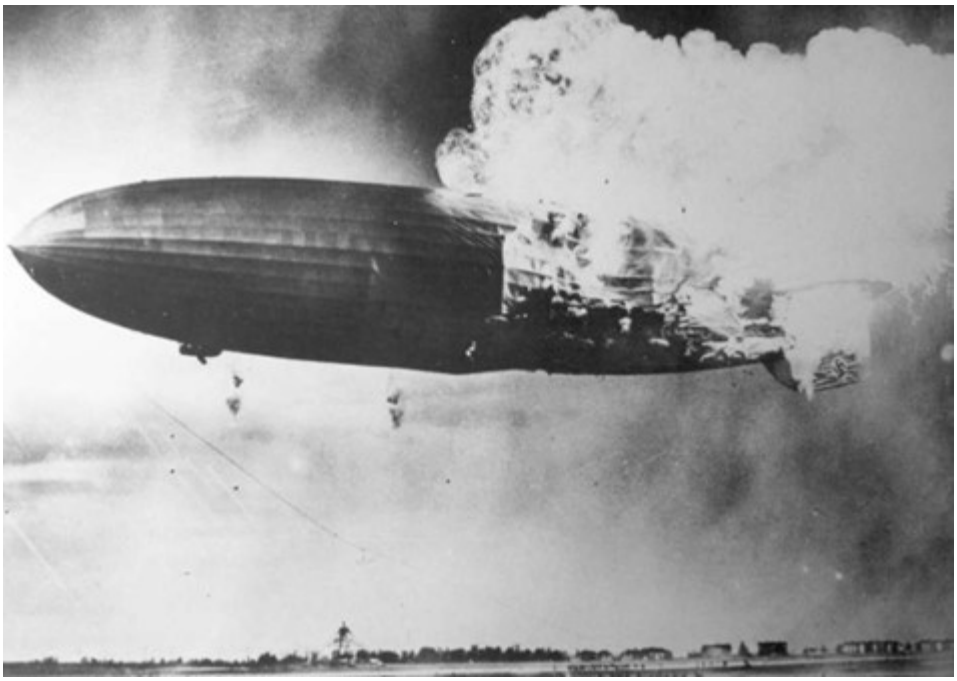

Figure 1.1 – Hindenburg Disaster
Source: Britannica.com, *The Hindenburg, Before and After Disaster*

The disaster took place in 1937, and although Germany had not yet gone to war with the allies, there was significant propagandistic value of an image of a swastika burning. Radio journalist, Herbert Morrison's commentary and iconic quote "Oh, the humanity!" was "dubbed onto the newsreel footage; at the time [1937] no one heard and saw them together."[11] During WWII and in its aftermath, the conflation of Nazi hubris and US abundance of helium (relative to the rest of the world) as an inert lifting gas alternative to hydrogen likely contributed to the aversion regarding the use of hydrogen as a lifting gas and as a fuel which marked "the end of commercial lighter-than-air flight and the stalling of hydrogen as a reliable fuel."[12] The US Congress enacted a ban on the use of hydrogen as a lifting gas which, "when the US became the

[11] Alexander Rose, Empires of the Sky: Zeppelins, Airplanes, and Two Men's Epic Duel to Rule the World (New York: Random House, 2020), 457.
[12] Martin Kelly, "The Hindenburg Disaster," accessed 6 February 2021, https://www.thoughtco.com/the-hindenburg-disaster-104703.

dominant aviation power, its regulations were "rubber-stamped" into aviation regulations around the world, including Canada."[13] Despite the fact that Fellow for the American Institute of Chemical Engineers, William Van Vrost found "that the material used to coat the "skin" of the airship, not hydrogen, was the cause of the disaster."[14] Aluminum powder and iron oxide were used to coat the skin of the airship's "envelope" (the inflatable lifting gas tank on an airship). There is still debate over what the cause of the fire was and specifically what role the hydrogen played and what role the flammable metals used in the paint to coat the envelope played.[15] Helium must be mined from pockets of rock in the earth. Prior to the Hindenburg disaster, lobbying work had already begun in the USA by the Bureau of Mines to ensure the long-term market for helium. In 1922 two airship accidents (the K5 and ZR-2) led to the formation of a congressional committee resulting in a hearing on the future of helium as an alternative to hydrogen as a lifting gas. Until that time, no one had shown that hydrogen caused or exacerbated the K5 and ZR-2 accidents. When an ignition source is introduced into a hydrogen-air mix, it burns "near-instantaneously and invisibly."[16] Lobbyists who had "been part of the effort to isolate and bottle helium in practical concentrations had been wondering if they had any future" viewed the hearing as an opportunity to take advantage of the accidents and manipulated lawmakers into pursuing helium as the safest lifting gas for use in airships in the US. Described as a "P.T. Barnum-quality performance to baffle the lay Congressmen."[17] Director of the Bureau of Mines' National Helium program Clifford Seibel confesses that the Bureau of mines team "took advantage of the two accidents to keep their helium empire funded in the postwar

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[13] Buoyant Aircraft Systems International "Possibilities as a lifting gas." Accessed 6 February 2021, https://www.buoyantaircraft.ca/hydrogen.php.

[14] "Hindenburg Disaster Explained." *Chemical Engineering Progress* (Aug, 1998): 7.

[15] Alexander J. Dessler "The Hindenburg Hydrogen Fire: Fatal Flaws in the Addison Bain Incendiary-Paint Theory" (3 June, 2004) Accessed 17 February 2021, https://spot.colorado.edu/~dziadeck/zf/LZ129fire.pdf.

[16] Richard G. VanTreuren. *Airships vs. Submarines*. Edgewater, Florida: Atlantis Productions, 2009: 15

[17] Ibid.

drawdown."[18] Seibel admits to suggesting a demonstration using two toy balloons: one filled with helium and the other hydrogen.[19] The Congressional Committee observed the following demonstration:

> Holding a helium-filled yellow balloon at the end of a string, [the demonstrator] applied a burning taper. His hand was trembling and the wobbling taper merely seared a spot on the balloon, weakening it enough for the gas to escape with a hissing sound, but without bursting the balloon. When the taper was applied to the red balloon filled with hydrogen, there was a terrific explosion. The windows were rocked, and Congressmen raised out of their seats. [the demonstrator] must have been as surprised as any member of the group, but he never batted an eye. 'Gentlemen,' [the demonstrator] said, 'if any of your boys are flying in military balloons or airships, do you want their ships filled with helium or will you be satisfied if they use hydrogen?' Afterwards, a member of the group said, 'We can't make the Army and Navy use helium, but we can say that none of the money we appropriate can be utilized to fill balloons or airships with hydrogen.' From that day on there was never a question about the advisability of using helium in lighter-than-air craft.

Seibel admitted later that the demonstrator accused him of adding some air to the red balloon to create an explosive mixture which Seibel coyly states was "something I never admitted."[20] This lobbying attempt in 1922 combined with the Hindenburg disaster resulted in a hesitancy to use hydrogen as a lifting gas. Pure hydrogen will not burn; if the hydrogen is contaminated with air in excess of 25%, it can.[21] U.S. politicians banned hydrogen's use in airships because of a fraudulent demonstration. A number of other countries ignored this prohibition. For example, in 1930, "the hydrogen-filled, British-built R100 airship, known as the "Emperor of Canada," flew [to Canada] and hundreds of thousands of people lined up to see it in Montreal, Ottawa, Toronto and Niagara Falls."[22] Since the Hindenburg disaster in 1937, there have been significant advancements in both materials and engineering. It bears a reexamination of the ban of hydrogen

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[18] Ibid.
[19] Ibid.
[20] Ibid.
[21] Barry Prentice, "Remember the Hindenburg? Forget the Hindenburg!", *Financial Post*, 30 September 2020, accessed 21 April 2021 https://financialpost.com/opinion/remember-the-hindenburg-forget-the-hindenburg.
[22] Ibid.

as a lifting gas when this ban is rooted in a political decision "made in a foreign country, 98 years ago, at the behest of dishonest lobbyists"[23] instead of engineering research.

Not only is helium an inferior lifting gas due to its heavier atomic mass than hydrogen, but because helium is a finite resource, it cannot be used in the same way as hydrogen. Airships that use hydrogen as a lifting gas (such as the Hindenburg) simply "vented excess hydrogen into the atmosphere to compensate for the weight of fuel burned. This was an acceptable solution because hydrogen was both inexpensive and easily generated wherever the ships were scheduled to land and refuel."[24] Conversely, helium, which is considerably more expensive, must be shipped in heavy gas cylinders from a mine or warehouse. This increases the engineering challenges because the helium gas is to be conserved throughout flight and compensated for using air and/or some other ballast. This is illustrated in Figure 1.2.

[23] Ibid.
[24] Walter O. Gordon, Chuck Holland, and Karen S. Wilhelm. "Back to the Future: Airships and the Revolution in Strategic Airlift." Air Force Journal of Logistics 29, no. 3 (Fall, 2005): 49

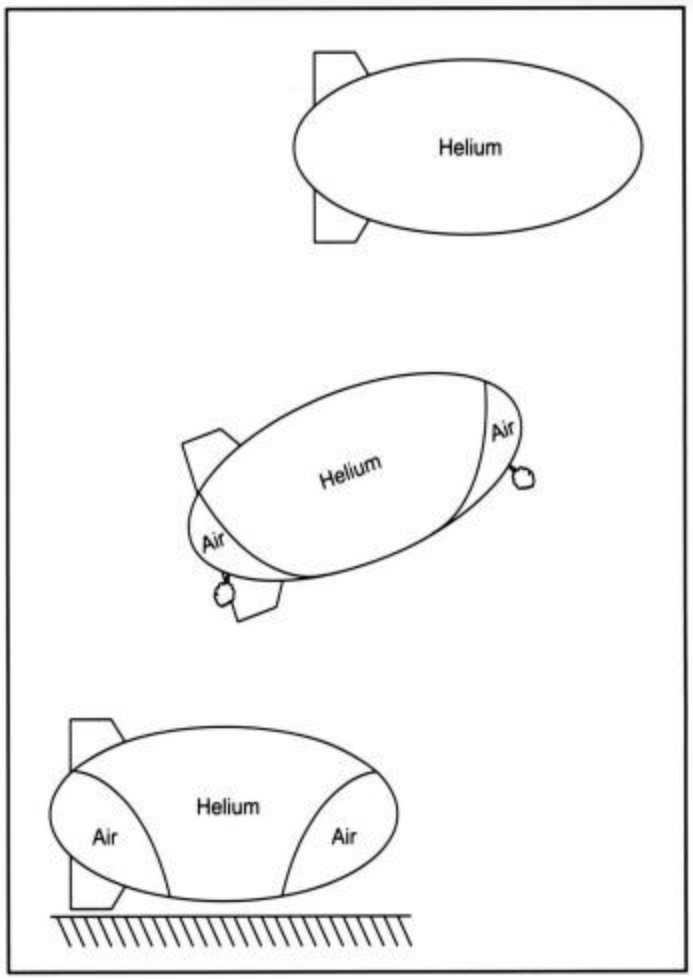

Figure 1.2 – Ballonets at Takeoff, Climb, and Pressure Height
Source: Gordon, *et al*., *Back to the Future*

This also means that the materials used to contain the helium must be airtight to reduce or minimize the loss of helium gas throughout flight. It is unfortunate that Transport Canada's Airworthiness Manual Chapter 541 - Airships still indicates that "Hydrogen is not an acceptable lifting gas for use in airships."[25] This anti-hydrogen view is problematic from the perspective of producing a sustainable lifting gas but not so much as to make the use of airships in the Canadian Arctic or in an expeditionary role in an otherwise remote/inhospitable region. As the technology

[25] Transport Canada, Part V – *Airworthiness Manual Chapter 541 – Airships* (Ottawa: Canadian Aviation Regulations, 2009), 541.7.

advances, hopefully a transition away from helium (towards hydrogen) as a lifting gas for airships can be safely affected. This would make the entire endeavour sustainable and much more carbon-neutral because there would be no need to mine and ship helium gas. Additionally, hydrogen can be manufactured electrolyzing water. The only input that is required is energy which could be sourced from renewables. Before the banning of hydrogen as a lifting gas, it was manufactured in a symbiotic manner with the chemical production industry which treated it as a waste product. The experiments of Dr. Konstantine Danilewsky who lived in what is present-day Kharkov, Ukraine published a book in 1900 called "A Steerable Flying Apparatus."[26] In his book Danilewsky wrote that he was "always amazed that the production of hydrogen is considered an expensive production. Even the Aero-club in Paris has awarded a prize to someone who will reduce the cost of hydrogen. In the past (1898), in my report, I pointed out that the production of hydrogen is almost free."[27] This was because of the following symbiotic relationship between chemical plants that produce iron sulphate and the airship industry at the time:

> Chemical plants, where iron sulphate is produced in large quantities, look at hydrogen as a waste product while aeronauts, needing the hydrogen, look at the iron sulphate as waste...simple logic will tell you that in the first case, each of them must be given what is valuable to him: the aeronaut to be provided hydrogen, and the chemical plant - iron vitriol. The chemical plant, therefore, will pay the aeronauts all the cost spent on obtaining hydrogen.[28]

Iron vitriol "is the iron salt produced from the chemical reaction of sulfuric acid and iron."[29] Today, the product is used as a pigment, fertilizer, and medically as an iron

[26] Bill Welker. "Hydrogen for Early Airships," WelWeb.org (2016) accessed 22 April 2021 https://welweb.org/ThenandNow/Hydrogen%20Generation.html.
[27] Ibid.
[28] Ibid.
[29] Ibid.

supplement.[30] Danilewsky produced hydrogen as a lifting gas for airships at his own hydrogen plant. The apparatus he used is pictured in figure 1.3.

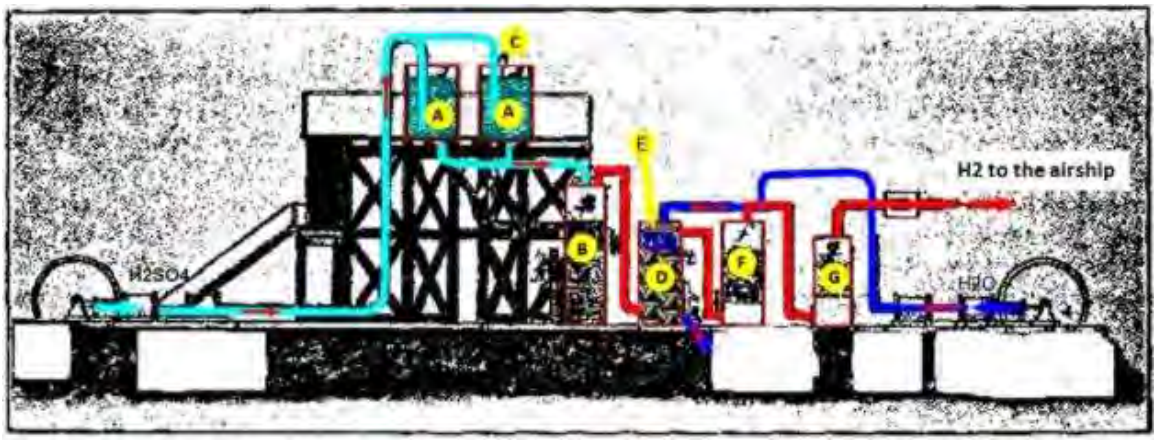

Figure 1.3 – Konstantine Danilewsky's Hydrogen Production Apparatus
Source: Welker, *Hydrogen for Early Airships*

What follows is a description of how this apparatus was used to produce hydrogen:

> Sulfuric acid, properly diluted, is pumped into tanks "A". The acid is regulated by valve "C" (one valve for each tank A), and flows into tank "B" as a spray or "rain" onto the iron fillings in tank "B". This is represented by the light-blue lines in the figure. The hydrogen produced (red line) flows out of tank "B" into the bottom of tank "D". Tank D is filled with coke, through which the hydrogen percolates. When the hydrogen emerges from the coke, it encounters a spray of water, "E" which has been pumped in to the tank (dark-blue lines). The hydrogen, thus "washed" to give up its molecular water, is allowed to pass to tanks "F" and "G" which are filled with caustic lime. This bubbling of the hydrogen through the lime further purifies it […] and the purified hydrogen (red line) is then passed to the airship envelope. […] the iron sulfate from tank "B" is drained and processed into the product marketable as the [iron] vitriol.

Regardless of if the electrolysis of water technique is used, a technique similar to Danilewsky's, or some other process is employed to produce hydrogen, there is ample opportunity to produce hydrogen in a way that produces a much smaller environmental footprint than helium which must be mined, compressed into tanks, and shipped to the location where it is required.

[30] Ibid.

Blimp vs. Rigid Hull:

Using airships in a remote/inhospitable region, especially in regions with large variations in temperature and humidity, will eliminate blimps from contention as a viable solution. This is because non-rigid airships (blimps) are pressurized, thus subjecting them to climatic vulnerability. Amontons' Law demonstrates that the pressure of a gas is directly proportional to its temperature. As temperature decreases, so does pressure, meaning the envelope will deform with non-rigid airships as temperature decreases. This has a negative impact on aerodynamic performance. Figure 1.4 shows this envelope deformation as a function of temperature and humidity of a blimp.

Figure 1.4 – Temperature & Humidity vs. Envelope Deformation
Source: Buoyant Aircraft Systems International, *Cold Weather Testing*

If the CAF is to use airships, it is important to note that rigid-hulled airships provide a form of lighting protection because their frames act as Faraday cages. This would be a very important consideration if an airship is to be used to transport cargo that responds negatively to lightning (such as ammunition and explosives); because they do not have rigid metal frames, blimps do not possess this added safety feature.

Speed/Payload/Range:

The US has already started researching options for an airship design. Specifically, Defense Advanced Research Projects Agency's (DARPA) "Walrus" program is looking at an airship solution that "would carry more than 10 times the average payload as a C-17 but would travel at only one-fourth the speed."[31] In looking at options to address gaps between the airlift and sealift requirements, DARPA's Walrus program proposes the use of an airship with a 500-ton payload that "could operate from unimproved locations and transport its load anywhere in the world in a few days. […] Estimates of achievable speeds for […] airships range from about 80 knots to 120 knots. For this analysis, CBO assumed an average speed of 100 knots."[32] 100 knots is equal to 185.2 km/h.

At the annual 2020 Annual Canadian Transportation Research Forum, a Canadian airship solution was proposed that could be used to sustain mining operations as well as deliver supplies to remote Northern communities. The payload capacity for the proposed cargo airship is 30 metric tons and there would be a need for water to be available at each base to act as ballast. [33] The ballast factor is a key consideration because airships have constant lift. If a return load weighs less than the airship's lift capacity, ballast (potentially in the form of water) would be

[31] Congress of the United States. "A CBO Study: Options for Strategic Military Transportation Systems." *Congressional Budget Office*, (September 2005), xiii.
[32] Ibid, 23.
[33] Ibid.

required to ensure the amount of lift is appropriate for flight.[34] The cruising speed for the proposed airship was 150km/h.[35] This design has significantly less payload than DARPA's design and is a bit slower. In the interest of keeping estimates of proposed capabilities that could be used by the CAF conservative, the author will be working with the figure of 150 km/h for speed. As DARPA has shown though, improved specifications in both speed and payload capacity are within the realm of the technologically possible.

Ceiling

When looking at the feasibility of operationally employing airships for sustainment in the Arctic or for use in an expeditionary capacity, the maximum altitude an airship can reach becomes a restraining factor. Much of the literature surrounding lighter than air craft describes solutions in a conceptual phase. That said the maximum cruising altitude tends to be in the range of 9,000 ft.[36] – 10,000 ft.[37] Fixed wing heavier than air aircraft currently used for sustainment such as the C-17, have cruising altitudes in excess of 30,000 ft.[38]. While this enables overflight of nearly every region on the globe, C-17s must land at an established airport with a runway with a minimum length of 3,500 ft.[39] As seen in figure 1.5, airships are much more versatile in linking-up with nodes and other vessels to transfer personnel and cargo.

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[34] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 433.
[35] Ibid, 432.
[36] Walter O. Gordon, Chuck Holland, and Karen S. Wilhelm. "Back to the Future: Airships and the Revolution in Strategic Airlift." Air Force Journal of Logistics 29, no. 3 (Fall, 2005): 51
[37] Congress of the United States. "A CBO Study: Options for Strategic Military Transportation Systems." *Congressional Budget Office*, (September 2005), 24.
[38] Ibid.
[39] U.S. Air Force. "C-17 Globemaster III." *Fact Sheets*, (14 May, 2018).

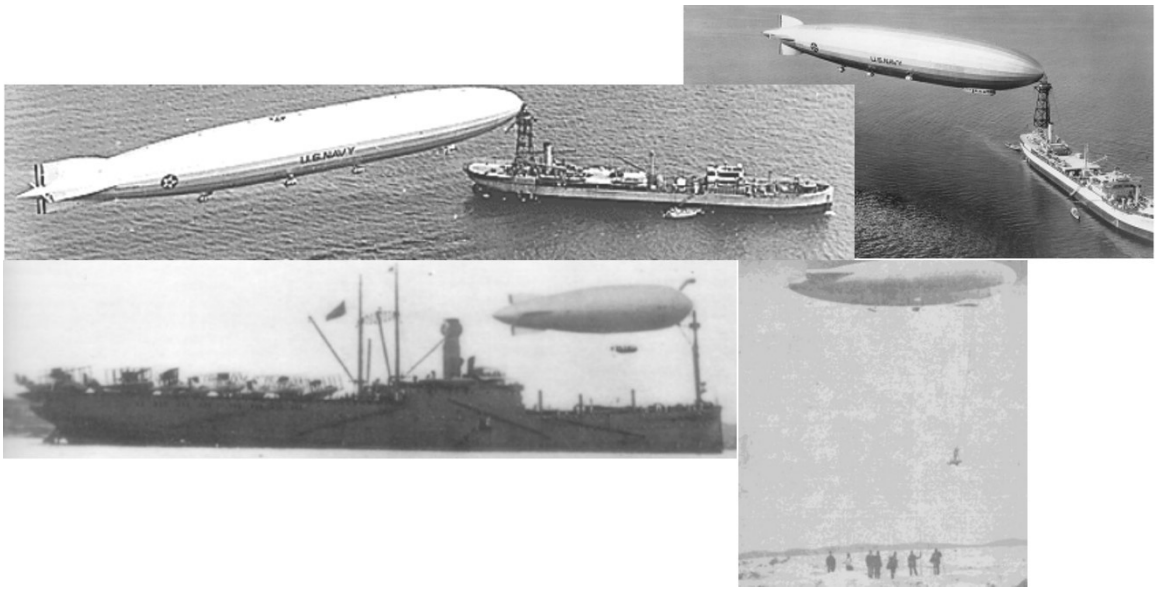

Figure 1.5 – Photos of Airships Transferring Cargo Without the Use of an Airport
Source: VanTreuren, *Airships vs. Submarines*

As seen in the photos above, it is possible to conduct replenishment at sea between a conventional seagoing supply vessel and an airship as well as to hoist cargo between the ground and the airship. This versatility combined with the tenfold increase in payload capacity (relative to the C-17) is the plus side of the trade-off between speed and payload (an airship travels at 25% of the speed of a C-17).

The 9,000-10,000 ft. ceiling could be a problem if airships are to be used in an expeditionary capacity because overflight permissions "might be more difficult to obtain for airships because their passage would be much more apparent than that of a conventional aircraft. Consequently, nations willing to quietly allow high altitude overflights might be more reluctant to permit low, slow overflights by airships."[40] In the next chapter, the author proposes a concept of support that seeks to conduct sustainment activities in Canada's Arctic. The highest point in the region that an airship would need to fly over would be Barbeau Peak on Ellesmere Island at

[40] Congress of the United States. "A CBO Study: Options for Strategic Military Transportation Systems." *Congressional Budget Office*, (September 2005), 24.

8,583 ft[41]. Other than to avoid weather, an airship conducting sustainment activities in the Arctic would not need to fly over this mountain but it should be considered as a limiting factor in any design parameter for airships used in Canada's Arctic regarding the ceiling. The Canadian Arctic is also sparsely populated with 79 communities in the region.[42] If the overflight of a large airship were to become problematic for one of these communities, there is ample space in the region for that airship to divert around the community to address this potential issue.

Maintenance, Repair, and Overhaul

One of the more risk-laden operations with airships is when they are transiting to/from a hangar. This is because if a crosswind emerges as the airship is partially in the hanger, the force exerted by the wind could exceed the force required to continue moving the airship in or out of the hanger. In figure 1.6 it is easy to imagine a scenario where a crosswind acting on the airship could push it into the side of the hangar wall, thus damaging the airship.

[41] Britannica.com. Barbeau Peak

[42] Arctic-Guide.net, "Canada's Arctic Towns. Home to Inuit, Metis, Various First Nation & European Descent People. Rich in Culture, Heritage & History," accessed 18 April 2021, https://www.Arctic-guide.net/Arctic-towns.html.

Figure 1.6 – Photo of Airships Partially Outside Hangar
Source: Airships.Net, *Graf Zeppelin History*

To safely use a conventional hangar to conduct maintenance, repair, and/or overhaul (MRO) activities, the hanger must be significantly larger than the airship itself. This alone stands to significantly add to the cost of owning and operating these assets. A safer technique would be to land the airship vertically into the MRO facility. Buildings with retractable roofs are also typically expensive. In conducting the research for this paper, the author interviewed Dr. Barry Prentice, Professor of Supply Chain Management for the University of Manitoba. Through this interview, the author encountered a concept whereby open-pit strip mines at the end of their life (as seen in the Figures below) could be used as landing sites for airships as an alternative to a conventional hangar.

Figure 1.7 – Open-Pit Mine Near Thompson, Manitoba
Source: Dr. Barry Prentice, *e-mail*

Figure 1.8 – Aerial View of Open-Pit Mine Near Thompson, Manitoba
Source: Dr. Barry Prentice, *e-mail*

As can be seen in figure 1.8, the open-pit (the ovular shape in the centre of the photograph) is already connected to the ground transportation network by road and the town of Thompson, Manitoba is connected to the rest of Canada by both road and rail. Thompson also has a regional airport, though the runway is only 3,000 ft. (500 ft. short of a C-17 requirement). Remediation of an open-pit mine can be an expensive undertaking. If an MRO facility is built on the site of a no longer viable mining site, the costs associated with remediation stand to be significantly reduced. There is already interest in airships by the mining sector due to the potential transportation cost savings that could be realized by not requiring roads and vehicles to reach remote areas. Cargo airships have been estimated to function for 300 days per year.[43] This means one MRO facility could handle many airships over the course of a year. Building an MRO facility in partnership with a mining company that also uses airships presents a very real opportunity to develop synergies between the private sector and DND. In speaking with Dr. Prentice, the author discovered that there are four mines in Thompson, Manitoba that could all hold airships possessing payloads in excess of 100 tons. The concept would be for the airship to land vertically in the MRO facility so that the time exposed to a potential crosswind could be reduced. Additionally, a roof may not be required, especially if the envelope of the airship is rigid and does not require dismantling. Also, much of the MRO work would likely take place near the bottom of the airship or internally because that is where the majority of the moving parts requiring MRO are situated. This would be a similar concept to drydocks in shipyards which do not require roofs for MRO functions to be performed.

[43] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 433.

Crewed vs. Un-crewed

Because the airships could be used in an environment where there are long-haul, predictable routes that are traversed at relatively low airspeeds (150km/h), the potential exists for autonomous, semi-autonomous, or remotely operated airships to be used. These airships would be broadly categorized as "un-crewed." The "EOS" platform (see figure 4.1) designed by Avalon Airships has been touted as being a "zero emissions, unmanned airship platform […] [w]ith rapid charging and water landing, [capable of reaching] even the most remote destinations"[44] This platform boasts "[f]ully automated flight controls and silent power-train [and] low cost, continuous 24-hour use."[45] Not only would an un-crewed airship be cost-effective by not requiring a crew, but much of the trepidation surrounding airship disasters (especially if hydrogen is once again permitted for use) could be alleviated. In the event of a crash, all that would be lost is cargo and the airship itself (assuming the crash did not take place over a populated area). Additionally, because airships are being applied as solutions to cargo movements through remote areas, the risk of having to recover a downed pilot/crew in an inhospitable and/or difficult to access location would be mitigated.

The un-crewed option would be particularly useful in Canada. This is because current Canadian Air Regulations "have no regulatory system to enable the training of airship pilots in Canada, or the requirements for instructors to certify airship pilots."[46] In fact, "Transport Canada has misdirected airship companies to obtain a hot air balloon pilot's license that is not valid for powered flight."[47] That said, transport Canada does have a path to obtaining a

[44] Avalon Airships, EOS.
[45] Ibid.
[46] Isopolar, Airship Regulator Framework.
[47] Ibid.

drone licence for advanced operations.[48] Because drone technology is relatively new, these regulations are also relatively new. To be classified as "advanced operations" according to Transport Canada, one or more of the following criteria must be met: flight in controlled airspace; flight over bystanders; flight within 100 feet of bystanders measured horizontally. Because of the broad nature of the Transport Canada's definition, an un-crewed lighter than air craft with a cruising speed of 150 km/h and a 30-ton payload that moves cargo between remote communities within the Arctic technically meets the definition of advanced drone operations. According to Transport Canada's regulations, the operator of the proposed air ship could obtain a license from transport Canada by registering the drone with them, marking the drone with its registration number and passing a basic exam (while being prepared to produce a pilot certificate and proof of registration while flying).[49] Pragmatically speaking, if un-crewed airships started emerging and moving freight around the Arctic with this rather scant regulation, it may compel Transport Canada to define un-crewed airships as different from drones but at the time this paper was written, this distinction has not been made. If the CAF has an interest in using airships to conduct sustainment activities in the Arctic, it could take the lead on regulating and licensing operators for this activity.

Cargo Airships Fill a Modal Gap

Conventionally, movement by air is the quickest but most expensive mode of transportation.[50] Compared to the other modes of transportation (road, rail, pipeline, and sea), not only is air the most expensive but the "level of emissions produced by air transport are also the

[48] Transport Canada, Advanced Operations.
[49] Ibid.
[50] "The 6 Modes of Transportation", *Mihlfeld & Associates* 19 October 2018, https://blog.mihlfeld.com/the-6-modes-of-transportation.

highest of any mode."[51] This means that air transportation should be used for cargo that is time-sensitive where the cost in fuel is worth the minimal time spent in transit. Air transport is also limited to the carrying capacity of the cargo. The size of the plane that is available is limited to the size of the runway that can accommodate it; larger shipments require longer runways. Pipelines notwithstanding, using airships to ship cargo stands to fill a transit time and lift capacity gap that currently exists between the conventional sea and ground modes.

When comparing airships to conventional ground modes of transportation it is important to consider both the cost of the ground vehicles themselves and the cost of preparing the surface over which these ground vehicles will travel. In Canada, the construction of extensive new rail lines to service the 70% of Canada that is inaccessible by ground is doubtful. This is because of the sizable upfront costs, lack of consistent demand to justify the widespread construction, and potential land use legal challenges from locally affected people. Road (not rail) construction has typically been how this region has been connected to the national transportation network. This was seen with the recent completion of the Inuvik to Tuktoyaktuk highway and with recent pressure to connect Churchill to the Canada's transportation network via road.[52] If road continues to be the ground solution, it is important to conduct a cost-comparison between ground and airships to see which one would be the most economically viable option to provide sustainment to CAF activities and/or regular supply runs to communities in the North. Figure 1.9 illustrates the theoretical gap that airships could fill vis-à-vis air ground transportation.

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[51] Ibid.

[52] Cameron MacLean. "'It's about time to build a road to Churchill': Engineer says it's possible" *CBC News* (24 June 2017): accessed 6 February 2021, https://www.cbc.ca/news/canada/manitoba/churchill-build-road-engineer-1.4174034.

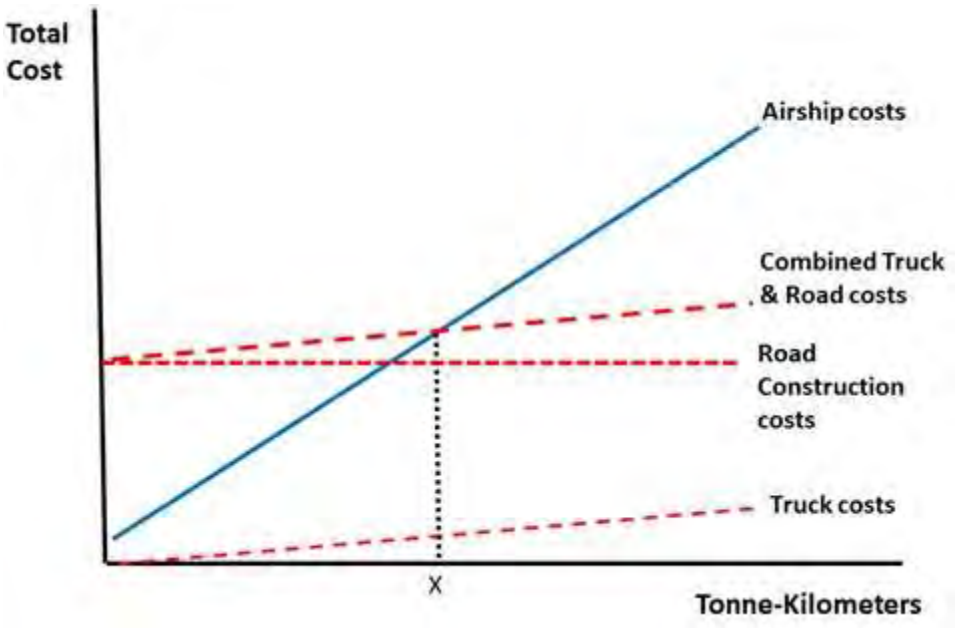

Figure 1.9 – Cargo Airships Versus All-Weather Roads – A Cost Comparison
Source: Prentice, *et al.* Cargo Airships Versus All-Weather Roads

Acknowledging that planned/corrective road maintenance would be required, the figure above assumes the total costs of a road are relatively constant for a given length. The truck costs increase with the number of tonne-kilometres carried because the volume of a single truck is finite therefore the transportation of greater volume leads to more trucks. Like trucks, airship costs are also a function of the volume of cargo transported (more airships would be required to transport more cargo assuming the capacity of a single airship was insufficient to meet demand). However, regarding infrastructure requirements, other than a hangar (airdock), these are minimal. At the point indicated by "X", the cost to move cargo to a given destination by airship are equal to the costs of road/trucks. To the left of the X, it is less expensive to use airships. This is a conservative cost analysis. As soon as trucks are placed on the road and used, there will be increased road maintenance costs as well as increased wear and tear on the trucks. This means that the slope of the red dashed "Combined Truck & Road Costs" line should be steeper than just the sum total of "Road Construction Costs" + "Truck Costs". In this case, "X" would be driven

further to the right, expanding the space where airship operation is the more economically viable cargo solution. This graph was presented for use in a mining application where mine sites are fixed and thus a road to a fixed location that will need sustainment can be constructed. It would be feasible to use airships in the Arctic to support activities that are not in a fixed or predicable location. The CAF's signature northern operation, consisting of a series of Arctic activities and exercises called Operation NANOOK, is an example of the CAF conducting activities in the Arctic that happen predictably in time but not space (Op NANOOKs have been conducted annually from 2007-2020).[53] Additionally, airships used to conduct sustainment in the Arctic would require the ability to deviate from a set location for the sake of weather or to respond to an emergency such as a casualty evacuation. Roads could not be economically built in the region to support all the potential uses airships could preform in the Arctic. So not only are airships an economical solution in the space to the left of X, they are also the only economical solution when the final destination of the cargo changes over time.

[53] Canada. Department of National Defence. *Operation NANOOK*.

CHAPTER 2 – DOMESTIC FUNCTIONS: SUSTAINMENT

This chapter will demonstrate the feasibility of using airships to conduct sustainment activities in Canada's Arctic. The logistical challenge the Arctic region poses has undeterred explorers; disasters such as the lost Franklin expedition exemplify the challenges faced by anyone attempting to establish lines of communication (LOCs) through the Arctic. In 1914, map maker John Bartholomew produced an isochronic map that illustrates the length of time it would take to travel from London to destinations around the world.[54] Figure 2.1 is a reproduction of this isochronic map.

Figure 2.1 – Isochronic Map from 1914
Source: Rome2Rio. *Time flies? According to these maps it does*[55]

[54] "Time Flies? According to these maps it does." Accessed 6 February 2021, https://www.rome2rio.com/blog/2016/01/08/time-flies-according-to-these-maps-it-does/.

[55] Ibid.

From the map, one can see that in 1914, the high Arctic in Canada would have taken over 40 days to access from London. In 2016, the multimodal transport search engine "Rome2Rio" produced an updated map pictured in Figure 2.2.

Figure 2.2 – Isochronic Map from 2016
Source: Rome2Rio. *Time flies? According to these maps it does*[56]

Even after 102 years, the high Arctic remains one of the world's least accessible locations. Many of the islands in the Arctic are not covered by Rome2Rio's 2016 isochronic map. This chapter will demonstrate that airships could be used to improve the accessibility of this region significantly, including accessing the remotest islands in the region.

As mentioned in Chapter 1, interest in using airships in Canada has been primarily on linking mining operations in the North to the existing lines of communication (LOCs) and transportation nodes such as road/rail networks and air/seaports. The Arctic is of particular

[56] Ibid.

interest to the mining industry because it contains a vast and untapped source of minerals.[57] Furthermore, "[r]educed sea ice in the Arctic over the last decade, improved ship access and new infrastructure have contributed to heightened mineral exploration interest in the region."[58] There are also "major concerns about the major vulnerability of the environment and social impacts."[59]All of this is pointing toward a solution that is flexible, environmentally friendly, sustainable, and has a small infrastructure footprint/bill. Similar to the mining industry, if the CAF seeks to operate in an efficient and environmentally conscientious way in the Arctic, a solution to sustainment must consider similar constraints associated with operating in an extreme environment by using assets that take up minimal infrastructure footprint while maximizing the use of existing LOCs.

Critical Potential Transportation Nodes

The established LOCs in Canada are pictured in figures 2.3 and 2.4. Figure2.3 outlines the Rail and Port infrastructure. Tuktoyaktuk, Hay River, the Mackenzie River, Churchill, and Moosonee are all critical nodes that can be seen in this figure and will be discussed further.

[57] P. A. J. Lusty and A. G. Gunn. "Challenges to global mineral resource security and options for future supply." In *Geological Society, London, Special Publications* 393 (2015): 272, https://sp.lyellcollection.org/content/specpubgsl/393/1/265.full.pdf.

[58] Ibid, 272.

[59] P. A. J. Lusty and A. G. Gunn. "Challenges to global mineral resource security and options for future supply." In *Geological Society, London, Special Publications* 393 (2015): 272, https://sp.lyellcollection.org/content/specpubgsl/393/1/265.full.pdf.

Figure 2.3 – Rail and Port Infrastructure
Source: *Statistics Canada*[60]

The blue oval that spans Hay River and Tuktoyaktuk represents the Mackenzie River LOC. This LOC connects settlements on Great Slave Lake (such as Yellowknife and Hay River) to Tuktoyaktuk and other communities on the Arctic Ocean. Barges are "coupled into 'trains' for the river journey. […] From Tuktoyaktuk, the barges are towed by sea-going tugboat to the Inuit communities along the coasts of Canada's Arctic islands."[61] Hay River is of particular interest because there is a large shipyard there that "maintains the fleet of tugs and during winter months.

[60] Statistics Canada, The Canadian Transportation System (Ottawa: Transportation Data and Information Hub, 2018).

[61] Canadian Council for Geographic Education. "Mackenzie River: Barging ahead" (2011): accessed 6 February 2021, https://web.archive.org/web/20111028020808/http://www.ccge.org/resources/rivers_of_canada/mackenzie_river/barging_ahead.asp.

There is a floating dry dock in Tuktoyaktuk for emergency repairs during the short, hectic navigation season."[62] This LOC is not open for an extended period. In the 2020 season for example, the Mackenzie LOC was only open from 10 July to 19 September.[63] The Mackenzie River LOC is of particular interest because it functions much like a sea LOC but its route is overland. Also, with climate change's disproportionate negative impact on the Arctic. Generally, the Arctic has "experienced temperature increases of 4 to 6 C compared to the global average of 1 C."[64] It stands to reason that the window this LOC is open will increase over time.

Churchill, Manitoba currently does not have road access. However, it does have a seaport, a regional airport with access to Winnipeg, and rail access. The completion of the Inuvik to Tuktoyaktuk highway has generated a number of lessons learned and there has been recent pressure to connect Churchill to Canada's road network.[65] This would establish redundancy along the existing rail ground LOC. Churchill also has a deep-water port with four deep sea berths that can accommodate Panamax class vessels (vessels that can fit through the Panama Canal).[66]

Moosonee is not connected to Canada's transportation network by road, however, there is a rail LOC to Moosonee and a regional airport. Its relative proximity to southern Ontario and Quebec position it as a key node in Eastern Canada.

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[62] Ibid.
[63] Government of Northwest Territories. GNWT completes marine resupply for northern communities. (2020).
[64] Aaron Kylie. "Climate change disproportionately affects the Arctic" *Canadian Geographic* (25 January 2016): accessed 26 February 2021, https://www.canadiangeographic.ca/article/climate-change-disproportionately-affects-arctic.
[65] Cameron MacLean. "'It's about time to build a road to Churchill': Engineer says it's possible" *CBC News* (24 June 2017): accessed 6 February 2021, https://www.cbc.ca/news/canada/manitoba/churchill-build-road-engineer-1.4174034.
[66] Government of Manitoba. Manitoba's Strategic Advantages: Seaport at Churchill, Manitoba.

Figure 2.4 outlines the Highway and Airport infrastructure. Goose Bay, Labrador City, Iqaluit, and Nanisivik are all critical nodes that can be seen in this figure and will be discussed further.

Figure 2.4 – Highway and Air Infrastructure
Source: *Statistics Canada*[67]

CFB Goose Bay is capable of handling a variety aircraft (C-17 included) and is connected to a road network with intermodal road/rail connections to the Quebec North Shore & Labrador Railway (QNSL) connecting Sept Îles, Quebec to Labrador City, Newfoundland.[68] Airships are

[67] Statistics Canada, The Canadian Transportation System (Ottawa: Transportation Data and Information Hub, 2018).
[68] Glyn Williams, "Railways in Labrador and Quebec North Shore," accessed 6 February 2021, https://www.sinfin.net/railways/world/canada/lab-qns.html.

large objects that spend time in the air and CFB Goose Bay is a Royal Canadian Air Force (RCAF) base. Depending on the final concept of employment and how disruptive airships in the proximity of an RCAF base could be in conducing conventional air operations, it might be more feasible to use Labrador City as the node to ship cargo via the road/ the QNSL for staging an onward movement rather than Goose Bay.

Another key location in the Arctic is the Nanisivik Fuel Facility. This facility will act as "the Arctic logistics and refuelling hub for the Navy's Arctic Offshore Patrol Ships."[69] The concept is to have it sparsely crewed[70] but there will inevitably be consumable items used for maintenance and repair that will periodically need to be shipped to Nanisivik. If Nanisivik is to act as a hub, it will require sustainment of its own and its location on Baffin Island makes it isolated from ground shipment and sea shipment for much of the year. There is an airstrip nearby but other than that it is currently logistically isolated for much of the year. Iqaluit is Nunavut's capital and, as will be touched on later in this chapter, could be used to receive both sealift and C-17-sized air shipments for onward movement into the region. One of the locations this onward movement could target would be the Nanisivik Fuel Facility.

Much like the Operational Support Hub (OS Hub) "hub and spoke" sustainment concept where a force may be deployed into a theatre of operations and established along the Strategic lines of communications with specific "spokes" getting activated for specific support[71], a similar concept could be used with airships in the Arctic. This would see the use of existing LOCs and transportation nodes to establish a circuit that could be traversed by airships as indicated by the

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[69] Defence Construction Canada. One-of-a-kind ship fuelling system coming online in Canada's North. (Ottawa: DCC at Work, October 2019) accessed 6 February 2021, https://www.dcc-cdc.gc.ca/english/dcc_at_work/2019/october/1910_article2/.

[70] Ibid.

[71] Department of National Defence. B-GL-005-400/FP001. *Canadian Forces Joint Publication 4-0 Support*. (Ottawa : DND Canada, 2016), 2-14.

red line on figure 2.5. This would allow for all-season regular cargo delivery windows for the entire region.

Figure 2.5 – Proposed Airship Sustainment Circuit
Source: *Statistics Canada*[72]

The green stars indicate sites that could have existing access to ground LOCs. These sites could function as nodes and represent potential locations where the shipping mode could be changed from ground to airship. One or more of these nodes could be used as a "hub" from which onward movement via airship into the Arctic region could be initiated. The impetus for maximizing ground LOCs results from the fact that air is "by far, the most expensive way to ship

[72] Statistics Canada, The Canadian Transportation System (Ottawa: Transportation Data and Information Hub, 2018).

[73]" than the other modes of transportation (road, rail, pipeline, and sea). Establishing nodes at the terminus locations of existing ground LOCs enables cargo to be pushed forward into the Arctic region conventionally and then transferred to an airship that will be transiting a circuit. This circuit could either be on a regular or *ad hoc* "freight run" depending on shifts in demand and/or weather conditions.

The blue stars indicate sites that could be used as nodes which are only accessible by sea or air. Nanisivik has already been discussed, but Iqaluit is another key location. It has an international airport (linkages to Greenland), it can accommodate the C-17 Globemaster III [74] and will soon be home to a deep sea port.[75]

Airship Freight-Run – Concept of Employment

It is anticipated that military demand on an airship freight run as proposed here will be of a surge nature. Military exercises and operations in the regions such as Op NANOOK take place over a finite period of time and follow a pattern: deployment, sustainment, draw-down. This means that the proposed Arctic airship freight run that only responds to the requirements of the CAF would have surplus capacity during the periods of time when military presence in the region is high and down-time when the military is not operating in the region. Cargo airships have been estimated to be functional for upwards of 300 days per year.[76] This means that there would be significant surplus availability to ship cargo during the periods of time that the military

[73] "The 6 Modes of Transportation", *Mihlfeld & Associates* 19 October 2018, https://blog.mihlfeld.com/the-6-modes-of-transportation.

[74] "Jet blast from cargo plane smashes windows out of Iqaluit van." *CBC News* (23 Jul 2015): accessed 6 February 2021, https://www.cbc.ca/news/canada/north/jet-blast-from-cargo-plane-smashes-windows-out-of-iqaluit-van-1.3164605.

[75] Dustin Patar, "Iqaluit deepsea port project remains on schedule for 2021 completion." *CBC News* (13 October 2020): accessed 6 February 2021, https://nunatsiaq.com/stories/article/iqaluit-deepsea-port-project-remains-on-schedule-for-2021-completion/.

[76] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 433.

is not using the airship freight run to support/sustain operations. Intelligence, Surveillance, Reconnaissance (ISR) functions could be completed during this down time. The potential ISR role will be discussed further in Chapter 3, however, this surplus capacity could be used to augment commercial supply chains that currently service Arctic communities. Currently, many Arctic communities only receive a sealift shipment once per year.[77] This means that there is no commercial means of transportation that fills the gap between annual sealift and expensive airlift (often on airstrips that can accommodate aircraft much smaller than a C-17). In offering up this surplus capacity to be used to augment existing commercial shipping to the region, it will also be important to avoid creating a non-competitive market that forces the private sector shipping companies in the region to withdraw from providing existing service. Failure to analyze existing commercial shipping service providers risks pushing the CAF airship sustainment airship freight run from an augmenting commercial shipping to becoming the primary service provider. This would effectively put the CAF in direct competition with industry. It is not the CAF's role to compete with the private sector thus, this needs to be carefully analyzed so that CAF-private sector competition can be avoided.

Canada's Arctic also has a high percentage of indigenous peoples as a share of the total population. Figure 2.6 demonstrates that unlike other Arctic states, in much of Canada's Arctic, many regions have greater than 75% indigenous people as a share of the total population.

[77] "High Arctic Haulers" *CBC* (20 Nov 2019): accessed 7 March 2021, https://www.cbc.ca/television/highArctichaulers/the-sealift-is-a-critical-part-of-survival-in-remote-Arctic-communities-1.5365820.

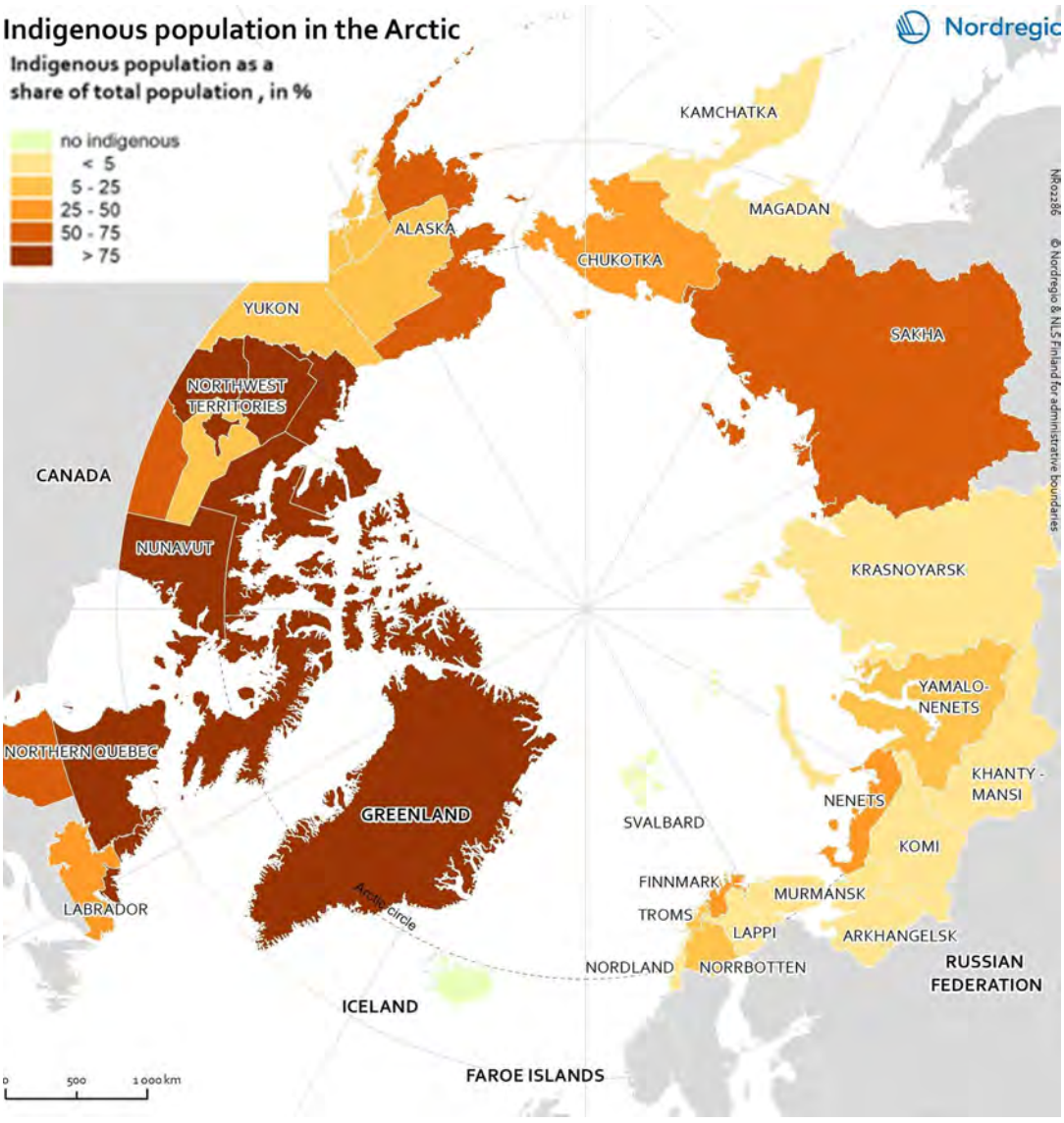

Figure 2.6 – Indigenous Population in the Arctic
Source: *Nordregio*[78]

This means that in addition to being concerned with potentially competing with the private sector, the employment of airships in Canada's Arctic region will also entail significant consultation and collaboration with indigenous stakeholders in the region. As will be expanded upon in Chapter 3, there is certainly both an appetite within indigenous communities to both

[78] Nordregio. "Indigenous population in the Arctic." *Nordregio-Maps*. Accessed 7 March 2021, https://nordregio.org/maps/indigenous-population-in-the-Arctic/.

bring down the price of cargo to Canada's north and invest in large infrastructure projects to accomplish that aim.[79] This paper was written having not yet completed that consultation and collaboration with the private sector and indigenous communities in the area and as such will be limited to the author's CAF lens with full acknowledgment that one of these or other stakeholder groups may find the following proposal of an Arctic airship freight run untenable as articulated. That said, it is the author's hope that with the engagement of all stakeholders in the region, this overall concept could be adapted and employed to conduct sustainment of CAF exercises and operations in the region in a cost-effective and environmentally sustainable way that stands to produce surplus cargo shipping capacity that could be used to service the entire region.

An airship solution to the cargo delivery problem in Canada's Arctic is not a particularly new concept. Paris-based airship company called "Flying Whale" has "signed an exclusive deal with Canada that could advance plans to use the dirigibles as an Arctic-preserving cargo solution."[80] Flying Whale's proposed airships are 200 metres long with a rigid envelope and has a projected lifting capacity "of 60 tonnes, three times the maximum carrying capacity of a Hercules plane."[81] Flying Whale is planning on completing its first prototype by 2023 followed by "six months of ground testing and almost two years of flight testing before commercial production could be approved."[82] This pushes commercial production forecasts out to 2026 for Flying Whale.

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[79] Sima Sahar Zerehi "Nunavut hamlet seeks Chinese investors to build dream port" *CBC News* (30 Aug 2016): accessed 7 March 2021, https://www.cbc.ca/news/canada/north/nunavut-port-chinese-investors-qikiqtarjuaq-1.3740470

[80] Energy Mix, "Airship Company Plans To Float Cargo Gently Over The Canadian Arctic," 13 April 2021. accessed 17 April 2021, https://theenergymix.com/2021/04/13/airship-company-plans-to-float-cargo-gently-over-the-canadian-Arctic/

[81] Ibid.

[82] Ibid.

Another airship concept that could be used in a sustainment capacity for mining operations and remote community access in Canada was proposed at the 2020 Annual Canadian Transportation Research Forum and was developed by Buoyant Aircraft Systems International (BASI). At this forum, a concept of employment for airships to sustain mining operations as well as remote communities in Canada was proposed.[83] The proposed concept was for an airship to operate primarily by transiting between a combined hangar/warehouse where cargo would be shipped from industry to the mining operation/remote community. At the furthest forward point in the supply chain that the airship would need to travel, the proposal calls for the installation of airship-transportable fixed bases called Buoyant Aircraft Rotating Terminals (BARTs). Figure 2.7 illustrates the proposed model.

[83] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 433.

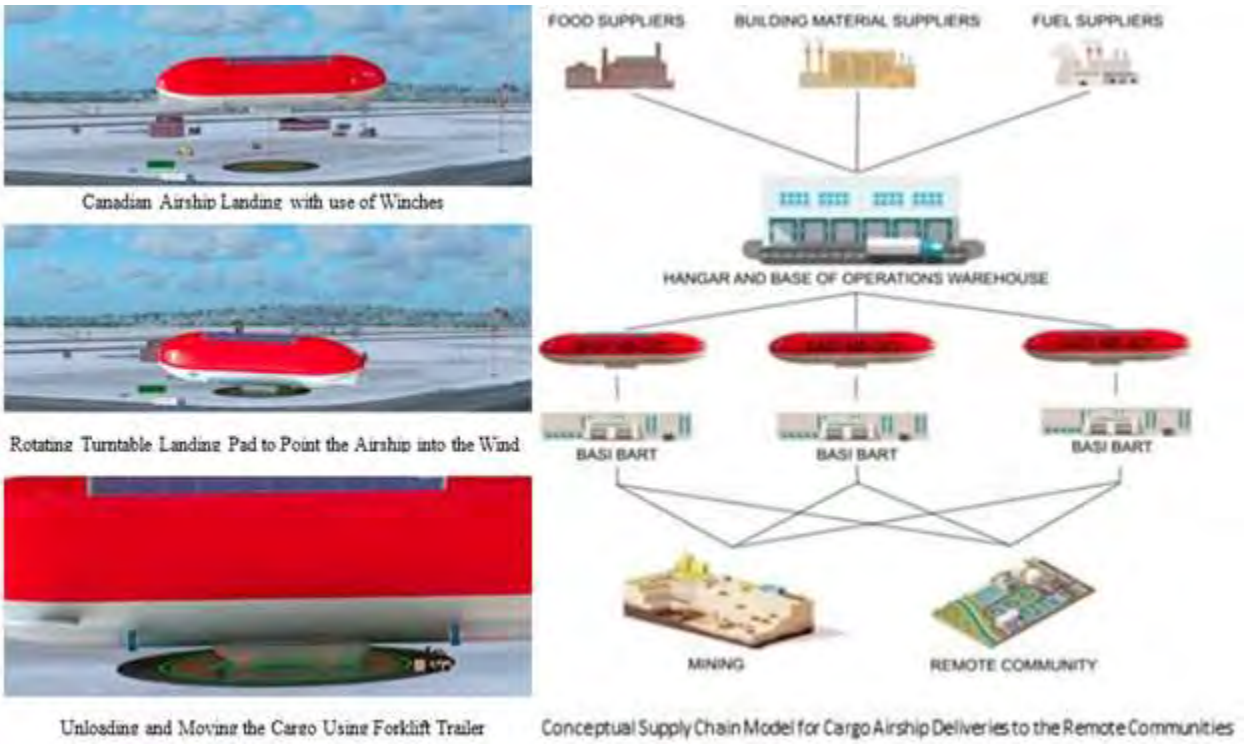

Figure 2.7 – Proposed Cargo Airship Transportation System
Source: Prentice and Wilms, *Cargo Airship Fuel Transport: Canadian Shield Case Study,* 433

As the diagram on the right side of figure 2.7 shows, this model proposes that cargo is pushed to a warehouse with the airship pushing out further into the remote region to facilitate the cargo delivery. Because this proposed model is primarily concerned with shipping items out that will all be consumed, there is no discussion of a reverse logistics cycle. If the CAF were to make use of a similar concept, good environmental stewardship would require that all items brought into the region are removed and either re-warehoused or disposed of accordingly. Items that are not consumed (requiring re-warehousing) could be a diverse group of goods ranging from modular tent to ammunition and explosives. Not all of these items are compatible in transit and arrive in a different configuration than they will need to depart (rations, for example, arrive on

pallets and depart as black water). This will necessitate a robust transportation plan for both deployment and draw-down/redeployment.

Reverse logistics notwithstanding, delivery under the concept that was proposed at the 2020 Canadian Transportation Research Forum would be affected with the use of winches similar to the "bear trap" on RCN vessels. A rotating landing pad would then be used which is fixed in place while the forklift transits from the ground onto the airship and then released so that the airship can remain pointed into the wind. This reduces stress on the airframe associated with maintaining an orientation other than into the wind. The proposal was for three airships and 22 BARTs. The cost estimate that was presented at the research forum has been reproduced in figure 2.8.

1. Turnaround time at each stop – 1.5 hour	
2. Average cruise speed – 150 kmph	
3. Days of Operation/yr – 300	
4. Fuel use - 500 liters/hr. at $1.00 per liter or C$500 per flying hour	
5. Crew cost on airship - C$200 per operating hour	
6. Cost to build one ship of a multiple series –	$50,000,000
7. Fixed costs based on initial years of service	
a. Aircraft (3) amortized over 20 years at 5%	$12,000,000/yr
b. Hangar ($50 million - amortized over 25 years)	$ 3,600,000/yr
c. BARTs (22 locations - amortized over 25 years)	$ 3.600,000/yr
d. Insurance (airships, hangar and BARTs)	$ 3,600,000/yr
e. Administration and ground support	$ 1,000,000/yr
Total Annual Fixed Costs	$23,800,000/yr
8. Depreciation Aircraft (3) per year at 5%	$ 7,500,000/yr

Figure 2.8 – Specifications and Cost Assumptions for three 30-ton Cargo Airships
Source: Prentice and Wilms, *Cargo Airship Fuel Transport: Canadian Shield Case Study,* 432

The costs outlined in figure 2.8 would be similar to those incurred by DND if this proposal was implemented. That said, rather than 22 x BARTs, DND could likely make use of seven (one at each of the proposed nodes in figure 2.5) plus two or three that could be packed up

and transported via airship to the specific location in the region that the military is seeking to operate.

The proposed cargo airship has a cruising speed of 150km/h.[84] This means that over 12hrs, the airship could intentionally deviate from its regular circuit by up to 1,800km to provide support in a location in the Arctic that is not along the regular flight path. This significantly increases flexibility regarding re-taskings for higher priority operations such as support to search and rescue, that said, if the airship is to be used to deliver cargo for that higher priority mission, the location of the cargo delivery would need to already be outfitted with an apparatus such as a BART to recover the airship and effect the delivery or else the first delivery will be a portable BART. Chapter 4 will further discuss the concept of a portable BART that could also be used in an expeditionary capacity.

In order to demonstrate the reach airships could reach as a function of time, an arc with a radius of 1,800 km has been superimposed over the potential Hay River node to demonstrate how over a 12-hr period, one airship could cover a substantial portion of the Arctic to support an Arctic operation and after a 24-hr period, any point in the entire Canadian Arctic region becomes accessible. This range is shown in Figure 2.9.

[84] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 432.

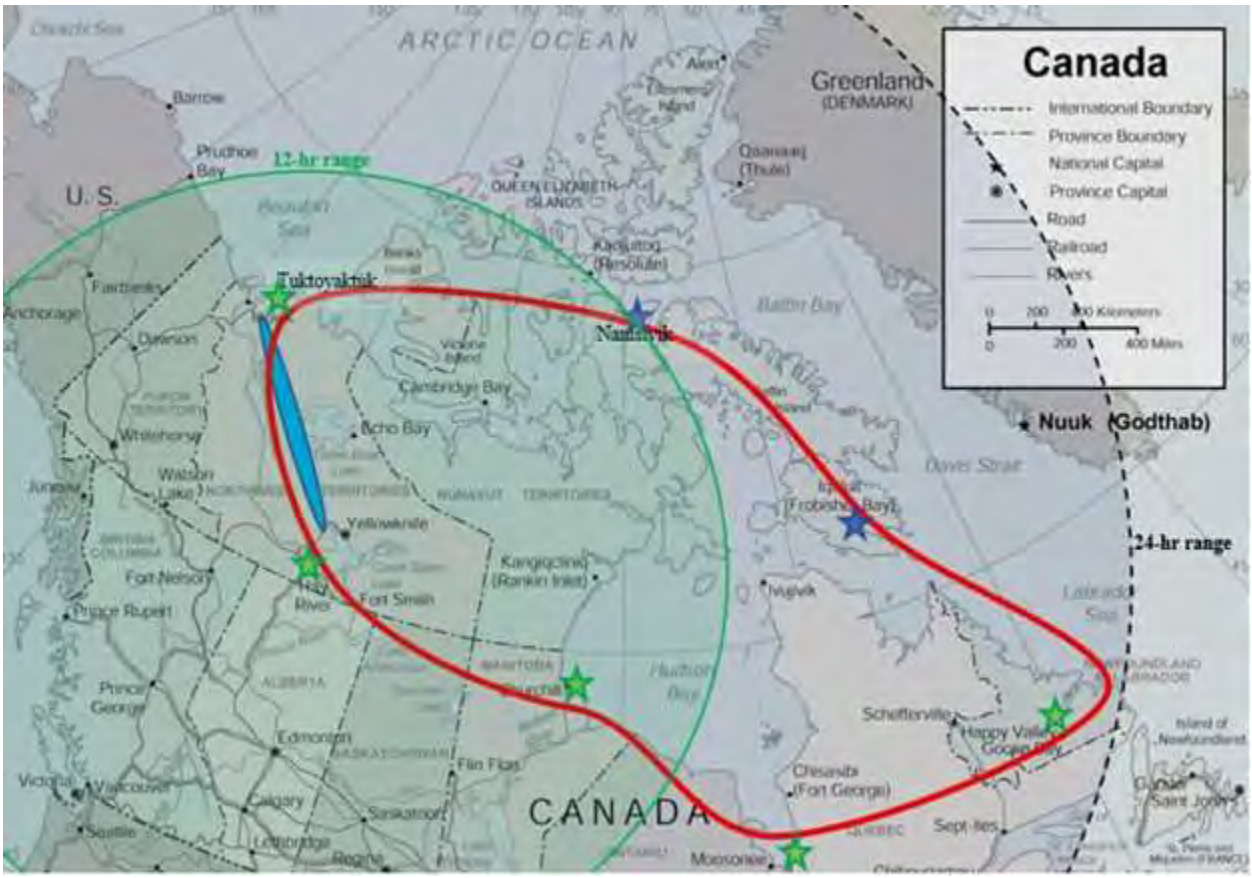

Figure 2.9 – Potential Airship Reach Within 12/24hrs from Hay River
Source: *Statistics Canada*[85]

The area inside the green arc reflects the distance an airship with a 150 km/h cruising speed could travel in a 12hr period in any direction away from a potential node in Hay River. Remarkably, only one airship delivering cargo as described would necessitate the redrawing of the 2016 Isochronic Map, making all the Canadian Arctic accessible for cargo movement inside 24hrs. Increasing the number of airships to two (add one to Moosonee) or three (add another to Iqaluit) will increase the coverage and response area as detailed in Figure 2.10.

[85] Statistics Canada, The Canadian Transportation System (Ottawa: Transportation Data and Information Hub, 2018).

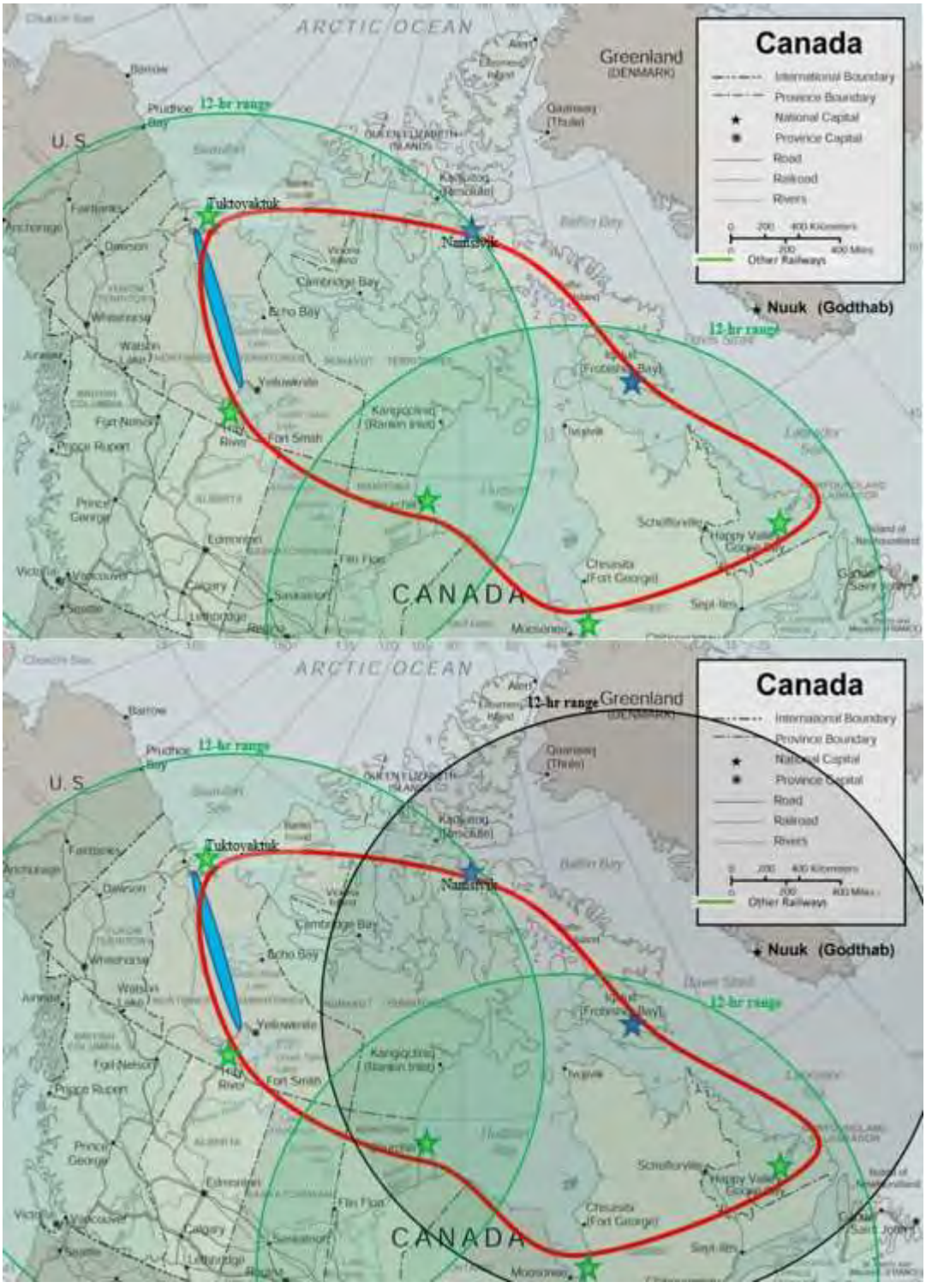

Figure 2.10 – Potential Airship Reach Within 12hrs with two/three Airships
Source: *Statistics Canada*[86]

[86] Statistics Canada, The Canadian Transportation System (Ottawa: Transportation Data and Information Hub, 2018).

In these proposed scenarios, the second airship was added to the Moosonee and the third airship to Iqaluit. The range of the Iqaluit airship is in black to differentiate it from the airships that have access to ground LOCs because the cargo transported by an airship based in Iqaluit will be limited to what can be transported via air/sea.

If cargo was continuously being pushed to warehouses in the nodes along the circuit, even one airship transiting a "freight run" circuit would be able to deliver cargo to anywhere within the Arctic region within a day. With two and three airships in the circuit, the region becomes much more accessible, enabling sustainment within 12 hrs of a node. One of the traditional limitations of airpower is a lack of persistence. This is because conventional aircraft must spend a much greater percentage of time on the ground than in the air. Airships represent an interesting hybrid of air and sea power vis-à-vis persistence. While still subject to severe weather and despite the fact that they need to be maintained and refueled, the time airships can spend in the air is much greater than conventional aircraft.[87] It is this persistence in the air domain that presents a real opportunity for cargo movements. With airships, cargo can effectively "loiter" in the area and can be deployed anywhere in the region within a day. The proposed airship solution at the 2020 Annual Canadian Transportation Research Forum had a 30-metric tonne payload capacity[88] but DARPA's Walrus program is looking at solutions with a 500 ton (508 metric tonnes) payload capacity.[89] The level of flexibility with respect to time and space to move that

[87] Defence R&D Canada, *Airships for military logistics heavy lift.* (Ottawa: Centre for Operational Research and Analysis: 2010) accessed 6 February 2021 https://cradpdf.drdc-rddc.gc.ca/PDFS/unc92/p532881.pdf.
[88] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 432.
[89] Congress of the United States. "A CBO Study: Options for Strategic Military Transportation Systems." *Congressional Budget Office*, (September 2005), 23.

much tonnage over a vast area with few LOCs is not currently achievable with any other mode of transportation than airships.

The DND solution should include a model that uses multiple airships. This is to build in redundancy when maintenance activities need to be performed on the airships or if one or more airships are required for ISR/expeditionary functions for a period of time. Cargo airships have been estimated to function for 300 days per year[90]. However, maintenance periods will require them to be taken out of the sky and repaired. The establishment of an airship maintenance facility (see Chapter 1) would also be required but this could potentially be handled with an in-service support contract.

Also, as airship technology advances, components such as "vectoring engines, tail thrusters and modern aircraft avionics that give pilots sufficient control to land and take off independently […] eliminates the need and expense of large ground crews."[91] This means at each of the nodes, personnel can be sourced locally and trained to handle the ground support piece when the airship needs to embark/disembark cargo at one of the nodes.

As a lifting gas, hydrogen was discussed in the previous chapter. That said, hydrogen could also be used as a source of fuel. Hydrogen fuel cells are currently being researched and developed for use in airships.[92] Hydrogen fuel would be an ideal fuel choice for airships in the Arctic. It is a zero-emission fuel and "has begun to be used in commercial fuel cell vehicles […] and has been used in fuel cell buses for many years."[93] As mentioned in the previous chapter, water can be electrolyzed to produce hydrogen and renewable energy sources can be used to

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[90] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 433.

[91] Barry E. Prentice and Robert Knotts, "Cargo Airships: International Competition," *Journal of Transportation Technologies* 4, (2014): 195.

[92] Buoyant Aircraft Systems International "Possibilities as a lifting gas." Accessed 6 February 2021, https://www.buoyantaircraft.ca/hydrogen.php.

[93] Ibid.

produce hydrogen.[94] If hydrogen fuel could be produced at some or all of the nodes proposed in this paper using a combination of renewables such as wind and solar, there would be no need to ship airship fuel to the nodes. This would have the effect of decreasing strain on the LOCs that feed the nodes. Using fossil fuels in the Arctic not only involves the shipping of the fuel itself, but the container that the fuel is shipped (steel drum) is either left onsite in the Arctic or shipped back to be filled again. This means that fossil fuel usage in the Arctic would strain both the logistics and reverse-logistics capacity of the overall system. A hydrogen fuel cell not only eliminates the emissions associated with fossil fuel combustion, if produced onsite, it would eliminate the need to ship fuel and fuel containers. Furthermore, the exhaust produced by burning hydrogen is water. As noted previously, water would be required in some cases to act as ballast. It is possible that the exhaust from a hydrogen fuel cell could be used to help perform a ballast function. If Transport Canada's policy against hydrogen use as a lifting gas does change,[95] the production of hydrogen for use as a fuel (at the node sites) could be upscaled to produce lifting gas, further easing potential supply chain stress associated with equipping airships with helium as their primary lifting gas.

Using even a single airship in Canada's Arctic would make sustainment throughout the entire region a matter of 24 hours transit time. There are already proposed designs, such as DARPA's Walrus, that have a cargo capacity in the 500-ton range.[96] With the hydrogen fuel cell being sought as a propulsion solution for airships used in remote regions for cargo transport, the opportunity exists to conduct sustainment in an environmentally responsible way as well.

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[94] International Renewable Energy Agency, "Hydrogen from Renewable Power," accessed 6 February 2021, https://www.irena.org/energytransition/Power-Sector-Transformation/Hydrogen-from-Renewable-Power#.

[95] Transport Canada, Part V – *Airworthiness Manual Chapter 541 – Airships* (Ottawa: Canadian Aviation Regulations, 2009), 541.7.

[96] Congress of the United States. "A CBO Study: Options for Strategic Military Transportation Systems." *Congressional Budget Office*, (September 2005), 23.

Regarding hydrogen as a lifting gas, DND already has an exemption from the transportation of dangerous goods act.[97] This means that it could technically be possible to trial hydrogen for use as a lifting gas for under a DND exemption. That said, any concept of employment for airships in Canada's Arctic will likely involve producing surplus shipping capacity when the military is not making use of the system. If this surplus capacity is to be used to transport commercial goods, the DND exemption would no longer apply meaning the Transport Canada prohibition would be in effect. For that reason, helium will need to be the lifting gas of choice over the short-term. That said, as seen in this chapter and as will be demonstrated further in Chapter 4, industry is already developing cargo airships that use helium as a lifting gas. If hydrogen is again able to be used in a safe way, it will only serve to increase environmental conscientiousness within the proposed sustainment model.

[97] Department of Justice, Transportation of Dangerous Goods Regulations (SOR/2001-286): National Defence (Ottawa, 2001), section 1.20

CHAPTER 3 – DOMESTIC FUNCTIONS SOVEREIGNTY

Before a discussion about how airships could be used to improve the exercise of Canadian sovereignty over the Arctic region can begin, it is first important to define certain aspects of what sovereignty means. Only after that has been defined can a solution-set be applied to exercise that sovereignty. The Stanford Encyclopedia of Philosophy distills sovereignty down to meaning "supreme authority within a territory."[98] For sovereignty to be exercised, two elements must be present: authority and territory. Only one of these two elements is capable of exercising sovereignty: authority. Authority without territory is a government in exile, unable to exert authority within a territory. Thus, territory is required to exercise sovereignty. Territory without authority is ungoverned space and cannot inherently exercise its own sovereignty. Parties claiming to possess authority can attempt to exert that authority in ungoverned spaces and if unchallenged, that party would achieve *de facto* authority. It is here that another aspect of the authority element emerges. Authority cannot exist in isolation without being recognized by an external party. This is because authority cannot exist without distinction. Specifically, there must be a distinction between the ability of one party to exercise power in a way that is different from another party. Therefore, not only does the Stanford definition of sovereignty necessitate the existence of an authority and a territory over which that authority can exert itself, but it also requires the existence of a party that sees itself as distinct from the party that exercises authority. This is an important point to underscore because sovereignty can be challenged by external parties if there is a difference between the self-perception of the scope of an authority and the perception held by parties external to that authority. A state may perceive that it has authority over a region but can be said to exert sovereignty over that region only if it has uncontested

[98] Edward N. Zalta "Sovereignty", *The Stanford Encyclopedia of Philosophy* (2020 Edition): accessed 8 March 2021, https://plato.stanford.edu/entries/sovereignty/.

authority over that territory. This becomes particularly pertinent to Canada's claim of sovereignty over the Arctic if the Canadian government is unable or less-able to exercise authority over the activities in the region than another party.

Much of the interest in the Arctic region to date has been driven by economic factors.[99] Some estimates claim that "the region is home to around 22% of the earth's remaining supplies of oil and gas."[100] Additionally, resource extraction in the Arctic does not have the same additional issues associated with "political violence and instability that can arise in the Middle East and Africa."[101] There has been much alarmism and mischaracterization in the media regarding Canadian Arctic sovereignty. The debate in the media typically starts with an alarmist identification of a very specific Russian threat such as a "vulnerability to naval vessels from Russia and other unfriendly nations passing through the Northwest Passage, or terrorists and smugglers seeking to enter North America from there."[102] The logistical challenges with terrorists and smugglers entering North America from the Arctic approaches aside, this sensationalism is often greeted with a discussion about how Russian freedom-of-navigation deployments through the Northwest Passage "would be politically senseless and counterproductive. […] Russia's Arctic sea routes are claimed on a similar basis. To challenge Canadian sovereignty […] would weaken Russia's jurisdiction over the various straits that make up the Northern Sea Route."[103] This debate is often too narrow and misses the wider issue of

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[99] Zachary Fillingham. "Arctic Ownership Claims." *Geopolitical Monitor* (8 April 2009): accessed 6 February 2021, http://www.geopoliticalmonitor.com/Arctic-ownership-claims/.

[100] Ibid.

[101] Ibid.

[102] Scott Borgerson and Michael Byers "The Arctic Front in the Battle to Contain Russia", *Wall Street Journal*, (8 March 2016): accessed 8 March 2021, https://www.wsj.com/articles/the-Arctic-front-in-the-battle-to-contain-russia-1457478393.

[103] Adam Lajeunesse and P. Whitney Lackenbauer "Canadian Arctic Security: Russia's Not Coming", *The New Humanitarian*, (14 April 2016): accessed 8 March 2021, https://deeply.thenewhumanitarian.org/Arctic/community/2016/04/14/canadian-Arctic-security-russias-not-coming.

sovereignty being the ability of a state to exercise authority in a particular territory. The exercise of authority requires an ability to enforce that authority.

Within the Arctic region, the United Nations Convention on the Law of the Sea (UNCLOS) has granted governance, management and jurisdiction of the Arctic Ocean to five countries: Canada, Denmark (Greenland), Norway, Russia, and the US.[104] UNCLOS establishes exclusive economic zones (EEZs) which provides for natural resources development rights over territorial waters out to 370km (200 nautical miles).[105] Under UNCLOS, the continental shelf is seen "as a natural prolongation or seabed that extends beyond the 200 nautical miles but not further than 350 nautical miles (400 miles; 650 km)."[106] This enables states to claim exclusive rights to harvesting natural resources to the extent of this natural prolongation. It should also be noted that the US is the only one of the five countries that has not ratified the UNCLOS over concerns that it would be against both the national security interests and be "economically disadvantageous to U.S. companies."[107] The Sector Principle is used to determine territorial claims in the Arctic. Also known as the "doctrine of contiguity, propinquity, hinterland, and continuity,"[108] if a state:

> occupies and/or exercises state functions over the territory, the government can be granted title to the area. The sector principle at its basic definition is simply drawing a line out from the coastal country's borders along longitudinal parallels to the North Pole. The longitudinal lines result in sectors for establishing the coastal countries' territory from the neighboring countries. Historically, claims based exclusively on the sector principle have been rejected by most nation-states. The general consensus in the international community is that for a country to establish sovereignty over a territory, it must be accepted under international law and the country must exercise governmental functions over the territory.[109]

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[104] Andrew J. Hund. "Arctic Territorial Claims and Disputes." In ANTARCTICA AND THE ARCTIC CIRCLE: A Geographic Encyclopedia of the Earth's Polar Regions. Vol. 1 2014.
[105] Ibid.
[106] Ibid.
[107] Ibid.
[108] Ibid.
[109] Ibid.

From this one can see that the key to the exercise of sovereignty over the Arctic region rests with a nation's ability to exercise governmental functions over the territory. There are three parties that could potentially challenge Canadian authority in the Arctic region, thus preventing or degrading the exertion of Canadian sovereignty over the Arctic region. These parties are Denmark, the USA, and the Inuit. This is not to say that these three groups pursue an agenda to undermine Canadian sovereignty, as will be shown, these parties have simply taken actions that prevent Canada from fully exercising its sovereignty (as defined above) and/or erode exiting Canadian sovereignty over the Arctic region. The Russian Federation is notably absent from this list of states that prevent/degrade Canadian Sovereignty in the region. As will be shown in the next subsection, at the time of writing, Russian territorial claims in the Arctic region do not overlap with Canadian claims. What follows then will be a discussion on how some Canadian sovereignty has been impinged upon in the past and how airships could be used to ameliorate that in the future, thus enabling Canada to exert sovereignty over the Arctic region that falls within its territorial borders, its EEZ, and prolongation of the continental shelf.

Denmark (Greenland)

Denmark is not traditionally associated with holding a competitive or adversarial relationship with Canada. That said, there are unresolved sovereignty disputes between Canada and Denmark. The first dispute is regarding the Lomonosov Ridge.[110] The Canadian government claims that the Lomonosov Ridge, pictured in figure 3.1, is an extension of Ellesmere Island (circled in red). Denmark claims that the ridge is an extension of Greenland.[111]

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[110] Ellis Quinn, "Canada files submission to establish continental shelf outer limits in Arctic Ocean" *Radio Canada International.* (27 May 2019): accessed 11 April 2021, https://thebarentsobserver.com/en/Arctic/2019/05/canada-files-submission-establish-continental-shelf-outer-limits-Arctic-ocean.

[111] Andrew J. Hund. "Arctic Territorial Claims and Disputes." In ANTARCTICA AND THE ARCTIC CIRCLE: A Geographic Encyclopedia of the Earth's Polar Regions. Vol. 1 2014.

Figure 3.1 – Canada's UNCLOS submission showing the Lomonosov Ridge
Source: *Government of Canada*[112]

Furthermore, there is a small island in the Nares Strait (the narrow stretch of water between Ellesmere Island and Greenland) called Hans Island whose ownership is also disputed between Canada and Denmark.[113] To date, the dispute has escalated to nothing more than planting, removing, and re-planting flags.[114] There are no known oil, natural gas, precious metals, or other minerals on Hans Island[115] because the climatic conditions in the vicinity of Hans Island have made natural resource exploration in the area cost-prohibitive to date. With the onset of climate change, this region will continue to become more accessible for exploration into possible natural resource reserves. Additionally, as Arctic sea temperatures continue to rise, the

[112] Ellis Quinn, "Canada files submission to establish continental shelf outer limits in Arctic Ocean" *Radio Canada International.* (27 May 2019): accessed 11 April 2021, https://thebarentsobserver.com/en/Arctic/2019/05/canada-files-submission-establish-continental-shelf-outer-limits-Arctic-ocean.

[113] Andrew J. Hund. "Arctic Territorial Claims and Disputes." In ANTARCTICA AND THE ARCTIC CIRCLE: A Geographic Encyclopedia of the Earth's Polar Regions. Vol. 1 2014.

[114] Christopher Stevenson. "Hans Off! the Struggle for Hans Island and the Potential Ramifications for International Border Dispute Resolution." *Boston College International and Comparative Law Review* 30, no. 1 (2007): 267.

[115] Ibid.

Northwest passage will become navigable throughout the year. As a result the increase in Arctic shipping presents an opportunity for the country that controls the passage to generate revenue.[116] It should be noted that Russia also argued that the Lomonosov Ridge and the Mendeleev Rise "were an extension of the Eurasian continent, thus an extension of the Russian territory."[117] Because of its location relative to Canada (see Figure ##), the Mendeleev Rise claim would not impact Canadian territorial claims and because the Russian claim over the Lomonosov Ridge only extends to the North Pole,[118] this claim does not overlap with any existing Canadian claim.

While currently there have been "very low level of reported passages of the Nares Strait since the region was first subject to exploration,"[119] it has been noted that using the Nares Strait as a potential feeder to the hypothesized Transpolar Sea Route (TSR) and Northwest Passage (NWP) would improve shipping times by routing cargo through the NWP/TSR using the Nares Strait as a connector.[120] This potential sea line of communication (SLOC) that the Nares Strait Connector (NSC) would open is indicated by a purple dashed line on figure 3.2.

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[116] Ibid, 268.

[117] Andrew J. Hund. "Arctic Territorial Claims and Disputes." In ANTARCTICA AND THE ARCTIC CIRCLE: A Geographic Encyclopedia of the Earth's Polar Regions. Vol. 1 2014, 126.

[118] Ibid.

[119] Donald Rothwell. Arctic Ocean Shipping: Navigation, Security, and Sovereignty in the North American Arctic. Paperback book ed. Leiden;Boston;: Brill, 2018, 54.

[120] Mia M. Bennett, Scott R. Stephenson, Kang Yang, Michael T. Bravo, and Bert De Jonghe. "The Opening of the Transpolar Sea Route: Logistical, Geopolitical, Environmental, and Socioeconomic Impacts." *Marine Policy* 121, (2020): 104178, 6 *see note 3*.

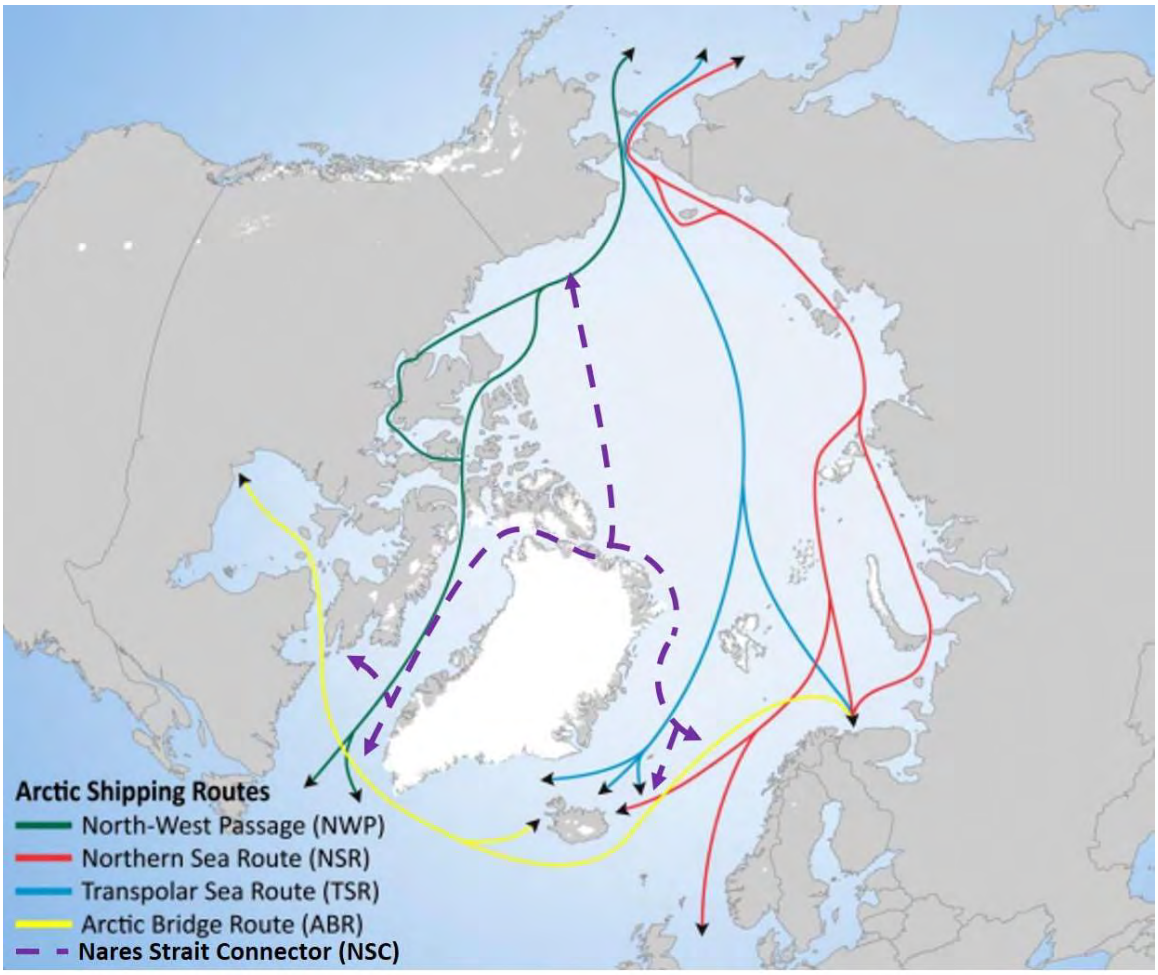

Figure 3.2 – Nares Strait Connector
Source: *Author's own work. Adapted from Humpert and Raspontnik*[121]

Estimates made in 2020 predict that the Central Arctic Ocean (CAO) "may be ice-free in summer as soon as the 2040s, setting in motion the seasonal opening of the TSR.[122] This means that there will be a number of geopolitical, environmental, and socioeconomic issues that emerge as a result of the reconfiguration of global shipping networks such that Arctic traffic increases through the territorial waters of Arctic nations. As an Arctic nation, Canada is a stakeholder in

[121] Malte Humpert and Andreas Raspotnik. "The Future of Arctic Shipping Along the Transpolar Sea Route." *Arctic Yearbook*. 1, (2012): 282.
[122] Mia M. Bennett, Scott R. Stephenson, Kang Yang, Michael T. Bravo, and Bert De Jonghe. "The Opening of the Transpolar Sea Route: Logistical, Geopolitical, Environmental, and Socioeconomic Impacts." *Marine Policy* 121, (2020): 104178, 11.

how the Arctic is used as a means to transport cargo. However, Canada's ability to regulate traffic in the region will improve commensurate with an increase in Canadian Government presence in the region. Through agencies such as the Canada Border Services Agency (CBSA), the Department of Fisheries and Oceans (DFO), and the Royal Canadian Mounted Police (RCMP), the Canadian Government regularly exercises its sovereignty by regulating marine traffic within Canada's coastal waters. Extending this regulatory coverage to the Arctic region becomes much easier if there is a regularly transited circuit of autonomous/semi-autonomous airships throughout the region. As demonstrated in chapter 2, an airship could access the entire Arctic region within 24hrs. This is substantially quicker than it would take an ocean-going vessel to transit the region even in completely ice-free conditions. An airship equipped with optical sensors similar to those found on the RCAF's CP-140 Aurora maritime patrol aircraft would be capable of searching for vessels within the region that are non-compliant with Canadian laws as they transit the region. The author has participated in inter-agency operations between the CAF, DFO, CBSA, and the RCMP where Naval and Air Force assets were used to photograph illegal activities such as drug smuggling and illegal logging. The diversion of an airship (equipped with adequate optical sensors) to observe vessels of interest that are transiting the Arctic region becomes possible, thus enabling Canada to exercise sovereignty over the region.

Even before the Nares Strait becomes a tenable SLOC for international shipping, there is another opportunity for airships to be used to exert Canadian (as opposed to Danish) sovereignty throughout the region. Despite the fact that the Nares Strait has been used sparingly for commercial traffic,[123] there remain reports of submerged submarine transits through the Nares

[123] Donald Rothwell. Arctic Ocean Shipping: Navigation, Security, and Sovereignty in the North American Arctic. Paperback book ed. Leiden;Boston;: Brill, 2018, 54.

Strait.[124] In accordance with Article 20 of UNCLOS, "In the territorial sea, submarines and other underwater vehicles are required to navigate on the surface and to show their flag.[125] There have been some nations that have interpreted a foreign submerged submarine that is travelling through that nation's territorial waters to mean that the coastal nation may attack a submerged submarine "because such passage is not innocent and therefore a violation of the coastal State's territorial sovereignty."[126] During the Cold War, the former Soviet Union accused foreign submarines "with violating Soviet territorial waters, and announced that they would be destroyed."[127] At the same time, the governments of Romania and Bulgaria had specific legislation that stated submerged foreign submarines would be attacked.[128] This interpretation was not limited to the Soviet Bloc during Cold War. The Navies of both Sweden and Norway "have launched depth-charges at submerged contacts in the Swedish and Norwegian territorial sea, and the Argentinian Navy has done likewise."[129] That rather aggressive interpretation of Article 20 of UNCLOS (a submerged foreign submarine automatically equates to non-innocent passage) differs from the interpretation of Article 20 of UNCLOS put forward by noted member of the International Law Commission of the United Nations and deputy-leader of the United Kingdom Delegation at the Geneva Conference, Sir Gerald Fitzmaurice. In recounting the results from the Geneva Conference on the Law of the Sea, Fitzmaurice offers the following interpretation of the requirement for submarines to navigate on the surface and to show their flag: "In short, a

[124] Harriet W. Critchley. "Polar Deployment of Soviet Submarines." *International Journal* 39, no. 4 (Fall, 1984): 828 Accessed 11 April 2021, https://search-proquest-com.cfc.idm.oclc.org/scholarly-journals/polar-deployment-soviet-submarines/docview/1290352936/se-2?accountid=9867.
[125] United Nations, United Nations Convention on the Law of the Sea (New York: UN, 1982), 31.
[126] Miyoshi Masahiro. "The Submerged Passage of a Submarine through the Territorial Sea -the Incident of a Chinese Atomic-Powered Submarine." The Singapore Year Book of International Law 10 (2006): 247.
[127] Daniel Patrick O'Connell and Ivan Anthony Shearer. *The International Law of the Sea*. New York; Oxford: Clarendon Press, 1982, 297.
[128] Ibid, 297, footnote 231.
[129] Ibid, 297.

submarine that traverses the territorial sea submerged or not showing her flag may possibly not be in innocent passage, but this will not be because she is submerged or not showing her flag.[130] That said, "most submariners will agree that submergence in the territorial sea for purposes other than avoidance of bad weather, or similar reasons of well-being, may be adopting a belligerent posture."[131] That is to say submergence in the territorial sea of another state for reasons other than weather or well-being "would not amount to innocent passage."[132]

> Innocent passage refers to passage through territorial waters in a:
>
> prompt, direct, and uninterrupted manner that does not interfere with the coastal states' security, peace, and/or stability. Things considered not innocent passage are polluting fishing in waters, firing missiles and weapons, and espionage activities. The coastal state can safeguard its security and temporarily suspend innocent passage in their territorial waters.[133]

Neither Canada nor Denmark has sought to deny the right of innocent passage through the Nares strait. However, Professor of International Law at the ANU College of Law, Australian National University Dr. Donald Rothwell notes, "the regime of territorial sea innocent passage allows for much closer regulation of shipping passing through Nares Strait than is the case with transit passage and Canada and Denmark would find this advantageous."[134] The temporary suspension of innocent passage for security reasons is another mechanism by which the Canadian Government could exercise its sovereignty by exercising governmental functions, suspending innocent passage in this case. Submarines are regularly used for espionage activities. Since 1950

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[130] Gerald Fitzmaurice. "Some Results of the Geneva Conference on the Law of the Sea. Part I. the Territorial Sea and Contiguous Zone and Related Topics." *The International and Comparative Law Quarterly* 8, no. 1 (1959): 73-121.

[131] Daniel Patrick O'Connell and Ivan Anthony Shearer. *The International Law of the Sea*. New York; Oxford: Clarendon Press, 1982, 296.

[132] Ibid, 297.

[133] Andrew J. Hund. "Arctic Territorial Claims and Disputes." In ANTARCTICA AND THE ARCTIC CIRCLE: A Geographic Encyclopedia of the Earth's Polar Regions. Vol. 1 2014.

[134] Donald Rothwell. Arctic Ocean Shipping: Navigation, Security, and Sovereignty in the North American Arctic. Paperback book ed. Leiden;Boston;: Brill, 2018, 54.

it has been common for Chinese, British, North Korean, American, and Soviet (and Russian) submarines to be used for undersea spying "with some regularity."[135] Additionally, "submarine intrusions into the territorial sea are not uncommon."[136] For innocent passage to be temporarily suspended on national security grounds, such as suspected submarine espionage, a country must be capable of both detecting and preventing passage of a submerged submarine. Currently, the detection of submarines under the ice involves the deployment of a device called a sonobuoy. It is beyond the scope of this paper to analyze how sonobuoys are used to detect submarines but a capability currently exists whereby sonobuoys can be air-launched and penetrate ice such that detection of activities below the ice can occur.[137] In the CAF, sonobuoys are deployed from both maritime helicopters and maritime patrol aircraft and do not require complex mechanical systems to be deployed. It is possible that the systems currently used on the RCAF's CP-140 Aurora maritime patrol aircraft to deploy sonobuoys could be fitted to an airship. Unlike the Aurora, the airship possess an ability to persistently loiter over a region for hours or days and deploy sonobuoys if there is a suspected submarine in the area. Once detected, the submarine can be prosecuted directly or the nation who owns the submarine can be contacted and the submarine ordered to leave the area. The payload of DARPA's proposed "Walrus" airship has a projected capacity of 500 tons.[138] Currently the CAF's CP-140 Aurora maritime patrol aircraft has a payload of six tons under wings and 7,252 lb internal payload for a total payload of 9.6 tons. This means that one Aurora aircraft has 1.9% of the payload capacity of Walrus-type airship. The Aurora prosecutes submarines with a combination of sensors, sonobuoys, and ultimately

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[135] James Kraska. "Putting Your Head in the Tiger's Mouth: Submarine Espionage in Territorial Waters." *The Columbia Journal of Transnational Law* 54, no. 1 (2015): 164.

[136] Ibid.

[137] Louis V. Feltz, Eric W. Reece, Clarence W. Young, Thigpen Lewis, and DEPARTMENT OF THE NAVY WASHINGTON DC. Air-Deliverable, Ice-Penetrating Sonobuoy 1991.

[138] Congress of the United States. "A CBO Study: Options for Strategic Military Transportation Systems." *Congressional Budget Office*, (September 2005), 23.

torpedoes. While it is doubtful that an airship would be exclusively employed for anti-submarine warfare (ASW), there certainly would be capacity from a weight perspective to equip airships with sonobuoys for submarine detection and potentially even torpedoes for prosecution. Using airships in an anti-submarine warfare role is not without historical precedence. While the global combat record for airships in the First World War is lost to history, WWI American Rear Admiral W. A. Moffett stated:

> During the World War, as far as we know, no convoy was ever attacked by a submarine when guarded by an airship. During the [final] seventeen months prior to the Armistice, British airships sighted forty-nine submarines and successfully attacked twenty-seven of them; they convoyed 2,000 surface vessels and carried out over 9,000 anti-submarine patrols; and from January 1 to November 11, 1918, there were only nine days in which these airships could not fly because of bad weather.

Although, an airship that exercised an ASW capability such as deploying sonobuoys in the Arctic region is certainly exerting sovereignty, sonobuoys can be used in a much less provocative role. The author has seen sonobuoys used to gather oceanographic information of a purely scientific nature as well as in search and rescue operations. This means that the deployment of sonobuoys from Canadian-owned airships in the Arctic could be used to support other non-military objectives, all under the auspices of preforming governmental functions over the Arctic, thus exercising sovereignty over the region.

USA (Beaufort Sea)

The fact that the US is one of Canada's closest allies does not mean that all territorial disputes between the two nations have been resolved. Currently, there is an ongoing dispute over sections of the Beaufort Sea vis-à-vis the maritime boundary between Alaska and the Yukon.[139]

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[139] Randy Boswell. "Canada, U.S. Flip Positions in Boundary Dispute; Beaufort Sea; Long-Running Dispute Over Position of Border." *National Post*, Mar 09, 2010. Accessed 17 April 2021 https://search-proquest-com.cfc.idm.oclc.org/newspapers/canada-u-s-flip-positions-boundary-dispute/docview/330975297/se-2?accountid=9867.

So far this dispute has only "flared occasionally when it came to fisheries management and oil-and-gas exploration."[140] As figure 3.3 shows, this dispute has created "a wedge-shaped, Lake Ontario-sized section of the Arctic Ocean that both countries claim is theirs."[141] Canada's claim is based on "the wording of the 1825 Anglo-Russian treaty, written in French, between Russia and Great Britain."[142]

[140] Ibid.
[141] Ibid.
[142] Gregor Sharp. "An old problem, a new opportunity: A case for solving the Beaufort Sea boundary dispute," *The Arctic Institute: Center for Circumpolar Security Studies,* 17 Jun 2016. Accessed 17 April 2021 https://www.theArcticinstitute.org/an-old-problem-a-new-opportunity-a-case-for-solving-the-beaufort-sea-boundary-dispute/.

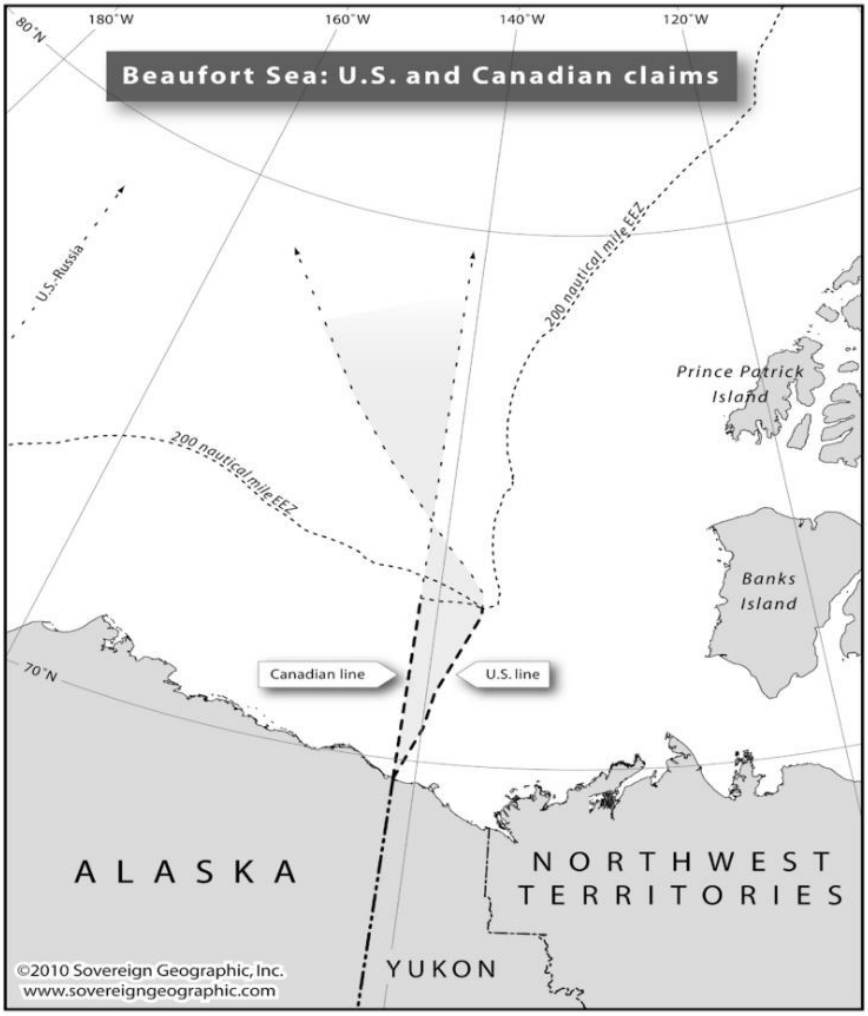

Figure 3.3 – Beaufort Sea: US and Canada Claims
Source: *Gregor Sharp*[143]

The US interpretation of the maritime boundary is obtained using "the "equidistance" principle based on the shape of the adjacent American and Canadian coastlines."[144] Interestingly, the US interpretation actually allows for more square kilometres of seabed to fall within the Canadian maritime boundary which is better for Canada from the perspective of access to natural resources

[143] Ibid.
[144] Randy Boswell. "Canada, U.S. Flip Positions in Boundary Dispute; Beaufort Sea; Long-Running Dispute Over Position of Border." *National Post*, Mar 09, 2010. Accessed 17 April 2021 https://search-proquest-com.cfc.idm.oclc.org/newspapers/canada-u-s-flip-positions-boundary-dispute/docview/330975297/se-2?accountid=9867.

in and under the sea. For example, it would give "Canada a greater share of the potentially oil-rich seabed."[145] Paradoxically, the Canadian interpretation whereby the territory is defined by a line that follows the 141st meridian, would benefit the US after 200 nautical miles. Canadian maritime law professor, Michael Byers, suggests that because of this relatively new discovery of a paradoxical benefit between both territorial claims, there is an opportunity for a win-win, negotiated solution in this dispute:

> [T]he introduction of extended continental shelves into the equation has only recently created a new bargaining environment, with the traditional US legal position conceivably favoring Canada and the traditional Canadian legal position conceivably favoring the United States. In other words, what appeared to be a zero-sum negotiating situation now offers opportunities for creative trade-offs [146]

If the expression of sovereignty is a function of the performance of governmental functions over a piece of territory, it stands to reason that the first country (Canada or the US) that is exclusively able to perform government functions in a given piece of territory will obtain a firmer footing regarding a negotiated solution. This is because that nation can point to a history of uncontested activity in the territory. For example, if Canadian airships regularly transit the disputed territory to sustain military operations/exercises in the area and/or to deliver supplies to remote communities in the area, and/or conduct surveillance Canadian maritime approaches, Canada will have established a history of expressing its sovereignty into this region before the US is able to match that expression of sovereignty. The recent discovery of a new bargaining environment regarding the Beaufort Sea dispute has created an opportunity for Canada to re-affirm itself as a principle stakeholder in the region.

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[145] Ibid.

[146] Michael Byers and James Baker. *International Law and the Arctic*. Cambridge: Cambridge University Press, 2013.

The US and others (The Northwest Passage)

The Northwest Passage is another point of contention between the Canada and the US. The US, along with most other maritime countries, acknowledges that Canada owns the Northwest Passage. That said, there is still a dispute "over whether the Northwest Passage is Canadian internal waters or an international strait."[147] The implications of this dispute is described below:

> Classifying the Northwest Passage as an international strait allows for the free passage without Canadian consent for all international maritime vessels. Canada claims that the Northwest Passage is part of their internal waters and not international waters as specified under UNCLOS. Thus, the Canadians claim the Northwest Passage is under their sole jurisdiction, and they have the right to enforce their own navigable and shipping laws regarding fishing, vessel safety, and illegal transportation of goods or persons. Another concern of wanting to maintain the Northwest Passage as an international strait is that Canadian environmental regulations over internal waters are stricter than the UNCLOS. The Canadian government does not claim to have the right to close the passage, just to have jurisdictional authority over enforcement and regulation.[148]

Much like the Beaufort Sea dispute discussed previously, a negotiated resolution is much more likely to come down that favours Canada's claim if Canada can establish a history or pattern of exercising governmental functions in the region. The existence of stricter than UNCLOS Canadian environmental regulations does not help position Canada in a more favourable negotiating position unless Canada has the capability to enforce compliance with those regulations. As noted previously, airships in the Arctic could be used to improve existing surveillance over the area. There is an opportunity for other government departments such as Transport Canada (TC), DFO, the RCMP, and CBSA to utilize the information that is detected by airships transiting the Arctic conducting sustainment activities and/or ASW to levy fines or potentially impound non-compliant vessels that seek to transit the Northwest Passage. The more

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[147] Andrew J. Hund. "Arctic Territorial Claims and Disputes." In ANTARCTICA AND THE ARCTIC CIRCLE: A Geographic Encyclopedia of the Earth's Polar Regions. Vol. 1 2014, 126.

[148] Ibid.

stringent than UNCLOS Canadian regulations are largely meaningless without an ability to enforce those regulations. Enforcing compliance must start with the detection of non-compliance and with the Canada's current surveillance assets, no solution exists that would enable Canada to detect non-compliance with its environmental regulations throughout the entire Arctic region claimed to be Canadian territory. Periodically one air ship that is transiting a sustainment circuit (such as the one proposed in Chapter 2) could be temporarily diverted from its sustainment function and be used to detect instances of suspected non-compliance by internationally flagged vessels that are transiting the Northwest Passage. Punitive measures associated with that non-compliance could then be taken, such as fines and/or impoundment, by the appropriate government department (TC, DFO, RCMP, CBSA, etc.). The detection of and punishment for non-compliance with Canadian Environmental regulations that are more stringent than UNCLOS meets the definition of performing governmental functions over a territory and thus, by using airships to detect non-compliance, Canada would be effectively exercising sovereignty over the Northwest Passage regardless of any ongoing dispute over the Northwest Passage's status as territorial or international water.

Inuit Interests (Qikiqtarjuaq and China)

Both International and Canadian law provide for territorial rights of Inuit peoples "over Arctic waters, ice, as well as the resources that lie above and below the ice.[149] Inuit territory in the Arctic region is referred to as "Inuit Nunaat" and "includes lands in Canada, the United States (Alaska), Denmark (Greenland) and Russia. Importantly, it also covers large portions of the Arctic Ocean and some northern areas of the Atlantic Ocean."[150] As Indigenous peoples, the

[149] Robin Campbell. "An Introduction to Inuit Rights and Arctic Sovereignty" *LawNow* (7 May 2015): accessed 6 February 2021, https://www.lawnow.org/introduction-inuit-rights-Arctic-sovereignty/.
[150] Ibid.

UN Declaration of the Rights of Indigenous Peoples applies to the Inuit and states that they "have the right to the lands, territories, and resources which they have traditionally owned, occupied or otherwise used or acquired."[151] Section 35 of the Constitution Act establishes constitutional protection to Indigenous peoples' rights and Canada's Supreme Court "has confirmed that Aboriginal peoples hold Aboriginal title to their lands, based on their occupation and governance. The courts have specifically affirmed that Inuit hold Aboriginal title to their territories in Canada."[152] In this case we see that there is some overlap regarding the exercise of governmental functions (i.e. sovereignty) over the Arctic region. In theory, if the interests of the Indigenous peoples inhabiting Inuit Nunaat are aligned with the Canadian Government's interests, friction between the two stakeholders will not occur. Unfortunately, these interests are not always aligned. An example of this that could translate into a threat to Canadian sovereignty can be seen with the Nunavut hamlet of Qikiqtarjuaq. For decades, the hamlet has been lobbying both the federal and territorial governments for a deep-water port.[153] The concept for this deep water port can be seen in figure 3.4.

[151] Ibid.
[152] Ibid.
[153] Sima Sahar Zerehi "Nunavut hamlet seeks Chinese investors to build dream port" *CBC News* (30 Aug 2016): accessed 7 March 2021, https://www.cbc.ca/news/canada/north/nunavut-port-chinese-investors-qikiqtarjuaq-1.3740470

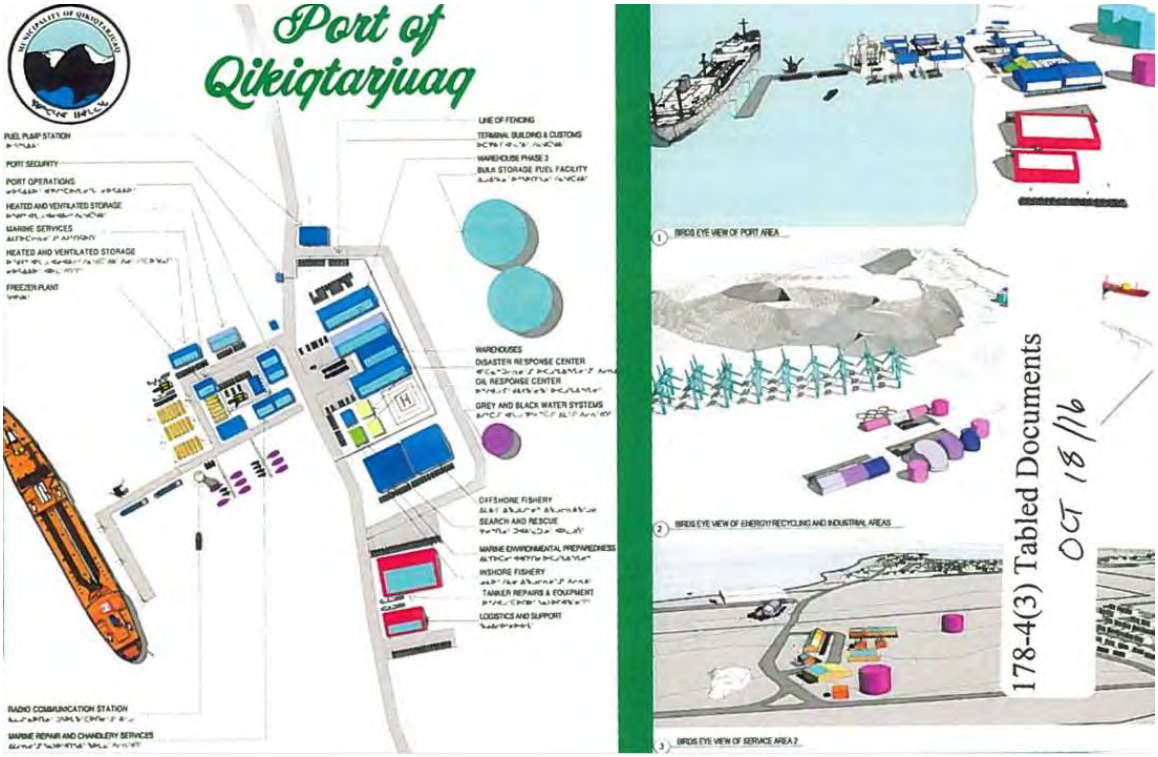

Figure 3.4 – Port of Qikiqtarjuaq - Concept
Source: *Pauloosie Keyootak*[154]

Though small in population (approximately 500 people), Qikiqtarjuaq is situated in a strategic position at the entrance to the Northwest Passage and has a "protected harbour, good anchorage and a moderate tide range."[155] The hamlet's director of finance, Arthur Nicomedes, acknowledged that both the Federal government and the government of Nunavut have already helped but that this help is insufficient in actually executing the construction of the port facility which has an estimated price of $50 million.[156] Nicomedes stated that some foreign investors have already come forward and that the hamlet is "extending an invitation to wealthy Chinese

[154] Pauloosie Keyootak. Legislative Assembly of Nunavut, *Qikiqtarjuaq Port Design Concept* (Nunavut: Tabled Documents) 178-4(3).
[155] Sima Sahar Zerehi "Nunavut hamlet seeks Chinese investors to build dream port" *CBC News* (30 Aug 2016): accessed 7 March 2021, https://www.cbc.ca/news/canada/north/nunavut-port-chinese-investors-qikiqtarjuaq-1.3740470
[156] Ibid.

businessmen."[157] Not only does Qikiqtarjuaq have geography in its favour by being near the entrance to the Northwest Passage but there are valuable fishing grounds in the area. Presently, most fishing vessels in the region transit across the Davis Strait/Baffin Bay stretch of open water to Greenland to offload fish, refuel and conduct crew changes. This open stretch of water is indicated with a blue oval in Figure 3.5 below.

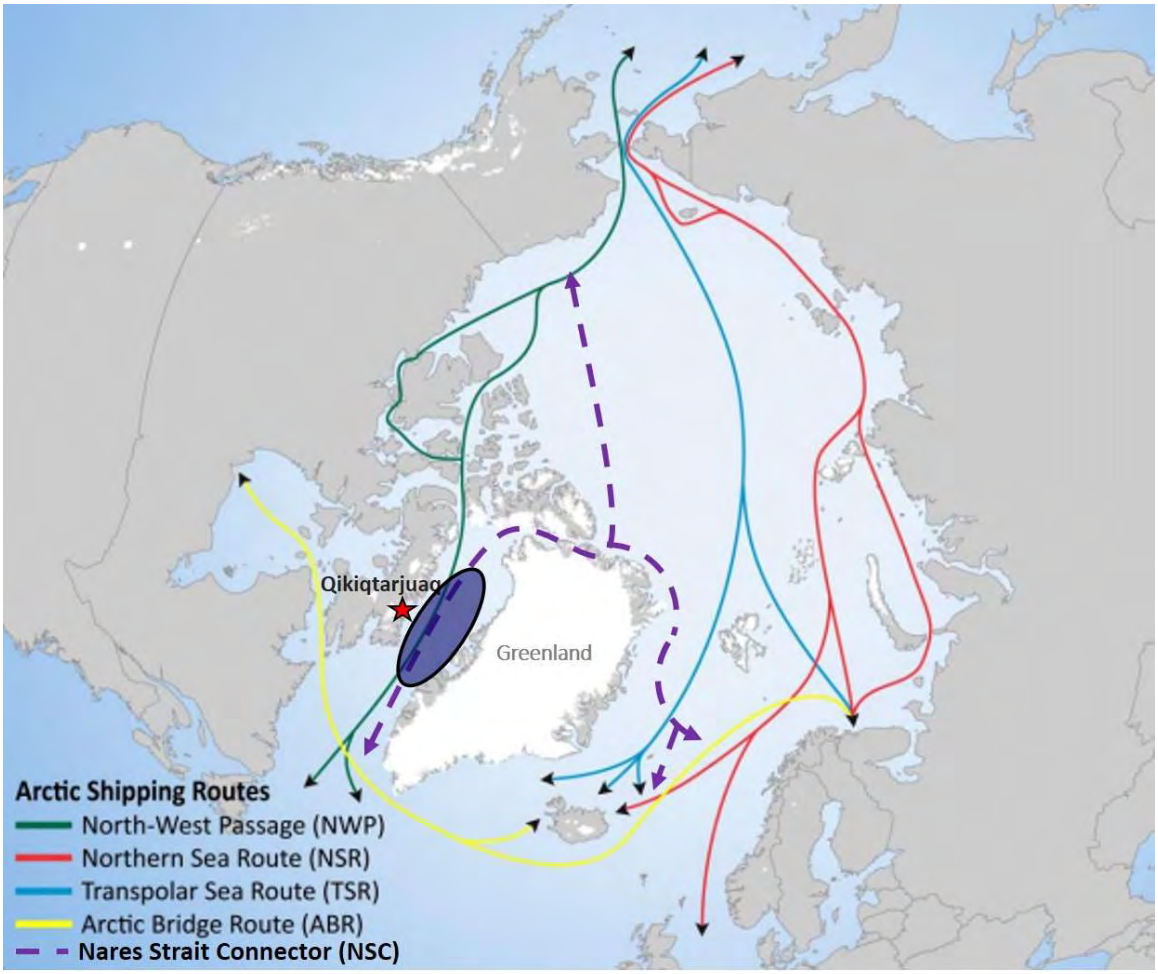

Figure 3.5 – Northwest Passage with Qikiqtarjuaq
Source: *Author's own work. Adapted from Humpert and Raspontnik*[158]

[157] Ibid.
[158] Malte Humpert and Andreas Raspotnik. "The Future of Arctic Shipping Along the Transpolar Sea Route." *Arctic Yearbook*. 1, (2012): 282.

A deep water port that was situated in Qikiqtarjuaq could feasibly "support a processing plant near the fishing grounds, open opportunities for selling shrimp locally, and create more local jobs, like net-making and welding."[159] If a fish processing capability was established in Qikiqtarjuaq, entire Canadian fishery would essentially have vertically integrated a portion of the supply chain. Because of the shortened transit time associated with an airship circuit, it is possible to leverage that shortened transit time to ship perishable commodities such as fish to national or international markets, thus streamlining the supply chain even further. The leg of the airship sustainment circuit proposed in chapter 2 of this paper that connects Iqaluit to Nanisivik passes close to Qikiqtarjuaq. The hamlet is marked by a red star on figure 3.6.

Figure 3.6 Proposed Airship Sustainment Circuit with Qikiqtarjuaq Labelled
Source: *Statistics Canada*[160]

[159] Sima Sahar Zerehi "Nunavut hamlet seeks Chinese investors to build dream port" *CBC News* (30 Aug 2016): accessed 7 March 2021, https://www.cbc.ca/news/canada/north/nunavut-port-chinese-investors-qikiqtarjuaq-1.3740470

[160] Statistics Canada, The Canadian Transportation System (Ottawa: Transportation Data and Information Hub, 2018).

The circuit proposed in chapter 2 needs to have some inherent flexibility built-in to avoid inclement weather conditions. As alluded to throughout this paper, this flexibility could be used to divert an airship for any number of reasons: to sustain a military exercise, to assist with search and rescue (SAR) operations, to help move cargo both within the region and in/out of the region. Qikiqtarjuaq is just one Arctic community that seeks to develop economically by improving the lines of communication (LOCs) that feed and connect the region. There are 78 other communities in the Arctic[161] all with unique interests but a common challenge throughout the entire region is a lack of connectivity to the transportation networks in the rest of the world. airships that use Hydrogen fuel, potentially manufactured in the Arctic region, could connect these Arctic communities with a minimal carbon footprint. A federally own network of airships that is capable of conducting a broad range of activities would be flexible enough to respond to periodic other requirements of communities in the region. There is little doubt that there would be demand for airship cargo service to occupy a position between the once-per-year sea shipment or expensive conventional air shipments. It is worth highlighting the fact that the "level of emissions produced by air transport are also the highest of any mode."[162] Once established, it is entirely possible for a hydrogen-fuelled airship to fill the gap previously filled by conventional heavier-than air craft to transport cargo to the Arctic with much less of a carbon footprint. Forty years ago, the Arctic was predicted by climatologists "to be one of Earth's most sensitive climate regions and thus extremely vulnerable to increased CO2. The rapid and unprecedented changes observed in the Arctic confirm this prediction."[163] The concept of a hydrogen-fuelled airship that

[161] Arctic-Guide.net, "Canada's Arctic Towns. Home to Inuit, Metis, Various First Nation & European Descent People. Rich in Culture, Heritage & History," accessed 18 April 2021, https://www.Arctic-guide.net/Arctic-towns.html.

[162] "The 6 Modes of Transportation", *Mihlfeld & Associates* 19 October 2018, https://blog.mihlfeld.com/the-6-modes-of-transportation.

[163] Patrick Taylor, Bradley Hegyi, Robyn Boeke, and Linette Boisvert. "On the Increasing Importance of Air-Sea Exchanges in a Thawing Arctic: A Review." *Atmosphere* 9, no. 2 (2018): 1.

produces very few if any greenhouse gasses would certainly seem to be a solution to Arctic shipping that would receive buy-in from communities in the region but the need for meaningful consultation between the Government of Canada and these communities cannot be overstated. Protests and disputes over infrastructure projects, such as the recent dispute over British Columbia's GasLink pipeline between the Wet'suwet'en hereditary chiefs and the Government of Canada/TC Energy, often center around whether "meaningful consultation" took place.[164]

From a shipping perspective the airship sustainment circuit could be demand-driven. Surplus cargo capacity on an airship could be booked when the established lines of communication (conventional sea and airlift) are unsatisfactory in meeting the demand for cargo in the region. Surplus cargo capacity could also be booked when the established lines of communication to send products from the region to market are insufficient in doing so. To be effective though, all of this potential for improving the LOCs in the region must be socialized with the Indigenous communities in the region so as not to impinge on their own sovereignty and jeopardize Canadian sovereignty. If an airship sustainment circuit is established without an overarching imperative that seeks to align the interests of the Indigenous peoples in the region with the Canadian Government's interests, Canada risks pushing Indigenous communities to seek foreign investment from groups that satisfy their concerns but may run counter to the Canadian national interest. For the purposes of this paper, the author has identified Qikiqtarjuaq as one example of a community that could positively benefit from an airship sustainment circuit but Canada's Arctic region contains 78 other communities[165] all with their own unique interests;

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[164] Jillian Kestler-D'Amours, "Understanding the Wet'suwet'en struggle in Canada," *Al Jazeera,* (1 March 2020): accessed 22 April 2021, https://www.aljazeera.com/news/2020/3/1/understanding-the-wetsuweten-struggle-in-canada.

[165] Arctic-Guide.net, "Canada's Arctic Towns. Home to Inuit, Metis, Various First Nation & European Descent People. Rich in Culture, Heritage & History," accessed 18 April 2021, https://www.Arctic-guide.net/Arctic-towns.html.

a solution to conducting sustainment in the Arctic must include extensive consultation and collaboration with these communities.

CHAPTER 4 – EXPEDITIONARY USES

The proposal for an airship sustainment circuit that transits the Arctic region discussed previously in this paper has centered around using two to three airships constantly. This is partly to ensure the entire system has redundancy in the event of unplanned maintenance being required for one of the other platforms due to damage, malfunction, or some other cause. This recommendation for two to three airships is also because there are opportunities for airships to be used in an expeditionary role to augment either deployment or sustainment operations that the CAF is involved with throughout the world. With current radar and anti-aircraft armaments available to countries and non-state actors around the world, it is doubtful that airships would be a tenable deployment/sustainment option in contested or non-permissive regions. Regardless, it is beyond the scope of this paper to analyze how airships could be used to conduct sustainment to military operations in a non-permissive environment. That said, the CAF regularly participates in operations that rely on the use of permissive air lines of communication (LOCs) for deployment and sustainment functions. Airships that are used regularly to move cargo to and throughout the Arctic could be diverted to augment deployment/sustainment transportation to expeditionary theatres of operation.

One such theatre could be an area that suddenly has a requirement for humanitarian aid and/or disaster relief (HA/DR). The CAF does not deploy to these regions for HA/DR operations without the permission from the affected state(s) so it stands to reason that a CAF airship operating in a country requiring HA/DR would be doing so in a permissive environment. That is not to suggest that the threat from non-state actors would evaporate but the affected state would

have an interest in facilitating the movement of the airship through their airspace. HA/DR operations in countries that are wholly confined to an island, such as Haiti, or archipelagic nations such as Indonesia, the Philippines, and Japan, or the Falkland Islands, present particularly challenging regions to logistically sustain. This is because nations like these require a higher degree of intermodal transportation. These nations rely on either air or sea transportation to move people and equipment into the country. From there, all ground lines of communication are internal to the country (i.e. there are no ground linkages to other non-affected nations). The loss of a node where the intermodal transport could take place (such as an airport or seaport) could act as a critical single point of failure in that country's transportation network. Additionally, HA/DR events such as earthquakes, hurricanes, tsunamis, forest fires, etc., tend to inflict damage onto the existing ground lines of communication (LOCs) such as road and rail lines. This means that island/archipelagic countries are particularly vulnerable because they are not connected by any LOCs to non-affected states that can deliver HA/DR relief supplies. Also, if HA/DR shipments can make it to a node (seaport/airport) but not inland, due to damaged and/or congested road/rail networks, shipping more HA/DR relief to that node will only serve to congest the entire network, exacerbating existing bottlenecks.

Private sector interest in airships for HA/DR is already building. An airship solution to HA/DR is being developed by Google cofounder, Sergey Brin. For over four years, Brin personally invested over $100 million in a company called LTA Research and Exploration[166]. LTA is the acronym for "lighter than air" and can trace its origins to 2017 within NASA's Ames

[166] Avery Hartmans, "Google cofounder Sergey Brin has been working on a secretive airship company for over 4 years. Here's how the billionaire plans to use the 'air yacht' to deliver humanitarian aid," *Business Insider*, 18 April 2021 accessed 20 April 2021, https://www-businessinsider-com.cdn.ampproject.org/c/s/www.businessinsider.com/google-sergey-brin-airship-company-lta-explained-2021-4?amp.

Research Center.[167] LTA's concept is to use lighter than air craft to "bring humanitarian aid, including food and supplies, to remote areas of the world."[168] The versatility of take-off and landing, whereby airships do not require a traditional airport runway, is being touted as a significant advantage airships bring to the HA/DR problem set.[169] Additionally, a company called "Avalon-Airships" has designed an autonomous airship called "EOS" which has multiple variants that could be applicable to a HA/DR mission. These variants are displayed in figure 4.1.

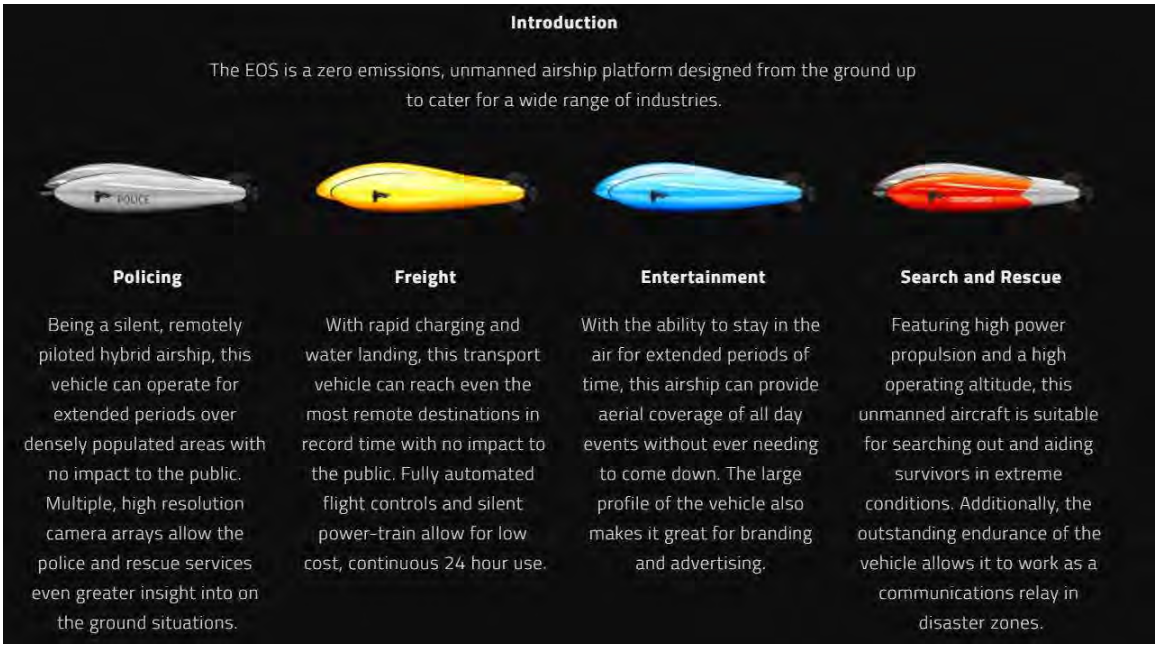

Figure 4.1 – EOS Variants
Source: *Avalon Airships*[170]

Specifically, the "Search and Rescue" and "Freight" variants would be particularly applicable to a HA/DR mission. The fact that the private sector is already committing resources toward the research and development of airships that could be used in this role presents an opportunity for the CAF/Government of Canada to share some of the research and development costs associated with employing airships in any number of potential roles (HA/DR included).

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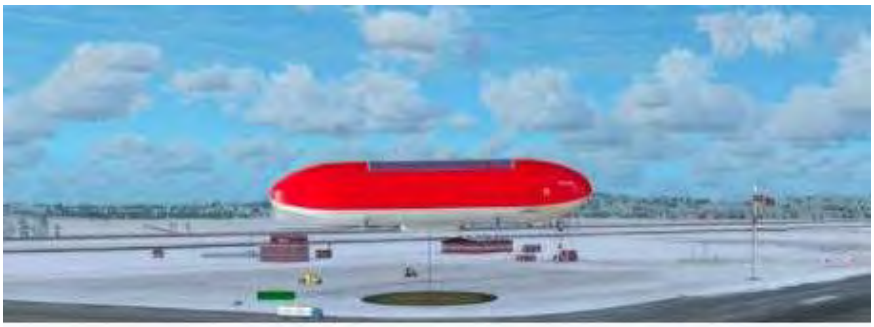
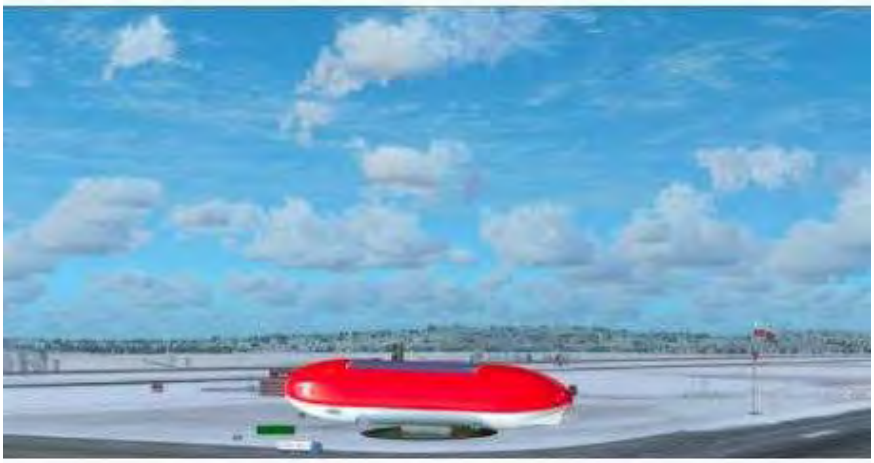
[167] Ibid.
[168] Ibid.
[169] Ibid.
[170] https://www.avalon-airships.com/

In the author's experience, Naval assets have been used extensively in HA/DR operations because they can remain self-sustained in an area for an extended period of time. That said, Naval assets take time to arrive at a HA/DR scene. For example, in the author's experience, planning to take five to seven days for a Canadian Naval vessel to depart Halifax, arrive in Haiti, and start conducting HA/DR operations would be an extremely aggressive timeline. An airship previously tasked to conduct Arctic sustainment could make the journey within 24hrs. Presumably the airship would have to stock up on HA/DR supplies first but this would also be true of the Naval ship. Additionally, if an airship deployed with a portable airship terminal, it would not risk contributing to the congestion at an existing airport in-theatre. One such portable terminal was proposed at the 2020 Annual Canadian Transportation Research Forum.[171] This was introduced in chapter 2 but the author wanted to draw particular attention to the airship-transportable fixed bases called Buoyant Aircraft Rotating Terminals (BARTs) that were presented at this forum. Figure 4.2 illustrates the proposed model.

[171] Barry E. Prentice and John Wilms, "Cargo Airship Fuel Transport: Canadian Shield Case Study." Canadian Transportation Research Forum. Proceedings Issue: 55th Annual Meeting (2020): 433.



CANADIAN AIRSHIP LANDING WITH USE OF WINCHES



ROTATING TURNTABLE LANDING PAD TO POINT THE AIRSHIP INTO THE WIND

UNLOADING AND MOVING THE CARGO USING FORKLIFT TRAILER

Figure 4.2 – Proposed Buoyant Aircraft Rotating Terminals
Source: Prentice and Wilms, *Cargo Airship Fuel Transport: Canadian Shield Case Study,* 433

Expeditionary usage in a HA/DR scenario might see two of the three airships in a sustainment circuit leave the Arctic. One airship could stop at a previously established warehouse, likely at one of the proposed nodes such as Moosonee, pick up a portable BART and however many HA/DR pack-up kits will fit onboard and then proceed to the affected country. The second airship could stop and exclusively pick-up HA/DR equipment. Presumably, the CAF's disaster assistance response team will have already been spooled-up and on route to the area concurrent with the airship's diversion and pick-up of the portable BART and HA/DR pack-up kits. Under this scenario, members of the disaster assistance response team would have to be trained in recovery of the airship and they must be able to receive and set-up the BART. Once the BART is established on-site, subsequent HA/DR kits can be transported in a constant stream from Canada to the affected country via airship.

HA/DR is just one expeditionary role in which airships that regularly transit the Arctic region could be employed. As mentioned in chapter 2, the CAF currently uses a "hub-and-spoke" distribution model to "enhance the CAF's ability to respond rapidly to crises worldwide, and enable more efficient, effective, and economical support to integrated operations."[172] This hub-and-spoke model produces locations around the world called "Operational Support Hubs (OS Hubs)". These OS Hubs "are established along the strategic lines of communications, and "spokes" are activated to support a specific operation."[173] There are three generic employment postures for OS Hubs: Caretaker OS Hub; Cadre OS Hub; and Fully Activated OS Hub.[174] These are depicted in figure 4.3.

[172] Canada. Department of National Defence. B-GL-005-400/FP001. *Canadian Forces Joint Publication 4-0 Support*. Ottawa : DND Canada, 2016, 2-14.
[173] Ibid.
[174] Ibid.

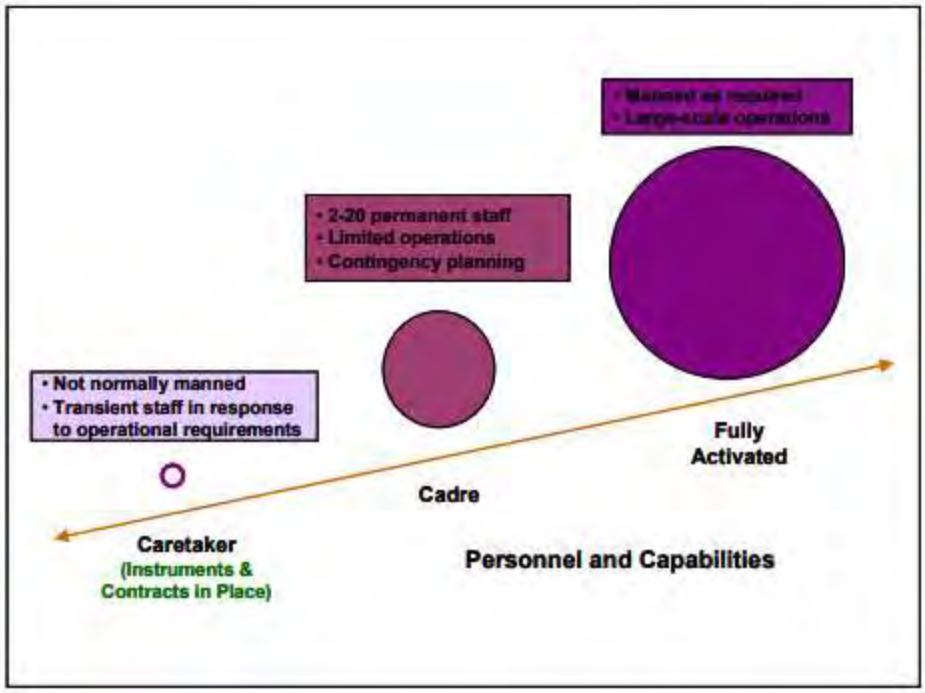


Figure 4.3 – Operational Support Hub Employment Postures
Source: *B-GL-005-400/FP001 - Canadian Forces Joint Publication 4-0 Support,* 2-15[175]

The CAF currently has six OS Hubs in various states of development and under various employment postures.[176] The locations of these OS Hubs are depicted in figure 4.4.

[175] Canada. Department of National Defence. B-GL-005-400/FP001. *Canadian Forces Joint Publication 4-0 Support*. Ottawa : DND Canada, 2016, 2-15.
[176] Carla Harding. "Sustainment: A Combat Function and a 'domain'", Toronto, ON, 5 January 2021

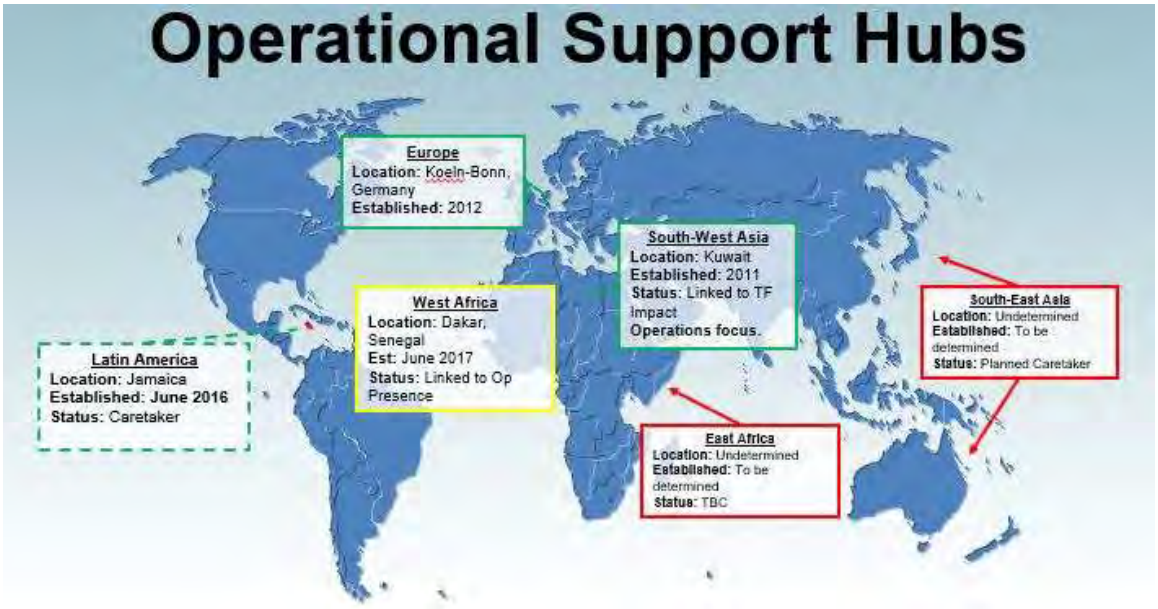


Figure 4.4 – CAF Operational Support Hubs
Source: *Harding*[177]

The OS Hubs indicated with a green box are the longest running OS Hubs. The one in West Africa is the newest OS Hub used by the CAF and at the time of writing, the OS Hubs indicated in red did not yet have specific locations assigned. These would be considered "pre-caretaker" OS Hubs. It is entirely possible that an airship that is conducting sustainment in the Arctic could be diverted to either augment the strategic lines of communications that connect Canada to the OS Hub or to augment the cargo that is sent along "spokes". As mentioned previously, this all would assume a permissive environment for air movements. Additionally, the ceiling on many of the proposed concepts for airships that the author has reviewed, have projected ceilings well below that of conventional aircraft. While a C-17 can cruise at 30,000ft, well above the threat posed by many anti-aircraft weapon systems, even the most advanced airship concepts for use in the US Military such as DARPA's "Walrus" design, sees the airship

[177] Carla Harding. "Sustainment: A Combat Function and a 'domain'", Toronto, ON, 5 January 2021

cruising at an altitude of around 10,000 feet or lower.[178] Another possible disadvantage that could pose an expeditionary employment challenge the fact that an airship design like DARPA's "Walrus" airship would fly at a speed of 80 to 100 knots as opposed to more than 400 knots for the C-17.[179] The slower speeds and lower altitudes could also make overflight rights more challenging to obtain than for a conventional C-17-type aircraft. This is because the passage of airships "would be much more apparent than that of a conventional aircraft. Consequently, nations willing to quietly allow high altitude overflights might be more reluctant to permit low, slow overflights by airships."[180]

While the low overflight and slow speeds involved with airships may be a detractor when it comes to overflight permissions, these very attributes of airships enable them to be employed in unique niche areas. Within the domain of wind turbine installation, the author found that the challenge in Europe is that roads are constructed to remote areas where wind can be economically farmed and the turbines are installed in those locations with a conventional crane. The roads are then returned to the environment. This makes access with a conventional crane problematic. Not only do conventional cranes require conventional roads, the areas where wind can be economically farmed often present challenges to conducting crane work. When objects that have faces with a large surface area that can be exposed to the wind (such as a wind turbine blade), they become very difficult and often unsafe to control as they are being hoisted into position. A private company in Europe called "Skylifter" has endeavoured to apply an airship solution within the gap where conventional cranes become cost-prohibitive for the maintenance and repair work conducted on these pieces of equipment. Unlike the more conventional notion of

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[178] Congress of the United States. "A CBO Study: Options for Strategic Military Transportation Systems." *Congressional Budget Office*, (September 2005), 24.
[179] Ibid.
[180] Ibid.

the “cigar-shaped” airship, Skylifter’s design is a lenticular shape more akin to a disc-shape see figure 4.5.

Figure 4.5 – Skylifter Crane Airship
Source: Skylifter.eu, *Aircrane*

The airship depicted above has a 20-ton lift capacity and is a more economical solution for moving large parts, especially items that do not lend themselves to shipping via standard geometric sea containers. Skylifter’s airship concepts includes the development of an airship with a 150-ton payload that could move “aid or even portable hospitals to remote areas - such as rural regions or disaster zones - that have limited or no available infrastructure such as roads.”[181] In discussing the solution that Skylifter brings to the airship market, the author discovered that the lenticular design has been considered by some to be unstable. There are some unique technological solutions to this concern that the company uses to ensure the highest degree of stability possible. For Skylifter, stability is paramount due to the fact that their airships are effectively taking the place of a conventional crane (which is capable of positioning equipment

[181] Glenda Kwek “Introducing Skylifter, a new giant of the sky,” *The Sydney Morning Herald*, 8 Oct 2010 accessed 21 April 2021, https://www.smh.com.au/technology/introducing-skylifter-a-new-giant-of-the-sky-20101008-16agy.html.

in precise locations). To address stability, the Skylifter ship uses suspended propellers that place the center of gravity of the airship below center of buoyancy. Furthermore, their sensor suite enables the aircraft to detect changes in wind direction at the leading edge of the aircraft so that the airship's propulsion can be adjusted to compensate accordingly. Additionally, to deploy an airship to a site that needs crane work would take much less time than to deploy a conventional crane especially if there are no roads accessing the area of interest. Skylifter is currently servicing customers with a very specific requirement: the craning of equipment into remote areas. A Skylifter-type of airship with a 150-ton payload could certainly be used for transcontinental cargo movements. However, this airship is still in the concept phase. Skylifter's current customers are interested in smaller payloads. This means that using a smaller Skylifter airship, that is used for moving cargo such as wind turbine blades, to move cargo potentially thousands of kilometres from Canada to an area of operations where it could be required may seem untenable. That said, even these smaller airships could be deployed via strategic airlift to an OS Hub where they could be assembled and used to support the movement along the "spokes" of the hub-and-spoke concept, especially where ground lines of communication are unusable and/or there is no usable airstrip for conventional fixed wing aircraft to be used. The ideal expeditionary concept of employment for airships might include large "cigar shaped" rigid hulled airships moving cargo to and/or between OS Hubs while Skylifter crane-type airships push the cargo out to the areas in the region where the cargo is required.

In summary, there are many opportunities for airships to be used in an expeditionary capacity but there are some additional challenges that will need to be overcome or worked around for an airship solution to be applied to an expeditionary operation. Using airships in a HA/DR capacity seems to be a natural fit because in these situations local infrastructure such as

airports, seaports, roads, and rail may be damaged or already extremely congested due to the HA/DR event. Airships also integrate well with the OS Hub concept that the CAF is currently working with. Private sector investment to date has primarily been focused on employing airships so that they generate profit which means that currently available solutions are tailored for niche sectors like mining and conducting crane work in remote areas. That is not to suggest that there would not be value in applying a commercial off the shelf solution but for the CAF to reap the benefits that airships can bring to expeditionary operations, an airship solution for the CAF would need some modification and potentially more design work.

CONCLUSION

Canada holds a privileged place by being one of only five nations granted governance, management and jurisdiction of the Arctic Ocean.[182] Climate change is rapidly exacerbating the criticality of managing this region in an ethical and environmentally conscientious manner. Climate change disproportionately impacts the Arctic. The Arctic has "experienced temperature increases of 4 to 6 C compared to the global average of 1 C."[183] The consequence of this accelerated climate change will be to adversely impact ground transportation in the region. Dr. Barry Prentice, Professor of Supply Chain Management for the University of Manitoba, succinctly described this problem as follows:

> Since 2000, the ice roads have lost half their season and the risks of accidents are increasing. Even existing roads and landing strips are under threat as permafrost zones become more active. Impassible sections of sinking and buckling infrastructure are disrupting Northern transport as the climate becomes warmer.[184]

What has worked in the past to connect the Arctic with the rest of the world is rapidly becoming untenable. As this paper demonstrates, the speed, payload, and range of many conceptual and some prototypical platforms in industry could already add value to this problem set. For the purposes of proof of concept, a commercial "off the shelf" design could be used to demonstrate the utility of airships in the arctic or at least yield valuable lessons learned from which a bespoke tenable Canadian solution emerges. Throughout this paper, the author has identified numerous platforms that could be used to develop this proof of concept. DARPA's "Walrus"; Flying Whale's cargo airships; Avalon Airships' EOS variants; Skylifter's lenticular

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[182] Andrew J. Hund. "Arctic Territorial Claims and Disputes." In ANTARCTICA AND THE ARCTIC CIRCLE: A Geographic Encyclopedia of the Earth's Polar Regions. Vol. 1 2014.

[183] Aaron Kylie. "Climate change disproportionately affects the Arctic" *Canadian Geographic* (25 January 2016): accessed 26 February 2021, https://www.canadiangeographic.ca/article/climate-change-disproportionately-affects-arctic.

[184] Barry Prentice. "Transport Canada 2030 strategic plan missing a key plank." *The Hill Times* (22 February 2021).

airship cranes; Buoyant Aircraft Systems International's Buoyant Aircraft Rotating Terminals all present novel solutions to the problem of cargo delivery to the Arctic. As an industry, airships used to transport cargo is still in an embryonic phase. There are numerous innovative solutions within industry that could be applied to the problem of a tenuously connected Arctic region. That region has numerous stakeholders outside of the CAF. Because of the multiplicity of stakeholders, the author recommends feasibility review through ADM(Mat) of a sustainment plan that employs airships in a sustainment circuit as described in this paper. The feasibility review should incorporate the feedback from other government partners so that the CAF solution could also be leveraged by these partners where there exists surplus capacity in the sustainment system. The concept would be for an airship solution to be configured to perform multiple roles so that other agencies can achieve maximum benefit from shared use where there are overlapping and complimentary interests. Alongside garnering feedback from other governmental partners such as the RCMP, CBSA, and DFO, it is of the utmost importance to socialize a proposed solution with the current inhabitants of the region. Proceeding in a way that is uncollaborative with current inhabitants risks generating a misalignment of sovereignty interests between the indigenous people in the region and the interests of the Government of Canada. Therefore, the arctic sustainment circuit proposed in this paper will not unfold in the same way as the procurement of other CAF platforms where the primary stakeholder in the procurement is the CAF. It will require extensive collaboration between government departments and local communities. This paper began with an epigraph that quotes former Canadian Prime Minister William Lyon Mackenzie King who in 1936 opined: "If some countries have too much history, we have too much geography."[185] As this paper has demonstrated airships represent an

[185] Barry Prentice. "Transport Canada 2030 strategic plan missing a key plank." *The Hill Times* (22 February 2021).

environmentally conscientious solution that addresses that “too much geography” and the CAF has an opportunity to be a leader in developing and applying that solution.

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