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SOVEREIGNTY ASSERTION – AIRSHIPS FOR THE ARCTIC

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SOVEREIGNTY ASSERTION – AIRSHIPS FOR THE ARCTIC

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Abstract

This paper provides an overview of Canadian Arctic sovereignty concerns and methods by which the Canadian Forces (CF) may employ strategic lift hybrid airship technology to address such problems. The Government of Canada's (GoC) responsibility in the North is of growing concern as climatic changes raise the spectre of increased commercial, military, and criminal activity. In this context, the background of historical airship operations and the justification for the development and use of strategic lift airships in a modern setting is presented as a valid approach to asserting a Northern sovereignty strategy. The Arctic operating environment, including its people, weather, challenges, and opportunities, are examined to demonstrate the need for efficient and effective mobility and resupply assets. The paper demonstrates how airship technologies are combined and integrated into existing and new airship designs to produce unconventional heavy lift aircraft. Hybrid airships are compared to aerodynamic and aerostatic airlift assets, highlighting hybrid airships' non-traditional concept of operations and applications. The paper delves into a proposed concept of operations for strategic lift hybrid airships in the Arctic while scrutinizing the advantages and disadvantages of integrating an alternative platform within the existing CF operational framework. The paper concludes with a forthright discussion of hybrid airship challenges, technical, operational, and environmental. The paper contends that strategic lift hybrid airships could greatly improve the GoC's assertion of sovereignty in the Arctic, synergistically integrating with the CF's current force structure. It is recommended, however, that the CF merely remain apprised of airship technology developments, investing only as it nears operational status as strategic lift hybrid airship technology remains in its infancy.

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Introduction

> The first and highest priority of our northern strategy is the protection of our Arctic sovereignty. And as I have said many times before, the first principle of sovereignty is to use it or lose it.[1]
>
> Prime Minister Stephen Harper

The above quotation by Canada's Prime Minister does not adequately describe modern sovereignty challenges or the risk posed simply by existing in the North, but it does indicate the intensity of rhetorical debate surrounding the future of the region while sounding a clarion call for renewed action in the face of impending change. At its root, sovereignty involves the state's recognized dominion over its territory and inhabitants, yet the definition has evolved over time, becoming increasingly more inclusive. Modern notions of sovereignty now include the concepts of safety and security, not just from a military perspective, but also from a social vantage point. The Government of Canada (GoC) in particular fulfills its sovereignty obligations by protecting its citizens from external aggression by contributing to domestic, continental, and international peace support operations. The GoC also contributes to a more modern notion of sovereignty, which includes the duty to prevent, by safeguarding its citizens in a social sense, protecting them from malnutrition, poverty, and natural and human-caused disasters.

Maintaining and enhancing claims of sovereignty, both traditional and modern, in the Arctic is no simple task. The North is a relatively desolate and harsh landscape, thinly populated by an array native and foreign peoples whose cultures and social norms can vary quite drastically. While government rhetoric regarding the region heats up, so

[1] Stephen Harper, quoted by Bruce Campion-Smith, *The Star*, August 23, 2010.

does the Arctic, literally, enticing businesses to expand the search for and extraction of the area's relatively untapped but plentiful reserves of minerals and energy resources.[2]

As foreign interest in the Canadian Arctic increased so has the GoC's promotion of a militarized response to the perceived threat. The government's *Northern Strategy* and *Canada First Defence Strategy* explicitly identify the Arctic as a burgeoning area of concern requiring a concerted defence response. CF surveillance and sovereignty patrols have markedly increased, plans for new maritime space-based military assets are in the works, and annual defence exercises have increased in scope and frequency.[3] The GoC even touts infrastructure and social spending as a means to enhance territorial sovereignty. Yet, in many cases, government funding of these projects have failed to materialize and national responses to crises in the North have proven an abject failure.[4]

If the GoC is to truly bolster its sovereignty claims over the Arctic it must match its military-enforced territorial claims with a capacity to protect Northern inhabitants and respond rapidly and appropriately when they are threatened. The GoC, let alone the CF, is not prepared to respond to the full spectrum of emergencies in the Arctic. Airfields and seaports are too few, too distant, and lacking the infrastructure to support strategic lift assets containing the personnel, equipment, and supplies that would be needed to counter a disaster. Canada's only strategic lift air asset, the C-17 Globemaster, can only service a few communities in the North, and the CF's other flexible air assets may be too small to provide the necessary response to an emergency.

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[2] Franklyn Griffiths, Rob Huebert, and Whitney Lackenbauer, *Canada and the Changing Arctic* (Waterloo: Wilfred Laurier University Press, 2011), 146-147.
[3] Foreign Affairs, Trade and Development Canada, "Canada's Arctic Foreign Policy," accessed 4 July 2013http://www.international.gc.ca/arctic-arctique/arctic_policy-canada-politique_arctique.aspx?lang=eng.
[4] Senate, "Sovereignty & Security in Canada's Arctic – Interim Report. Standing Senate Committee on National Security and Defence," (Ottawa: March 2011).

Strategic lift hybrid airships may prove a solution to bridge the gap between the GoC's Arctic sovereignty assertion claims and the CF's transport and response capability deficiencies in the North. Airship technology has advanced significantly over the past quarter century to a point where novel ideas, once thought impossible, may soon prove a reality. Once useful only as passenger carriers or observation platforms, the combination of aerostatic and aerodynamic principles, coupled with advances in computer-aided design, increases in lightweight material strengths, and improved bonding techniques have made probable to create of airships capable of ferrying strategic payload around the globe.

Hybrid airships possess significant advantages over conventional strategic lift assets but also suffer from some inherent liabilities. Conceptual hybrids can transport greater payloads than solely aerodynamic craft and they can arrive at destination much sooner than sea-going vessels. Hybrids, employing aerostatic and aerodynamic principles, can take-off and land in much shorter distances, reducing the need for lengthy runways. Most importantly, these airships obviate that need for modern infrastructure and advanced facilities as they can take-off, land, load, or unload from truly austere environments as they do not need runways or port facilities but rather only a relatively flat piece of terrain upon which to conduct their operations.

Hybrid airships could serve as the ideal military platform in an expeditionary context, transporting troops, equipment, and supplies en masse to austere environments in theatre and close to the front. In fact, responding to a disaster in the Arctic would be as difficult, or even more so, as deploying overseas as the region is both isolated and desolate. Strategic lift hybrid airships could deliver response personnel, equipment, and supplies anywhere in the Arctic, not just the towns that have port facilities, to immediately address an oil spill, a mine collapse, a natural disaster, or a community-wide social emergency.

Industry leaders have test flown hybrid airships for the purpose of transporting large payloads but the visions of such aircraft capable of transporting 500-ton loads have thus far failed to materialize for a number of reasons including, but not limited to, investor skepticism, market collapse, loss of government support, and incomplete research and development. Although operational employment of these grand airships are likely a decade or more away from use, the GoC and CF could do more to hasten their arrival. In fact, integrating hybrid airships into the CF operational and doctrinal structure would not prove a significant hurdle owning to the flexible nature of the platform. CF airships could, by most measures, perform equally as well deploying to Afghanistan or the Arctic in GoC's bid to protect the nation at home and abroad. A key element of exerting Canadian sovereignty is the capability to respond to crises in order to protect and safeguard the lives of Arctic inhabitants; the integration of strategic lift hybrid airships into CF operational constructs will satisfy this requirement much more flexibly and robustly than current transport assets.

Chapter 1 – Establishing the Arctic Sovereignty Issue

Literature Review of Sovereignty and the Arctic Sovereignty Debate

Sovereignty

Sovereignty is not a new concept but its definition and application have changed dramatically throughout history. Greek philosophers are generally credited with introducing the notion of sovereignty as *supreme state authority*. Niccolo Machiavelli, author of the treatise, *The Prince*, recognised the supreme political authority of the ruler to use whatever means necessary to gain and maintain power over his territory and subjects.[5] The modern, broadly accepted international order of sovereign states was codified at the Peace of Westphalia in 1648 and remains the basis for global politics today. Thomas Hobbes viewed sovereignty as a necessary, but unnatural, condition between the state, or Leviathan, and man. From Hobbes' perspective, an absolute monarch was to rule more benevolently over man by way of a social contract to prevent him from living an anarchic life that would otherwise be solitary, poor, nasty, brutish, and short.[6]

Noted international relations expert, Stephan D. Krasner, identifies four basic types of sovereignty at work in contemporary society: domestic, interdependence, international legal, and Westphalian.[7] The UN Charter of Rights and Freedoms, the Law of Armed Conflict, and the Geneva Conventions serve to both enhance and provide order to the Westphalian concept of sovereignty. At their core, these agreements recognize the

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[5] Niccolo Machiavelli, *The Prince*, trans. W.K. Marriott, (Adelaide: University of Adelaide, 2012).
[6] Thomas Hobbes, *Leviathan*, eds. A.P. Martinich and Brian Battiste. (Peterborough: Broadview Press, 2010).
[7] Krasner, Stephen D., "Compromising Westphalia," *International Security* 20, no. 3 (Winter 1995-1996): 116.

supremacy and legitimacy of the state; the state is the sole arbiter of its actions within its borders. Krasner, Amitai Etzioni, and Francis Deng have identified an emerging trend toward an international recognition of sovereignty as responsibility, extending the social contract between the state and the individual, and distancing the definition from that espoused by Machiavelli. Deng, the International Commission on Intervention and State Sovereignty (CISS), and Lee Feinstein and Anne-Marie Slaughter have advanced notions of sovereignty as a responsibility to protect and even a duty to prevent.[8] They contend that, more important than control, states must not only protect their citizens but also prevent harm coming to citizens of other sovereign nations. This enlightened version of sovereignty has gained traction in academic circles and among many non-governmental organizations (NGOs), but most states have yet to follow its precepts.

The Arctic Sovereignty Debate

The Arctic sovereignty debate revolves around a complex series of issues that have gained prominence with and because of the environmental movement, increased prominence placed upon the North by the Government of Canada (GoC), and support from the *sovereignty as responsibility* movement. Literature on the subject of the role of government in Canada's Arctic ranges from political rhetoric to advance security issues, environmental alarmism to promote climate change action, and cultural and social welfare clarion calls to shape the region's future and its inhabitants. The GoC's policy statements regarding the Arctic are well documented. Prime Minister (PM) Stephen Harper regularly states that the Arctic is an environmental, sovereignty, security, and

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[8] Amitai Etzioni, "Sovereignty as Responsibility," *Foreign Policy Research Institute (Orbis)*, (Winter 2006): 71-72.

economic matter over which the GoC has full jurisdiction, and into which it will place its full resources to protect, in consultation with all Northern residents.[9]

There is also significant body of work by eminent scholars, including Franklyn Griffiths, Rob Huebert, Whitney Lackenbauer, and Michael Byers, who suggest that the Arctic is in crisis but that it is not a problem for militaries to solve. Rather than a battle to control the Arctic, Byers suggests that sovereignty and international cooperation are not incompatible, and that Canada should work with international partners to address development and environmental issues.[10] This group of commentators generally assess the GoC's strategy for the North as wanting, and focused too broadly on minor, even non-existent, military and traditional security issues. Although the government does often preach Arctic development and social improvement for the North's inhabitants, results are lacking. Lackenbauer argues "converting the strategy to deliverables that produce a more constructive and secure circumpolar world will be the real challenge.[11] Even when members of this group highlight Arctic defence concerns, as the more hawkish Huebert sometimes does, they provide little evidence of such likely occurrences in the short to medium term, continuing to stress the problems of the region as pertaining to that of societal, environmental, and developmental issues. [12]

Leaders on the environmental side of the debate include prominent organizations such as Greenpeace, the World Wildlife Fund, and the United Nations Environment Program, but also include Arctic inhabitants themselves. Scholars and activists who have

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[9] Stephen Harper, "PM Announces Government of Canada will Extend Jurisdiction over Arctic Waters," accessed 4 May 2013 http://pm.gc.ca/eng/media.asp?id=2248.
[10] Michael Byers, *Who Owns the Arctic?* (Vancouver: Douglas & McIntyre, 2009), 128-129.
[11] Griffiths, Huebert, and Lackenbauer, *Canada and the Changing Arctic*..., 228.
[12] Griffiths, Huebert, and Lackenbauer, *Canada and the Changing Arctic*..., and Rob Huebert, "Canadian Arctic Sovereignty and Security in Transforming a Circumpolar World," *Foreign Policy for Canada's Tomorrow*, no. 4, July 2009.

combined aspects of the environment, sociology, and sovereignty into a coherent debate have provided content more germane to the debate. Rob Huebert, a political scientist at the University of Calgary, has advanced all aspects of the Arctic debate. With other noted scholars, such as Kim Richard Nossal, he has identified current and potential changes to the Arctic's social, cultural, economic, and environmental landscape, providing options for the GoC to follow to reap the North's rewards while enhancing the lives of the region's inhabitants and controlling the activities of foreign entities. Huebert argued that "Arctic sovereignty can be understood in the context of the Canadian government's ability to control what happens in the area that it defines as its Arctic region."[13] Also central to the debate over Arctic sovereignty is the degree to which the GoC must stake its claim and how it should respond to climate change. Some regional inhabitants suggest the Government's claims of sovereignty are enhanced through environmental stewardship, while others suggest increased economic activity and resource extraction will increase jurisdiction by default.[14] State governments, including Russia, Denmark, Norway, and Canada, continue to assert that their jurisdictional claims will be strengthened through military presence, as demonstrated by both rhetoric and traditional claims to territories such as the North Pole, Hans Island, and even the Arctic sea floor. The definition of sovereignty continues to evolve in the ever-globalizing world. As the climate, environment, culture, and economic activity in the North changes, so, too, will the nature of sovereignty.

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[13] Huebert, *Canadian Arctic Sovereignty*…, 5.
[14] Yukon, Northwest Territories and Nunavut, *Developing a New Framework for Sovereignty and Security in the North* (Whitehorse: Government of Yukon, Northwest Territories and Nunavut, 2005), 6.

The Government of Canada's Policy for the North

Based on rhetoric and official policy announcements, the GoC has established an ambitious strategy for the Arctic, but these plans have yet to reach fruition. The PM, who routinely tours the Arctic, making policy announcements, declared in 2010, "The first and highest priority of our northern strategy is the protection of our Arctic Sovereignty[:…] to use it or lose it."[15] Based on the traditional Westphalian concept of sovereignty, the GoC plans to increase presence through economic and military activity in the region to assert its claims. On the economic development side, improvements to infrastructure to permit access to the North included road, airport, and seaport construction projects. The GoC's political and economic strategy in the Arctic is outlined in its *Northern Strategy* document. By 2013, a Senate report continued to recommend such investments, particularly in airports, but the long list of Northern transport infrastructure deficiencies demonstrates that both funding and construction had not yet materialized.[16]

On the military side, the GoC announced its Canada First Defence Strategy (CFDS) in 2008, apportioning a sizeable portion of the CF's budget, resources, and personnel toward conducting daily operations in the Arctic with specifically tailored equipment. The document stressed the role of the CF to "provide surveillance of Canadian territory…[,]maintain search and rescue response capabilities that are able to reach those in distress anywhere in Canada on a 24/7 basis…[and] assist civil authorities

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[15] Stephen Harper, "Arctic sovereignty a priority: Harper" CBC News, August 23, 2010, accessed 5 May 2013http://www.cbc.ca/news/politics/story/2010/08/23/harper-north html.
[16] Peter Worden, "Senate report slams airports" Northern News Services, April 29, 2013, accessed 5 May 2013, http://nnsl.com/northern-news-services/stories/papers/apr29_13air.html.

in responding to…natural disasters."[17] The CFDS also reiterated PM Harper's 2006 pledge to develop Arctic/Offshore Patrol Ships (AOPS) to provide year-round maritime presence in the North. As of May 2013, the AOPS project had not progressed past the design phase. Where government rhetoric has met with action in terms of military presence in the Arctic is in the number and complexity of CF exercises conducted in the region. These activities include Operation NEVUS, conducted annually on Ellesmere Island since 1982, and Operations NANOOK, NUNALIVUT, and NUNAKPUT, conducted annually since 2007, a combination of whole-of-government law enforcement, security, and sovereignty patrols.[18] The CF also relies on an indigenous corps of nearly 5000 Arctic inhabitants, the Canadian Rangers, to patrol the North. While the GoC, and the CF in particular, do maintain a presence in the Arctic, their activities do not match the level of political rhetoric and are focused mainly on the traditional Westphalian notions of sovereignty.

The Arctic Environment

The Arctic is a vast and varied landscape. Variously defined in cultural, geographic, and political contexts, it is broadly considered as the area encompassed by the three territories, Yukon, Northwest Territories, and Nunavut, and the northern areas of Quebec and Labrador. The three territories cover an expansive 3.92 million square kilometres.[19] The far north, or high north, is a barren region of tundra above the tree line while the near north, or subarctic, consists mainly of large boreal forests. Both regions

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[17]Government of Canada, *Canada First Defence Strategy*, accessed 5 May 2013 http://www forces.gc.ca/site/pri/first-premier/June18_0910_CFDS_english_low-res.pdf, 7.
[18]Government of Canada, *National Defence and the Canadian Forces - Recurring Operations*, accessed 5 May 2013, http://www.cjoc-coic forces.gc.ca/cont/rec-eng.asp.
[19]Statistics Canada, "Land and Freshwater Area," accessed 5 May 2013, http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/phys01-eng.htm.

experience cold winters, cool summers, and often receive little precipitation. Various topographical features, such as mountains, bogs, watersheds, and permafrost, make agriculture and construction difficult. In fact, the annual permafrost thaw routinely disrupts new and existing infrastructure, such as buildings, roads, and runways, necessitating their remediation each year. Some transportation links, such as ice roads, linking the North to supplies from the south exist only during the frozen winter months. The high north also experiences alternating periods of complete darkness and light during the winter and summer months, respectively.

The severe environmental conditions have kept both commercial interests from extensive participation in the North's activities and other states from disputing Canada's sovereign claims over the region. Decreased ice cover and improving technologies have facilitated the search for and extraction of the area's significant resource wealth. The Arctic is "estimated to contain approximately 25 percent of the world's remaining undiscovered oil and gas deposits,…the world's last major source of oil and gas."[20] Gas hydrates, diamonds, and other minerals remain of interest to large multinational firms. The harsh climate and geography shaped the region's indigenous inhabitants but various Government programs, climate and technological change, and increased business interest for resources has altered the lives of the population.

Arctic Inhabitants

Canada's North is a vast but sparsely populated area predominately featuring indigenous Inuit-Canadians located in rural areas and a mix of Inuit and European-Canadians occupying the few urban centres, such as Whitehorse, Yellowknife, and Iqaluit. With a population of approximately 105,000 in 2011 for the three territories, the

[20]Huebert, *Canadian Arctic Sovereignty*…, 12-13.

population density per square kilometre is a mere 0.03.[21] Although the region's residents produce a much higher GDP per capita and slightly larger average total incomes than the rest of Canada,[22] the Federal Government subsidizes most industries in the North, but fails to alleviate the poverty experienced by many of the Inuit.

Many Inuit communities live, so-called, traditional, subsistence lifestyles, utilizing resources locally available from the land and sea to survive. Many more, however, have adopted the typical Western lifestyle, dependant on technology and regular imports of foodstuffs, fuel, and building materials to maintain their standard of living. Most Arctic inhabitants, including the Inuit, work in primary industries, including fishing, hunting, fur trading, and mining. Aboriginal residents use their extensive knowledge of the Arctic's history to excel at many of their endeavors. Partly owing to their regional competency, the CF has recruited nearly 5,000 Inuit into the Canadian Ranger program. This dispersed organization of Northern participants aids Regular Force members in their understanding of and training within the Arctic, also providing a local early warning network for the GoC. In this manner, Arctic residents form part of Canada's sovereignty platform.

Threats to the Arctic

Threats to the Arctic, its inhabitants, and the GoC's attempts to secure dominion over the two manifest themselves in several forms. Foreign and defence policy expert, Rob Huebert, asserts that the Arctic is undergoing a startling transformation caused by

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[21]Statistics Canada, "Population and Dwelling Counts," accessed 7 May 2013 http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/hlt-fst/pd-pl/Table-Tableau.cfm?LANG=Eng&T=101&S=50&O=A.
[22]Canada Revenue Agency, "General Statement by Province and Territory of Taxation," accessed 7 May 2013, http://www.cra-arc.gc.ca/gncy/stts/gb09/pst/fnl/html/tbl1-eng html.

climate change, resource development, and geopolitical shifts.[23] Climate change is perhaps the driver of the latter two as warmer temperatures lead to thinning sea ice, which increase the navigable season, permitting increased economic activity in the North on the part of global actors. Climate change's direct threat to the North may materialize in the form local food insecurity as the predictability of game variety, availability, and migration patterns alter.[24] Warmer temperatures may also increase the risk and longevity of inspect-borne pathogens, further endangering residents. While warmer weather may improve the prospects of scheduled importation of food and aid, it also increases the chances of an unexpected food or disease related emergency.

Increased activity in the Arctic poses an even greater risk to the inhabitants and the ecological landscape of the region as unforeseen disasters can occur as a result of any number of actions, including the transit of vessels moving through the Northwest Passage, the arrival and departure of sea and aircraft delivering food, material, and personnel to and from population centres and worksites, and the operation of resource extraction facilities, such as mines and oil rigs. According to a study by the University of Stockholm and the Stockholm Environmental Institute, in 2012, "the amount of ice covering the Arctic Ocean had shrunk by half compared with average measurements from 1980 to 2000."[25] Such massive change may soon permit some states, such as China, from realizing their goals of stripping the Arctic of its resources, mainly oil and mining ventures. China's presence in the Arctic will pose traditional sovereignty issues for the GoC but the Communist state's poor track record on environmental protection presents a

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[23] Huebert, *Canadian Arctic Sovereignty*…, 13, 25.
[24] Huebert, *Canadian Arctic Sovereignty*…, 27.
[25] Nicole Gaouette and Niklas Magnusson, "China Granted Access to Arctic Club as Resource Race Heats Up," Bloomberg, May 15, 2013.

modern sovereignty challenge when an ecological disaster poses a threat to the environment, Arctic inhabitants, or both. Whether dealing with a routine operation or an emergency, the GoC has, and will for the foreseeable future, tremendous mobility, resupply, and response challenges in the Arctic.

Mobility and Resupply Challenges in the Arctic

The relatively harsh and inhospitable nature of the Arctic pose an array of mobility and response challenges for the GoC in terms of the speed and capacity of its response. The fragile nature of the environment and the tenuous hold on which the inhabitants have on the necessities of life makes any reaction to an emergency both difficult and important. Current efforts just to maintain communities, outposts, and operations are enormous. In fact, just to sustain approximately 55 personnel involved in intelligence, monitoring, and research activities at Canadian Forces Station (CFS) Alert requires hundreds of C-130 Hercules and C-17 Globemaster III sorties. In 2012, the RCAF flew at least 12 sorties a day from 12 to 28 April delivering 1.6 million litres of fuel used to power the station and operate its vehicles.[26] The replenishment activities occur annually as part of Operation BOXTOP, with fuel delivered in the Spring and dry food and construction material delivered in the Fall, while the station requires weekly deliveries of perishable items throughout the year.

The runway facilities at CFS Alert permit large volume aircraft, such as the Hercules and Globemaster, to deliver supplies and respond to emergencies, but not all communities possess such necessary infrastructure. Most Arctic communities are isolated such that they are only accessible year-round by air. Even communities more

[26] Lt Christopher Daniel, "RCAF Delivers Fuel to Canada's Most Northerly Post," RCAF, May 2, 2012, accessed 24 May 2013, www rcaf-arc.forces.gc.ca/8w-8e/nr-sp/index-eng.asp?id=12810.

populous than CFS Alert have smaller runways that can only support small volume aircraft, such as the RCAF's C-115 Buffalo. Although the Buffalo is a versatile aircraft capable of reaching remote locations, it is severely limited in range, 2240 km, and payload capacity, 2727 kg.[27] Conceivable disasters in remote locations with infrastructure incapable of supporting strategic lift craft have the potential to destroy the environment and communities of people.

For instance, the recent humanitarian disaster in the Attawapiskat First Nations community in Northern Ontario illustrates deficiencies in the GoC's abilities to respond rapidly in remote locations. Although Attawapiskat is not located in the Arctic, its remoteness, limited runway, substandard infrastructure and living conditions, and connection by ice road during the winter as its only land route serves as a model harbinger for future Arctic disasters. When the community declared a state of emergency on 28 October, 2011, the GoC soon after announced it would deliver 22 pre-fabricated homes to address the crisis. Based on the size of the homes and the limited transportation options available, the government was not able to send them immediately, delivering the shelters by ice road only by late February, 2012. Had the GoC possessed a transportation option capable of quickly transporting pre-made houses, the residents of Attawapiskat would not have had to wait nearly four months living in tents, overcrowded sheds, and houses, some containing mould and located near raw sewage spills, and without running water.[28]

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[27] RCAF, "CC-115 Buffalo," accessed 24 May 2013, www.rcaf-arc forces.gc.ca/v2/equip/cc115/index-eng.asp.

[28] Teresa Smith, "Attawapiskat gets Final Shipment of Modular Homes, Government Says," National Post, February 23, 2012, accessed 24 May 2013, News.national post.com/2012/02/23/Attawapiskat-gets-final-shipment-of-modular-homes-government-says/.

Aside from humanitarian emergencies, the GoC would have difficultly countering environmental disasters, such as those resulting from increased mining exploration and extraction, and oil spills from vessels transiting the Northwest Passage. Deploying a quick reaction combat force with its supplies and equipment is also no easy task for the CF in the North. Any strategic lift air assets in a civil or military role are restricted to the major runways in places like Whitehorse, Yellowknife, Iqaluit, Resolute, and Alert. Strategic lift sea vessels have even fewer adequate port facilities, as the government's upgrade of the Nanisivik seaport remains behind schedule. Tactical airlift can reach locations with prepared runways and only small aircraft, such as the RCAF's Buffalo and civilian turboprops, can service truly remote destinations but with limited range and payload. Existing government response plans, which include deployment of CF assets, take into account existing infrastructure limitations and the current mobility and resupply challenges of the Arctic, but they do not sufficiently address the potential for change in the North and it is evident that a different approach may be required.

Existing Arctic Supply and Disaster Response Plans

The GoC's *Northern Strategy* and its various emergency response plans serve as a means by which Canada asserts sovereignty over the Arctic. In the sense that the state has a duty to protect its citizens, such devices provide only a limited degree of sovereignty assertion as they fail to both adequately address Northern issues and adopt a sufficient and rapid enough response to foreseeable disasters. The *Federal Emergency Response Plan* merely outlines the concept and structure of a response to a domestic disaster. Although it mentions the types of emergencies that could occur in Canada, it neither describes them nor indicates the enormity of the challenge if they occurred in the

Arctic. The document also indicates that Public Safety Canada will serve as the coordinating department while the Department of National Defence (DND) may serve as either the primary or supporting department,[29] failing to note that the CF would likely conduct the bulk of Northern emergency operations regardless of its stated position given the relative lack of federal response resources currently allocated to the Arctic.

Canada's *Northern Strategy* and the Senate's interim report on *Sovereignty & Security in Canada's Arctic* both focus on sovereignty as security rather than the duty to protect and prevent. The Senate's report only addresses traditional security threats to the region and the *Northern Strategy* simply outlines rhetorical notions of protection for the Arctic. Only in the *Statement on Canada's Arctic Foreign Policy* does the GoC begin to identify and address unconventional and emerging threats to the North. The document suggests improvements to monitoring systems and agreements, environmental disaster mitigation strategies, and social support policies, but it does not offer response options when an emergency occurs.[30] Canada's definition of sovereignty must expand beyond traditional notions of security to include sufficient threats to people and the environment, rather than just territory.

Sovereignty Defined for a New Era

The requisite characteristics of state sovereignty have dramatically changed since the Peace of Westphalia in 1648. The pace of current, predicted, and potential change to the Arctic environment and way of life is equally astonishing. The GoC is rhetorically positioned to fulfill its sovereignty requirements in terms of security and responsibility, both to the Northern people and landscape, but it does not yet possess the military, law

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[29] Public Safety Canada, "Federal Emergency Response Plan," (Ottawa: Public Safety Canada, 2011), 2-3.
[30] Government of Canada, "Statement on Canada's Arctic Foreign Policy," (Ottawa), 9,10, 14.

enforcement, or social resources to address the future concerns it has identified. More importantly, the notion of sovereignty must now include not only the duty to protect and prevent, but also to respond. The GoC has neither identified an adequate response process for disasters in the Arctic nor does it possess the required capabilities to respond to a large scale emergency in the North. The CF will certainly be the main actor in a domestic emergency of epic proportions and it must prepare itself for such an event even though the GoC remains unprepared. While the CF is addressing its monitoring capabilities in the Arctic, it must do much more in terms of its strategic lift response if the GoC is to have any chance of responding swiftly and appropriately to an emergency, social, environmental, or military, in the remote Canadian Arctic.

Chapter Summary

The general trend regarding the characteristics of state sovereignty is one of increasing responsibility. From the responsibility to defend territory, sovereignty is now widely accepted to include concepts such as the responsibility to protect one's citizens, and increasingly, to prevent harm to coming to individuals throughout the world. The GoC ratcheted up sovereignty claims over the North during the Cold War, but a resurgence has occurred in the post 9/11 era whereby the Harper government has made increasing activity in the North a central political plank.

The Arctic is a remote and desolate place. It is general cold, inhospitable, and fragile. Yet, tens of thousands of indigenous people continue to work in and make the Arctic their home. Non-indigenous inhabitants of the Arctic have increased in numbers of the past half century, many to work in resource extraction industries, whereby they now constitute approximately 50% of the population. Whether congregating in the few small cities, work camps, or remote villages, most population centres remain inaccessible for a portion of the year with inadequate infrastructure to support daily life, let alone a social or ecological disaster. Such disasters become more likely with increasing commercial activity in the North and climate change threatening the ecological balance.

Mobility between Arctic communities is sometimes not possible while resupply from the South is not always available, on time, or adequate. Though capable, the CF expends great effort throughout the year to sustain its few operation facilities throughout the North. The CF is capable of rapid strategic resupply in a only a few prepared locations while its tactical lift services are limited in terms of range and payload. The CF forms part of the GoC's existing *Northern Strategy* but while both organizations recognized the importance of the Arctic, and the threats to it, neither have the resources to respond rapidly and adequately to a disaster in a remote part of the region. Before the CF can address the need for a robust strategic lift capability in the Arctic, the GoC ought to recognize sovereignty not simply as defence of territory and as a responsibility to protect, but also as a responsibility to respond. Once the enormity of the need and challenge inherent in responding to a major Arctic disaster, be it social, environmental, or military, is realized, the CF requirement for an alternative, robust strategic lift capability will be evident.

Chapter 2 – Introducing Strategic Lift Hybrid Airships

Literature Review of Airships

There exist two distinct streams of literature revolving around airships: popular and technical. The former, less important for the actual scientific developments of airships but spurring the latter, typically involves either naysayers or enthusiasts focused on conceptual designs of airships and their dangerous impractically or potential to revolutionize travel and war. The non-scientific stream of airship literature is punctuated by a high at the beginning of the 20th century while the nadir occurred just prior to WWII. Although aerostats and rudimentary hybrid airships primarily found use as light transport and reconnaissance platforms, H.G. Wells', *The War in the Air,* published in 1908, spawned the idea that lighter than air craft could serve as city destroying bombers.[31] Many European militaries endorsed Wells' notions, melding them with the ideas of air power enthusiasts, such as Giulio Douhet, to create concepts of operations later borne out in WWI and WWII. The low point for airship enthusiasm, nearly reducing airship literature to the realm of science fiction, occurred with the crash of the Hindenburg on 6 May, 1937. Commentators decried airships as both too impractical and too dangerous to a point where interest in airships only began to recover in the early 1990s.

A review of the more pertinent scientific literature regarding airships finds that such information continues to remain in the hands of the few militaries and even fewer companies that study the craft for their potential commercial and military benefit. The work of these groups has become pertinent to strategic lift hybrid airships only recently with the development of advanced materials, improved bonding techniques, and a better

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[31] H.G. Wells, *The War in the Air* (United Kingdom: George Bell and Sons, 1908).

understanding of aerostatic and aerodynamic forces. Three prominent hybrid airship groups include the US military, with the bulk of its research conducted in the early 2000s under the now defunded Defense Advanced Research Projects Agency (DARPA) Walrus program, CargoLifter of Germany, and various Canadian companies associated with Dr. Barry Prentice, a professor whose goal is to achieve regular airship flights to the Arctic to provide reliable resupply.[32] The literature presented by these and other groups are relatively united: the development of hybrid airships capable of delivering strategic lift loads is theoretically possible but not yet feasible due to the enormous costs associated with creating and testing prototypes. Groups have also published results of experiments demonstrating slightly smaller craft have successfully flown but without fully testing their predictions for maximum payload. As the relatively small market for hybrid airships is extremely competitive, data on the most advanced experiments is not freely shared. Any debate regarding the feasibility of hybrid airships capable of transporting load in excess of 200 tonnes will likely not be resolved until one is actually in operation, well beyond the experimentation phase.

Airship Definitions and Terms

To develop a complete understanding of strategic lift hybrids airship capabilities and limitations, knowledge of their fundamental principles is required. The following terms, definitions, and formulas will also serve to highlight the advantages and disadvantages between unconventional lift airships and existing transport aircraft:

Aerodynamic - The term aerodynamic refers to the study of forces generated on a body in a flow. As an aircraft moves through the atmosphere, pressure differences incident on

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[32] Barry E. Prentice, "Cargo Airships: Applications in Manitoba and the Arctic," *Presentation to the APEGM Annual Meeting*, (October, 2005).

airfoils create lift. Lift is described as a function of various aerodynamic properties as follows:

$$L = f(V, \rho, S, \mu, a)$$

Where:

L	=	aerodynamic lift force perpendicular to the relative wind
V	=	freestream velocity
ρ	=	freestream density pressure
S	=	shape of the airfoil
μ	=	viscosity coefficient
a	=	index for compressibility

Aerostatic - Refers to the static buoyancy of a body immersed in the atmosphere. The upward buoyant force acting on the body in air may be described as follows:

$$B = V(\rho_a - \rho_g)$$

Where:

B	=	upward buoyancy force acting on the body
V	=	volume of the body
ρ_a	=	mean density of the local atmosphere surrounding the body
ρ_g	=	mean density of the lifting gas

Lift - Achieved when the upward buoyancy force is greater than the total weight of the aircraft. This relationship is described more easily than above as follows:

$$L = B - W$$

Where:

L	=	upward lift
B	=	upward buoyancy force acting on a body
W	=	weight of the body

Hybrid Airship - A hybrid airship achieves the advantages of solely aerodynamic vehicles and purely aerostatic platforms by combining aerodynamic and aerostatic principles of lift.

Strategic Lift - An often nebulous definition, strategic lift in the Canadian context is usually described as the transport of a large number of personnel and/or over-sized heavy cargo over long distances within Canada or between Canada and an overseas theatre of operations. Strategic lift stands in contrast with tactical lift, which usually involves less cargo and short transit distances within a theatre.

Creep – The development of additional strains in a material over time. It is most prevalent under high stresses and temperatures but is not necessarily a mode of failure.

Modulus – The physical measurement of stiffness in a material, equalling the ratio of applied load (stress) to the resultant deformation of the material.

Monocoque – Airship whose body structure derives its strength and rigidity from the use of thin, shaped and joined panels.

Non-rigid – Airship whose shape is determined by the design of the envelope and internal gas pressure.

Reynolds number – A dimensionless parameter that compares inertial forces to viscous forces in flowing fluids.

Rigid – Airship whose shape and gasbag is contained by its internal transverse frame and structural shell.

Semi-rigid – Airship whose shape is determined by envelope design buttressed by a keel.

Fundamental Hybrid Airship Technologies

Hybrid Airship Designs

Existing conventional aerodynamic and aerostatic airframes provide capable platforms by which to transport personnel and cargo; however, advanced hybrid designs offer the potential for considerable advancements within the strategic transport realm. Traditional airships are typically ellipsoidal in shape, create lift through aerostatic means, are powered by petroleum-based fuel, have a structure that is either purely non-rigid or rigid, and carry payloads well short of 50 tonnes. Figure 2.1 illustrates the classic streamline hull shape. Proponents of hybrid airship designs claim the combination of aerodynamic and aerostatic principles, as well as other innovative techniques, will drastically transform, and improve the capability of transport airships. Altering the shape, lift, structure, and power source of airships may enable them to efficiently and effectively transport payloads approaching 500 tonnes across the globe.[33]

Figure 2.1 – Classic Streamline Airship Shape[34]

Airship Shapes

The classic streamline hull shape, an axisymmetrical elongated teardrop, remains an ideal compromise between structural and aerodynamic requirements for steady, forward, in-flight motion. This shape does present ground handling problems as airships tend to weathercock spontaneously around a mooring point when the wind direction changes.[35] The classic airship shape's purpose is to minimize the volumetric drag coefficient defined by the following equation:[36]

[33] Aeroscraft, accessed 30 August, 2013, http://www.aeroscraft.com/.
[34] Mike Woodgerd, "Ultra Large Airlifters (ULAs): A North American Window of Opportunity," *U.S. Army, Center for Army Analysis*, (2006), 580.
[35] Gabriel A. Khoury, *Airship Technology* (Cambridge: Cambridge University Press, 2000), 260, 269.
[36] Graham E. Dorrington, "Drag of Spheroid-Cone Shaped Airship," *Journal of Aircraft* 43, no. 2, 363.

$$C_{DV} = D/(\frac{1}{2}\rho U^2 V^{\frac{2}{3}})$$

Where:

C_{DV}	=	volumetric drag coefficient
D	=	drag force (assumed steady and parallel to hull major axis)
ρ	=	ambient density
U	=	airship's cruise velocity (assumed parallel to major axis)
V	=	given hull volume

To achieve significant increases in payload capacity required for strategic lift the envelope size must correspondingly increase. Minimizing drag is traditionally accomplished by maintaining an airship's maximum length to four to eight times its maximum diameter. As hull surface area increases, so too does hull mass, significantly decreasing maximum disposable load.[37]

Relatively recent studies by Graham E. Dorrington question the customary notions of airship shapes and their effect on drag and attainable payloads. Some of his experiments suggest that the volumetric coefficient of drag is insensitive to body contour shape, especially when the Reynolds number of an airframe is high.[38] These findings are especially important in the case of strategic lift hybrid airships because it may permit the design of shapes best suited for payload capacity, while effectively accounting for the problem of drag.

Lift and Airship Lifting Shapes

An innovation that may provide for increased payload without the associated problems of drag is the lenticular-shaped hybrid airship depicted in Figure 2.2. Greater in length and width than it is in height, the lenticular airship not only provides a lifting body shape, but also it presents a reduced lateral profile to crosswinds, making it less

[37] Dorrington, *Drag of Spheroid…*, 363.
[38] Dorrington, *Drag of Spheroid…*, 363-4.

susceptible to structural overload during mooring.[39] Lenticular airship designs do not confine distribution of payload along a narrow keel, as do traditional airships. This innovation offers the benefit of increasing the maximum acceptable size of individual objects slotted for transport.

Figure 2.2 – Lenticular-shaped Airship[40]

Intended to increase the operational effectiveness of hybrids, the development of envelope shapes that employ both aerodynamic and aerostatic lift may provide an important key to the viability of strategic lift hybrid airships. Conventional airships, like the Goodyear blimp, rely on vectored thrust in flight and attain lift through aerostatic means (the lifting gas contained in its envelope). Short take-off and landing (STOL) 'dynastat' hybrids dispense with the use of ballast, greatly facilitating ground handling and load exchange.[41] Hybrids that combine aerodynamic and aerostatic principles also perform well in flight and have increased payload capacities compared to traditional airships of similar size. Dynastats include winged hull, deltoid, flat body, multi-balloon, and lenticular shaped airships.

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[39] Khoury, *Airship Technology*…, 260, 405.
[40] Aeroscraft, accessed 30 August, 2013, http://www.aeroscraft.com/.
[41] Khoury, *Airship Technology*…, 309, chapter 25.

Winged hulls include designs as simple as wings merely attached to existing airship structures to completely new designs with fully incorporated wings. Displayed in Figure 2.3 is an example of the former. Winged hull airships often feature a trade-off between aerodynamic and aerostatic principles. They may be heavier than conventional airships because of the weight of their wings, but their lifting gas envelopes may be smaller since the wings provide much of the necessary lift required for aerodynamic take-off. Wings also increase handling and agility in flight, similar to that of an aeroplane. An apparent disadvantage of winged hull airships is the considerable increase in the total drag in steady flight due to parasitic and interference drag caused by the addition of numerous appendages to the streamlined hull.[42]

Figure 2.3 – Airship with Winged Appendages[43]

Flat body and multi-balloon, or multi-lobed, hybrid airships present advantages in terms of weight savings and decreased dependence on aerostatic lift. These designs possess the advantages of lenticular airships by distributing lift more evenly than

[42] Dorrington, *Drag of Spheroid*…, 364-5.
[43] Prentice, *Cargo Airships*….

lenticular or winged hull hybrids, generating their own aerodynamic lift.[44] Figure 2.4 illustrates an example of a multi-lobed hybrid airship.

Figure 2.4 – SkyCat's Multi-lobed Experimental Hybrid[45]

Structure and Weight of Airships

A critical aspect of a strategic lift hybrid airship's structural design, the weight and load-bearing capacity of the airship structure must support massive payloads without occupying too large a portion of the airship's gross weight. Airships can be rigid, semi-rigid, or non-rigid. Empirical data indicates non-rigid structures appear more suitable for smaller airships while rigid constructions are more suitable for larger airships; the largest non-rigid airship flown, the ZPG-3W, had a 20-tonne lifting capacity.[46] Regardless of the structure type, a target weight of no more than thirty percent of the gross lift is proposed as needed for the airship to be economically viable.[47]

[44] Khoury, *Airship Technology*…, 19, 463.
[45] Jeff Wise, "Just Don't Call it a Blimp," Popular Mechanics, August 29, 2006, accessed 27 August, 2013, http://www.popularmechanics.com/technology/aviation/airships/3764027.
[46] Globalsecurity.org, "ZPG-3W Airship," accessed 30 Aug 2013, http://www.globalsecurity.org/wmd/systems/zpg-3.htm.
[47] D. Howe, "Airships – General Considerations," *Airship*, no. 94, (December, 1991): 13.

While rigid airship structures are typically heavy, a proposed internal monocoque design reduces structure weight to twenty-eight percent of lift with new design techniques and composite materials.[48] Though non-rigid designs offer the tremendous weight savings, they are often of insufficient strength for use on strategic lift airships. For employment as heavy transport aircraft, non-rigid hybrids require computer aided design techniques and much stronger fabrics.

Airship Fabric Technology

Available fabrics confined the sizes and shapes of traditional airships. Advancements during the past two decades in fabric technology have made possible the theoretical design of massive envelopes of the semi- and non-rigid variety. According to a leading airship fabric technologist, massive envelope fabrics must have the following properties:

a. high strength to increase the maximum possible size of the envelope;
b. high strength to weight ratio to minimize the weight of the envelope;
c. resistance to environmental degradation through temperature, humidity, and ultraviolet (UV) light to increase envelope life and lessen maintenance requirements;
d. high tear resistance to give damage tolerance;
e. low permeability to minimize lifting gas loss;
f. joining techniques to produce strong, reliable joints, not subject to creep rupture; and
g. low creep to ensure envelope shape is maintained.[49]

Traditional airship envelope material incorporates two to three plies of cotton fabric bonded by natural rubber. These materials limit the size of non-rigid envelopes because they possess limited strength and permeability characteristics. Construction of large envelopes using these materials is only possible using bulky and heavy rigid frame

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[48] D.M.Richards, "Optimisation of Airship Structures," in *Proceedings of Symposium on "The Future of the Airship: A Technical Appraisal,"* Royal Aeronautical Society, 20 November 1975.
[49] Khoury, *Airship Technology*….

designs. With the availability and combination of low permeability laminate films, such as Mylar and Tedlar, and high strength polymer fabrics, such as Kevlar, Dacron, and Spectra, the same material restrictions no longer apply; long endurance and high payload capacities are possible in modern non-rigid airship envelope designs.[50] Figure 2.5 shows the typical layers for a modern laminate material envelope (layer widths are relative as they are only micrometers thick).

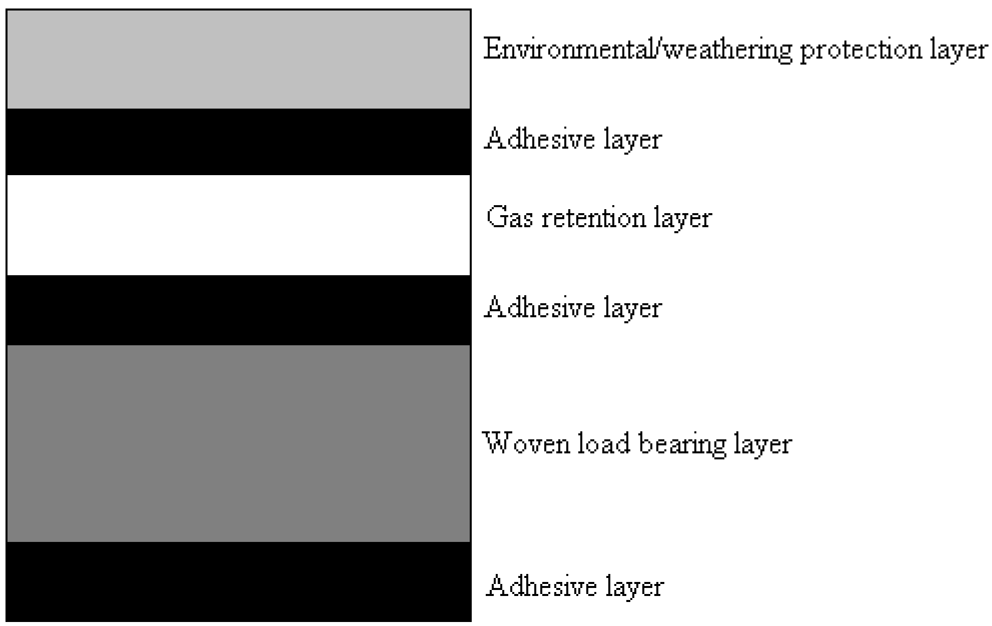

Figure 2.5 – Typical Airship Envelope Fabric Layers[51]

For example, aramids, such as Kevlar 49 and Kevlar 29 are slightly lighter than cotton but have a much higher specific strength, a greater modulus, and a much lower failure strain.[52] Synthetic materials such as Neoprene, Butyl, Hypalon, and Polyurethane have a much lower permeability than natural rubber. Even new absorber additives facilitate a Tedlar layer capable of blocking more than 99 percent of UV light over the

[50] Graham E. Dorrington, "Some General Remarks on the Design of Airships," *American Institute of Aeronautics and Astronautics*, 1999, 250.
[51] Khoury, *Airship Technology*….
[52] Khoury, *Airship Technology*….

energy wavelength range of 290-350 nm.[53] Advanced bonding techniques obviate the reliance on sewn joints, combining strong and low permeable materials to create massive single piece envelopes. A recent derivative of a single ply Dacron, laminated with Mylar and Tedlar using Hytrel as a bonding agent, was under development, expected to achieve a uniaxial strength of 14 kN/50mm at approximately 1 kg/m^2.[54] Figure 2.6 shows the layered components of the synthetic derivative while Table 2.1 compares the properties of traditional and advanced fabrics. Some experts believe that a non-rigid airship with an envelope of 1.1 million cubic metres is achievable with an advanced material of this strength.[55] An envelope of this size is greater than any other ever produced, easily permitting the lift of a payload in excess of one hundred tonnes, as strategic lift hybrid airship proponents propose. To date, the largest non-rigid airship envelope ever built was for the ZPG-3W, incorporating two piles of polyester fabric and measuring a mere 42,500 cubic metres.

[53] Wanggu Kang, “Mechanical Property Characterization of Film-Fabric Laminate for Stratospheric Airship Envelope,” *Composite Structures*, (June, 2006): 153.
[54] Khoury, *Airship Technology*….
[55] Khoury, *Airship Technology*….

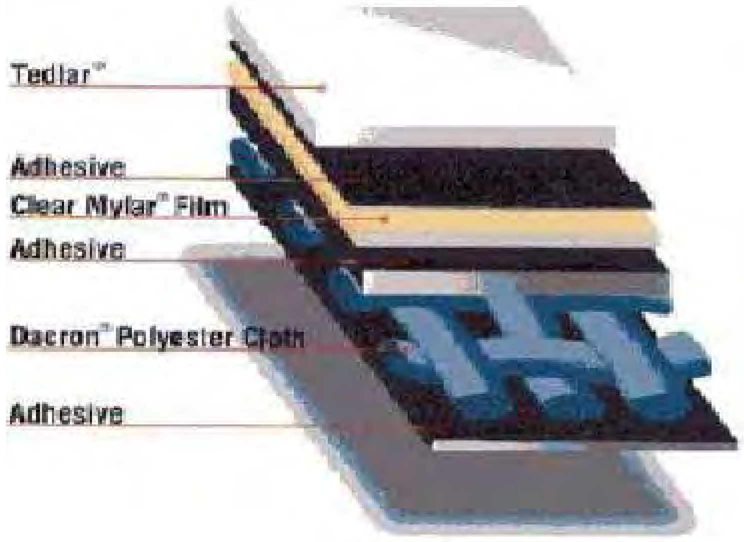

Figure 2.6 – Advanced Airship Envelope Structure[56]

Material	Fibre Specific Gravity	Fibre Tensile Strength Gpa (lb/in^2)	Fibre Modulus Gpa (lb/in^2)	Strain to Failure %
Cotton	1.5	0.4-0.55 (60,000-80,000)	-	-
Polyester e.g. Terylene, Dacron	1.39	1.0 (140,000)	12 (1,700,000)	10-15
Polyamide e.g. Nylon	1.14	0.8 (120,000)	5 (70,000)	20-25
Aramid – high modulus e.g. Kevlar 49	1.45	2.7 (390,000)	130 (18,800,000)	2
Aramid – low modulus e.g. Kevlar 29	1.44	2.7 (390,000)	60 (8,700,000)	4

Table 2.1 – Fibre Properties of Load Bearing Laminate Materials[57]

Airship Propulsion

The equation below defines the power required for steady, level airship flight. [58] Minimizing airship weight and its coefficient of drag while maximizing its lift coefficient

[56] Prentice, *Cargo Airships*….
[57] Khoury, *Airship Technology*….

will reduce total power required. Since every additional kilogram of weight is one kilogram lost in available payload, it is advantageous to reduce the weight of the power generation system.[59]

$$P_R = T_R U = \frac{WU}{C_L / C_D}$$

Where:

P_R	=	power required
T_R	=	thrust required
U	=	flight speed
W	=	airship weight
C_L / C_D	=	lift to drag ratio

Many hybrid designs include enormous envelope surface areas with relatively flat tops. Mounting solar arrays atop airship envelopes would permit power generation throughout the day with the added advantage over conventional fossil fuel burning systems of an overall decrease in weight and drag.[60] Approximate power requirement studies indicate that an airship with a hull volume of about 29,000 cubic metres requires roughly 2600 kW to achieve airspeeds in excess of 100 knots.[61] As current strategic lift envelope design sizes are several orders of magnitude larger, it is expected that heavy transport airships will require power well in excess of that figure.

The use of solar power will also depend on the efficiency of fuel cells and battery storage capabilities. Solar power also alleviates many of the problems associated with burning large quantities of liquid propellant in flight. A theoretical, purely solar powered hybrid is a constant weight vehicle. It would not experience any trimming or buoyancy

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[58] Tianshu Liu, "Aeroship: A New Flight Platform," in *24th AIAA Applied Aerodynamics Conference*, San Francisco, California, 5-8 June 2006, American Institute of Aeronautics and Astronautics.
[59] Khoury, *Airship Technology*…, 209, 480.
[60] Anthony Colozza, "High-Altitude, Long-Endurance Airships for Coastal Surveillance," *NASA/TM – 2005-213427*, (February 2005): 6.
[61] Dorrington, *Some General Remarks*…, 251.

issues since problems associated with weight loss based on fuel consumption would not arise.[62] Figure 2.7 shows the typical main components for a solar powered airship's power and propulsion system.

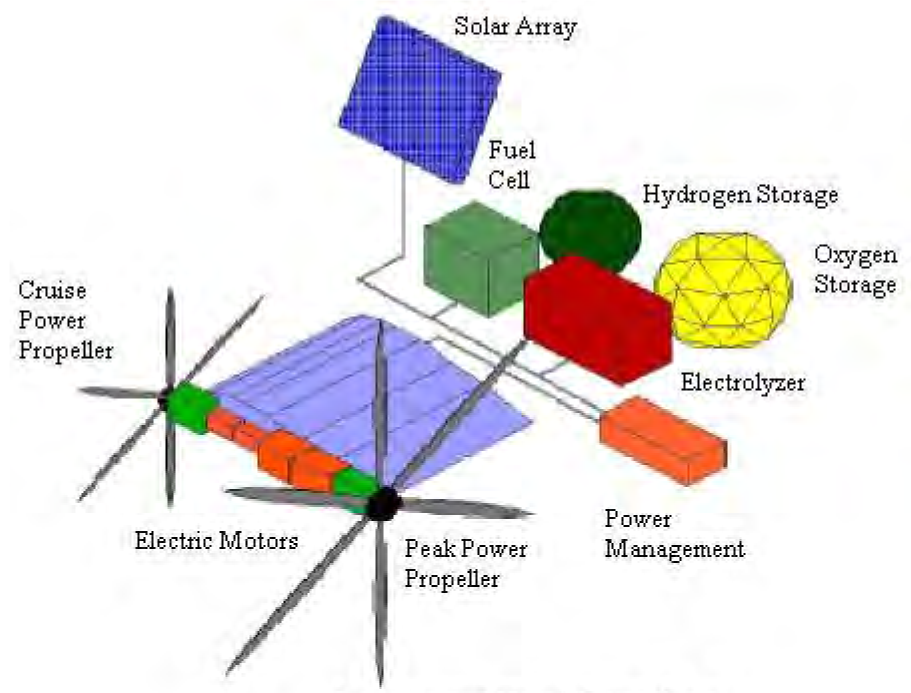

Figure 2.7 – Typical Airship Propulsion System[63]

Airship Air Cushion Landing System

An Air Cushion Landing System (ACLS) is not an integral component of all proposed modern airships, but it is an essential addition for a strategic lift hybrid airship. An ACLS enables hybrids to launch and recover from unprepared land and water surfaces, permitting cargo delivery to remote and austere environments.

The basic ACLS is neither a new technology nor one with which the CF is unfamiliar. A joint US-Canadian program successfully tested an ACLS intended for use

[62] Khoury, *Airship Technology*…, 520.
[63] Colozza, *High-Altitude*…, 9.

on the CC-115 Buffalo airplane during the 1970s.[64] The ACLS's basic components include the air cushion, or trunk, an air supply system to inflate the trunk, a braking device, or surface, and an internal airframe cavity and door system to store the trunk while in-flight to reduce drag. The SkyCat 1000 hybrid airship model achieves reduction of in-flight drag through deflation and retraction of the ACLS skirt against the fuselage without the use of a bulky or weighty door and cavity system.[65] Figure 2.8 illustrates SkyCat's conceptual design for their ACLS.

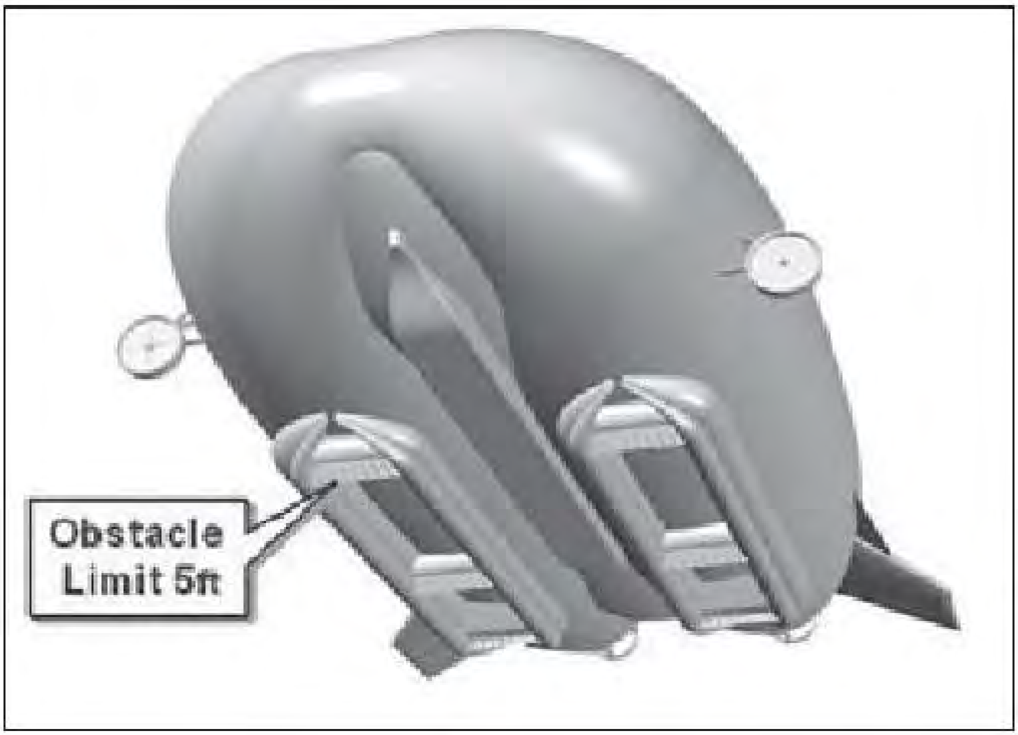

Figure 2.8 – SkyCat ACLS Conception[66]

During the approach and landing phases, bleed air inflates the cushion via the propulsion system. A cushion of proportionally large surface area, as compared to the

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[64] Lloyd Gardner, "An ACLS for the Medium STOL Transport," in *Conference on Air Cushion Landing Systems*.
[65] Skycat Technologies, *SkyCat 1000 Engineering Study*, Final Report 2003.
[66] Walter O. Gordon, "Back to the Future: Airships and the Revolution in Strategic Airlift," *Air Force Journal of Logistics*, vol. 29, issue 3, 2005.

airframe hull, permits relatively stable landings even on rough terrain. Unlike a conventional gear system, an ACLS does not have brakes and must rely on reverse thrust provided by the engines to reduce landing distances. The bottom of the ACLS can also be fitted with metal strips and or rubber treads to reduce landing distance. Studies have shown that durable, resilient tread is preferable because landings cause excessive trunk wear, particularly on the leading and trailing edges of the trunk.[67] This type of wear is a concern as abrasion can damage the peripheral jet hole area, possibly reducing the effective air pressure of the cushion during landing.

The most prominent advantage of ACLS technology, as it applies to hybrids, is the elimination of mooring infrastructure required at the points of departure and arrival. An ACLS operated in reverse, or suction mode, anchors the airship firmly against the ground without the need for external mooring equipment.[68] Suction is not required when the airship is negatively buoyant, as when loaded with cargo, or in low wind conditions. If neutrally or positively buoyant, when empty, or in strong wind conditions, the ACLS must remain in suction mode to maintain position.

The ACLS is also the final component necessary to permit the independent operation of strategic lift hybrid airships. The blowing and suction modes of the ACLS allow airships to land on unprepared surfaces, on land or on water, and to dispense with mooring equipment. As the ALCS provides ground stability, the need for ballast is not required. An ACLS equipped airship need not rely on massive water supplies at destination to act as ballast as cargo is unloaded. Such independence would allow hybrids to deliver cargo to and from any remote part of the globe completely

[67] Trafford J.W. Leland, “Preliminary Results from Dynamic Model Tests of an Air Cushion Landing System,” in *Conference on Air Cushion Landing Systems*, 499.
[68] Gordon, *Back to the Future*….

independently, aside from the personnel and equipment involved in loading and unloading operations.

Applications and Benefits of Modern Airship Advances

Increased Payload Capacity

The technological advancements in fabric construction and ACLS operation enable the development of enormous hybrids. The motivation behind their development stems from the desire for increased payload capacity. Proponents of hybrids whose envelope size and shape increase significantly to harness both aerodynamic and aerostatic lift envision hybrid airship payload capacities of up to 500 tonnes.[69] Current proposals envision cargo loaded into modular containers stored within the overall airship structure but separate from the lifting gas envelope. The number of containers depends on the size of the airship structure base because of the requirement to store cargo balanced along the keel. The aluminium, or other lightweight material, keel attaches to the bottom of the envelope, distributing the weight of the payload along the length of the envelope.[70] The commercial payload module variant proposed by SktCat is a long, rectangular, multi-level box measuring 265 feet long by 44 feet wide by 27 feet high capable of holding up to 195 'Twenty Foot Equivalent Unit' containers.[71] Figure 2.9 shows the specifications for the proposed SkyCat 1000 payload module.

[69] Charles E. Newbegin, "Modern Airships: A Possible Solution for Rapid Force Projection of Army Forces," *School of Advanced Military Studies*, Fort Leavenworth, Kansas, United States Army Command and General Staff College 2003, 23.
[70] Aerospace Technology, "Cargolifter CL160 Super Heavy-Lift Cargo Airship, Germany: 2006," accessed 29 Aug 2013, http://www.aerospace-technology.com/projects/cargolifter/cargolifter1.html.
[71] Skycat Technologies, "SkyCat 1000 Engineering Study," *Final Report*, 2003.

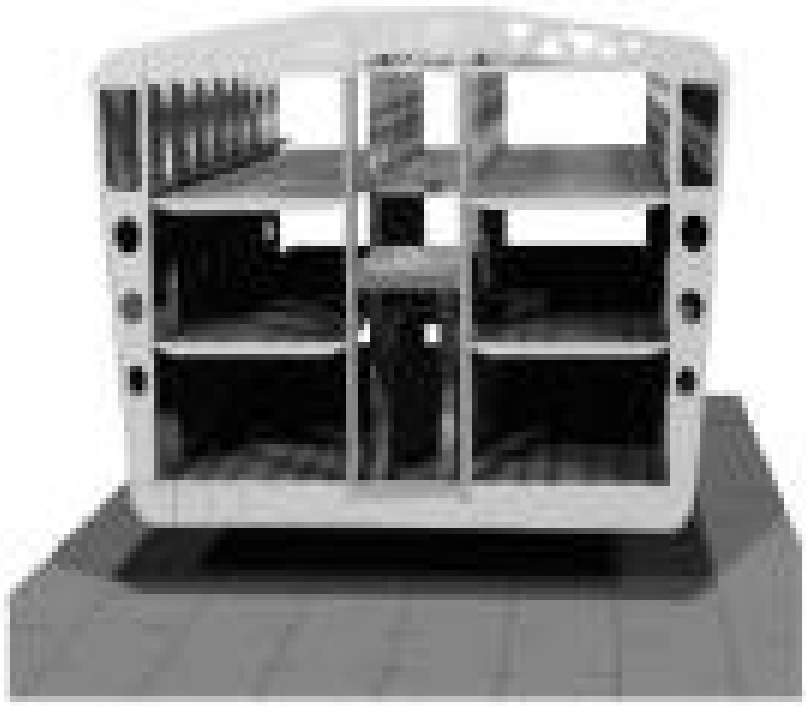

Figure 2.9: SkyCat 1000 Payload Module[72]

Speed and Endurance

While innovative shapes, lifting structures, and propulsion systems may vastly increase the payload capacity of future hybrids, these advances offer negligible improvement in terms of speed and endurance. Although improvements in the efficiency and weight of energy collectors, such as solar panels, and engines may occur, the carriage of the massive payloads will probably offset any performance gains envisioned. The maximum speed of strategic lift hybrid airships will remain well below 200 knots and the measure of the endurance of fully loaded airships will likely remain measured in days rather than weeks.

Freedom from Infrastructure

[72] Newbegin, *Modern Airships*…, 25.

An aircraft capable of STOL and self-mooring through use of an ACLS possesses advantages in terms of freedom from infrastructure. Advanced transport hybrid airships may not require port facilities or even the traditional airship mooring mast. Strategic hybrids may also expect to bypass traditional transportation chokepoints, such as seaports and airports, to deliver cargoes more efficiently, in both economic and temporal terms.[73] At destination, hybrids may offer a relatively small footprint, requiring limited personnel, primarily for payload operations.

Survivability

Although strategic lift hybrid airship envelopes will present adversaries with massive visual targets, these airships will not be prone to the same catastrophic damage as traditional airlift assets. The SkyCat Group was arguably, at one point during the mid-2000's, the leading hybrid airship company that designed and tested the vulnerability of strategic lift airships. SkyCat engineers determined that the envelopes of such airships could sustain hundreds of thousands of pinpricks from small arms fire and still operate for hours before repair.[74] Continued flight is possible because the internal pressure required to keep the envelope tightly inflated is very small; thus, even with holes in the material, the gas inside diffuses rather than rushes out.[75] It is likely that only a massive tear along a seam would force rapid lifting gas venting, producing a rapid and catastrophic descent or crash. SkyCat engineers calculated helium loss rates as a function of hole size, accounting for pressure differentials between the top and bottom of a generic

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[73] Mike Woodgerd, "Fantasy to Prophecy: The Need for a New Lighter-Than-Air Aerospace Capability," *Office of Force Transformation: Department of Defense*, (2004): 7.
[74] Newbegin, *Modern Airships*…, 32.
[75] Woodgerd, *Fantasy to Prophecy*…, 8.

envelope. Shown in Figure 2.10, the values considered included three different weapon systems producing holes of various size.

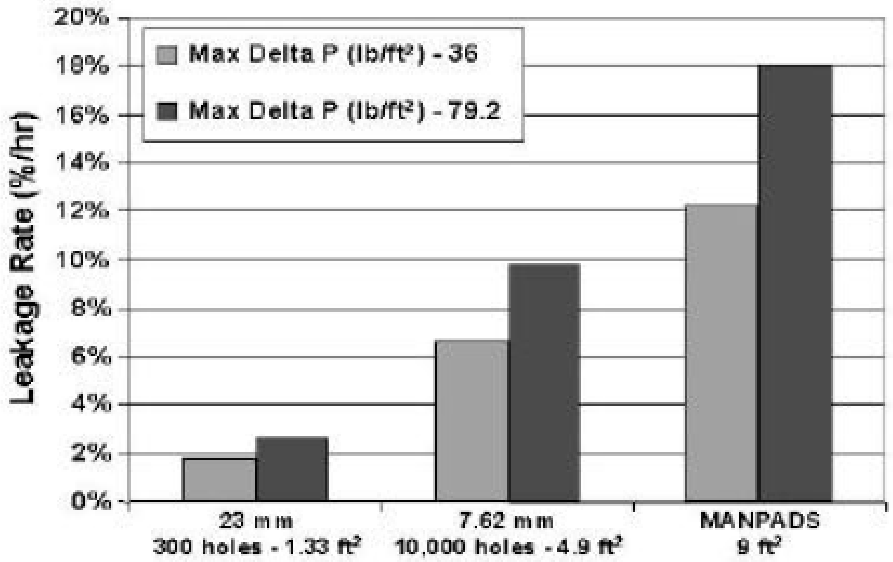

Figure 2.10: Airship Venting Rates[76]

Even with a severe amount of envelope damage caused by a man-portable air-defence (MANPAD) system strike and a maximum pressure of 79.2 lb/ft^2, the airship could still land under control. In fact, in 1998, a 25-storey weather balloon continued to drift aloft across the Atlantic Ocean, from Saskatchewan to Norway, even after CF-18s fired more than 1000 rounds into the envelope,[77] proving the survivability of airships with immense envelopes.

Strategic lift hybrids may also possess increased survivability based on their large size and carrying capacity. Strategic lift airships could easily carry an extensive set of defensive systems, such as missile warning systems and missile countermeasures. Sensitive components, such as the cargo compartments, piloting gondola, and engines,

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[76] Newbegin, *Modern Airships*…, D-1; or Skycat Technologies, *SkyCat 1000*…, 22.
[77] BBC, "America's US aces gun for rogue balloon," August 30 1998, accessed 4 July 2013, http://news.bbc.co.uk/2/hi/americas/160598.stm.

could be armoured with materials that are too heavy or bulky for use on conventional aircraft. Even if it sustains significant damage, a hybrid's low speed means that it would not be as susceptible to the large dynamic stresses that can cause conventional aircraft to break-up in flight.[78] Figure 2.11 shows predicted airship survivability.

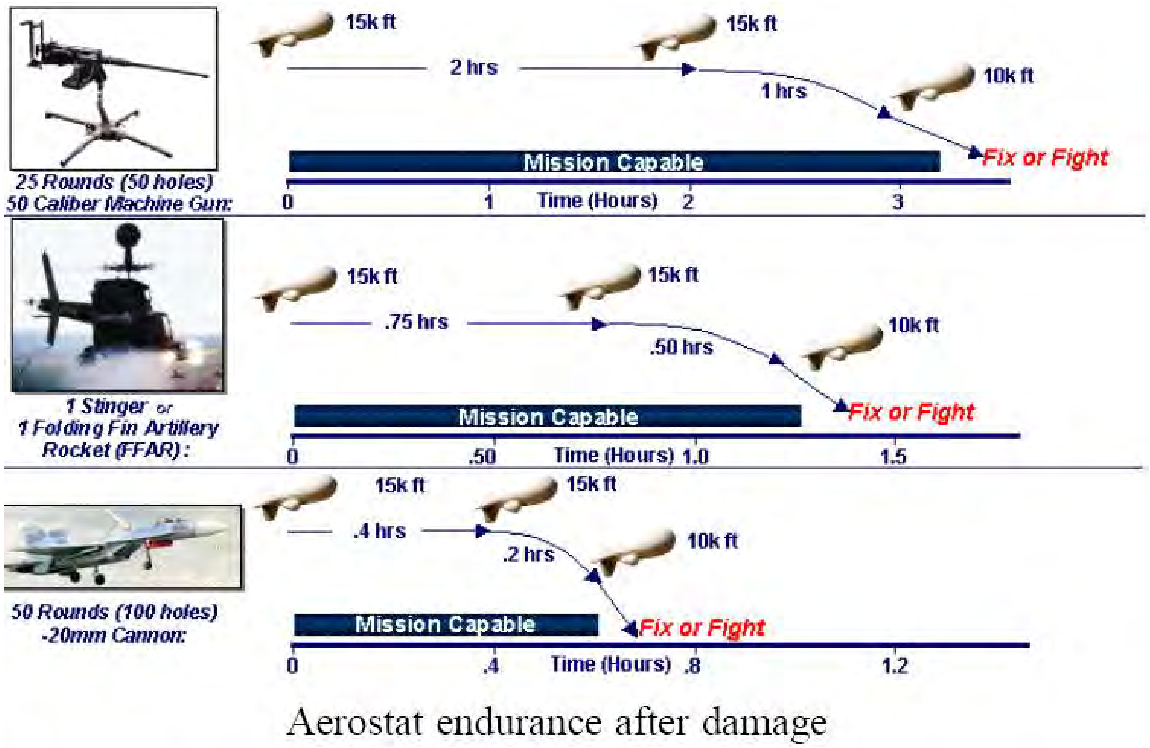

Figure 2.11 – Airship Survivability[79]

Hybrid Airship Concept of Operations

Strategic lift hybrid airships may operate considerably differently than traditional modes of strategic transportation. Hybrids possess many of the same benefits and limitations of conventional strategic lift platforms, but they also enjoy numerous unique characteristics. To serve as viable strategic lift platforms, hybrids must operate in a manner that minimizes their shortcomings while maximizing their inherent advantages.

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[78] Congress of the United States, "A CBO Study: Options for Strategic Military Transportation Systems," *Congressional Budget Office*, September 2005, 39.
[79] Woodgerd, *Fantasy to Prophecy*…, 9.

Besides possessing the ability to carry payloads in excess of current airborne assets, hybrids have the capability to support direct loading of cargo. Rather than marshalling equipment, personnel, and supplies at an embarkation facility, such as an airport or seaport, hybrid airships may rendezvous with their payloads wherever a flat surface exists, perhaps loading at a supply depot or personnel workplace. Hybrid take-off distances will vary depending on their design, configuration, and weight of payload, but hybrids will not require prepared runways. The take-off distance estimates for a fully loaded hybrid weighing in excess of 400 tonnes is slightly less than 2,500 m.[80] Direct loading of cargo will reduce overall deployment time.

Conservative estimates place strategic lift hybrid airship cruise speeds between 80 and 120 knots.[81] Global hybrid transits will require days as opposed to the current delivery time of hours for conventional airlift and weeks for sealift. Despite the long transits, hybrids would be large enough to provide accommodations to transport personnel with their equipment. Some airship proponents suggest that units could even conduct mission planning and tabletop mission rehearsals during transit, thus further decreasing time between receipt of movement orders and deployment to theatre.[82]

Design limitations of strategic lift airships confine hybrids to a maximum service ceiling of less than 10,000 feet.[83] Restricted to low altitudes and slow speeds, hybrids would be subject to several significant transit challenges, including uncooperative state governments and hostile military action and. To ensure global transits as quick and direct

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[80] Gordon, *Back to the Future*…, 54.
[81] Congress of the United States, *A CBO Study*…, 23.
[82] Congress of the United States, *A CBO Study*…, 38-39.
[83] Gordon, *Back to the Future*…, 54.

as possible, hybrids will require over flight agreements with countries above which they transit, and safe transit corridors.

Upon reaching the theatre of operations, a hybrid could land and disembark its payload anywhere a relatively flat surface exists. The distance required for landing would be shorter than what was required for take-off because, if relying on fossil fuels for power generation, it would have burned much of its fuel in-flight; thus, it would need less speed-generated dynamic lift for a gentle landing.[84] Hybrids would possess the added advantageous ability to disembark payloads as close to the staging area as the tactical situation allows because of their independence from airfield infrastructure. The size and capacity of the payload storage containers would also permit transportation of intact equipment. Eliminating equipment assembly time would further reduce overall time between movement orders and operational readiness in theatre. After unloading, the neutrally, or slightly positively, buoyant hybrid would be able to take-off almost vertically.[85] This is a decided advantage if its unloading area becomes besieged by the personnel, equipment, and supplies it just unloaded.

Challenges to the Construction of Hybrid Airships

There exist several risk areas and challenges before strategic lift hybrid airships become reality for the CF, let alone for civilian companies. Some heavy lift airship components require technological maturation, existing technologies require better integration, manufacturing on a larger scale is compulsory, more studies, including full-scale model experiments, are mandatory. Each hurdle is significant and requires tremendous financing efforts before strategic lift hybrid airships are created and fielded.

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[84] Congress of the United States, *A CBO Study*…, 36.
[85] Congress of the United States, *A CBO Study*…, 36.

In fact, many of the world's leading heavy lift airship companies have halted research and development efforts in recent years, claiming bankruptcy, entering into receivership, failing to garner further investor funding, or suffering from a perceived lack of commercial and government support. The latter occurred when the US Congress issued a less than favorable report on the feasibility of strategic lift airships, cancelling funding to the DARPA Walrus research project.[86]

While fabric technology has improved in recent years, the material required to produce fabric for a 500-tonne vehicle remains at the edge of studies proven in the laboratory. Although theoretically possible, such material has not yet been made into a flight-worthy fabric.[87] Several prominent airship company studies concluded they could build, operate, and maintain envelopes with technology available today, but the once preeminent SkyCat company noted that the envelope required to construct their 500-tonne variant was not yet feasible.[88]

Although air cushion landing systems are relatively mature, their incorporation into a strategic lift hybrid airship is unique. The ACLS serves a vital role as the airship's mooring system. The consequences of an ACLS failure could be catastrophic. If in a neutrally or slightly positively buoyant state, strong winds could blow the hybrid away. Lockheed deemed the ACLS a medium risk, not because of any new technology required, but because nothing like it has been built before for this type of application and a significant amount of new engineering is required.[89]

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[86] Congress of the United States, *A CBO Study*….
[87] Gordon, *Back to the Future*…, 56.
[88] Newbegin, *Modern Airships*…, 35.
[89] Gordon, *Back to the Future*…, 56.

The technical risk in developing hybrid airships may seem low since most necessary technology is commercially available. However, the sheer size and complexity of strategic lift hybrid airship envelopes pose significant integration problems. Engineering teams have not yet test flown full-scale models of their 500-tonne variants, let alone constructed them. Small-scale models tested by the DARPA Walrus program are capable of lifting only 2 to 3 tonnes. Uncertain of the risks posed to an integrated system, Walrus program experts even limit flight-testing in winds greater than 10 knots.[90] Flight tests by other industry leaders have not seemed to have progressed beyond the results achieved by SkyCat in 2006. Some firms have received renewed funding from DARPA and NASA but they have only begun to construct prototypes. If they have successfully test flown their hybrid ultra-large aircraft (HULA), these firms have not disclosed the results.[91]

Aside from technical risk factors, market forces have conspired against the construction and operation of strategic lift hybrid airships. Proponents claim hybrids will fill a niche role in the transportation industry, hauling large quantities of bulky cargo to remote areas faster than traditional sealift vessels and cheaper than air assets. However, such a commercial market is nearly non-existent. Typically, only military customers require the type of capabilities hybrids can provide. Without a strong private sector funding strategic lift hybrid technologies, these airships may remain mere conceptions. In fact, once one of the world leaders in strategic lift airships, Cargolifter of Germany halted production of a 160-tonne payload airship in May 2002 due to financial troubles.

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[90] Michael A. Dornheim, "SKUNKS Working," *Aviation Week & Space Technology*, 164, no. 6, (2006): 25.

[91] Defense Industry Daily, "Walrus/HULA Heavy-Lift Blimps Rise, Fall… Rise?" March 06, 2013, accessed 05 July 2013, http://www.defenseindustrydaily.com/walrus-heavylift-blimp-getting-off-the-ground-01103/.

The company soon after applied for insolvency [Aerospace-Technology 2006].[92] Reliance on defence finances poses a great risk to further hybrid developments. The US government-funded DARPA Walrus program was cancelled by the US Congress in 2006. Continued government funding remains sporadic with DARPA and NASA supporting hybrid research and development on a seemingly ad hoc basis.[93]

Challenges to the Operation of Hybrid Airships

Operational challenges pose equally significant difficulties. The two main operational risks are potential political and military action. To operate in an economically viable and militarily useful manner, strategic lift hybrids must proceed to and arrive at destination as quickly as possible. Hybrid airship speed is limited by technical factors and does not pose a risk in and of itself. To expedite the transit, the airship ought to take as direct a route as possible, taking into account favourable environmental and wind conditions. Restricted to low altitudes, airships are susceptible to political action, such as countries along its route denying them the necessary airspace transit corridors. Although traditional air assets face this same political risk, airships are less able to quickly circumvent such prohibitive actions. Its low and slow flight profile makes the use of strategic lift hybrid airships more useful to deliberate operations where a measured deployment and build-up of forces is required.

Although strategic lift hybrids will likely degrade gracefully if hit, they are certainly much easier to target than conventional airlift assets. Visually, the envelope will present an enormous target for ground installations or airborne weapons platforms, a function of both its large surface area and its low altitude. While the envelope itself will

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[92] Aerospace Technology, *Cargolifter*….
[93] Defense Industry Daily, *Walrus/HULA*….

not present a significant radar cross section (RCS), the 500-tonne payload inside the envelope probably will. The gondola can be armoured, and weapon warning receivers and counter measure dispensing systems can be fitted to the airship, but little can be done to protect the envelope from enemy fire. Armour and counter measure systems also add weight, decreasing allowable payload. Some effective methods to guard against enemy attack include preventative measures such as scouting ahead of the airship for potential enemy attacks. The time and resources required of other air assets to protect one hybrid airship could yield an untenable operational formula. Transport airships may simply depend on safety procedures and protective measures currently provided to conventional lift aircraft. Thus, they will be subject to similar threats and levels of risk.

Chapter Summary

Airship technology has existed for centuries and balloon-type aircraft have been in use for just as long by militaries and businesses alike. Whether known as dirigibles or blimps, the usefulness of lighter-than-air craft have been equally misrepresented by both sides of the utility debate, as either a panacea for travel and warfare, or an economically unfeasible airborne disaster waiting to happen. For the great portion of the 20th and 21st centuries, only a few large organizations, such as the US military, and even fewer niche business ventures, such as SkyCat and Cargo Lifter, have delved into the development of strategic lift hybrid airships.

Only recently have technological advances along a broad swath of industries allowed for the practical design of behemoth airships. Modern airships can safely and efficiently transport limited personnel and materiel across vast distances. New materials, material design, and material bonding techniques permits the construction of massive gas-carrying envelopes that would enable the carriage of strategic-sized loads. Advanced power generation, propulsion, and battery technologies will make hybrids lighter and more useful. The unique ACLS has the potential to provide airships with landing and take-off capabilities that no conventional aircraft possess. Integrating these seemingly disparate technologies provides both benefits and challenges to the strategic lift hybrid airship community.

The paramount benefit of proposed strategic lift airships is the ability to transport payloads approaching 500 tons in a single flight. More capable than any existing conventional aircraft, the incorporation of the ACLS would also enable airships to take-off and land nearly vertically while remaining relatively independent of airfield infrastructure. The ACLS and VTOL aspects of hybrid airships will allow for direct loading and unloading of cargo wherever relatively flat terrain exists, including austere environments. While airships are relatively slow craft, their incredible endurance permits direct flights without the need for en route refuelling. And although subject to attack operating at such low and slow flight profiles, the similar gaseous densities between the atmosphere inside and outside the envelope results in gradual, controllable descent.

Technical, economic, and political risk factors exist that prohibit the fruition of the 500-ton airship variant. While it appears that individual technological components may have reached maturity, envelopes of such enormity have never been created nor have they been integrated with an operable ACLS. Flying such a large craft may even result in unexpected aerodynamic and aerostatic forces. These technical and scientific challenges also prohibit the necessary funding as private investors and governments seem unwilling to finance the truly revolutionary hybrid proposals. Numerous companies have slipped into bankruptcy while still in the testing phase, and the highly secretive marketplace prevents the sharing of many lessons learned. Perhaps the most significant risk is political or psychological as the memory of the Hindenburg remains, preventing an acceptance of the merits of hybrid airship technology and the potential to realize the commercial, military, and humanitarian benefits.

Chapter 3 – Airships Versus Existing Airframes

Heavy Lift Comparisons

Discounting the RCN's two ageing supply ships, the CF's only non-contracted strategic lift asset capability resides with the RCAF's four C-17s. These aircraft have demonstrated their usefulness in deploying personnel, equipment, and supplies to various locations across the globe, including the Arctic, Haiti, Germany, and Afghanistan. Their reliability and usefulness make them a suitable platform for comparison against a strategic lift hybrid airship. To demonstrate the potential advantages hybrids may one day possess over conventional aircraft, the SkyCat 1000 concept airship will serve as the contrast model. Table 3.1 provides some basic characteristics for illustrative purposes in the example scenario.

Platform/Parameter	C-17	SkyCat 1000
Maximum Payload	78 tons	500 tons*
Maximum Payload Range	3,500 nm	12,000 nm*
Maximum Speed	400 kts	120 kts*
Service Ceiling	45,000 ft	10,000 ft*
Minimum Landing Distance	2,900 ft	1,500 ft*

* Estimated

Table 3.1: C-17 Versus SkyCat 1000[94]

Expeditionary Scenario Comparison

Although proposed strategic lift hybrid airships may be best suited to address the CF's capability deficiency with rapidly deploying strategic payloads to remote Arctic locations, all assets in the CF inventory must operate in a multitude of circumstances given the uncertain nature of crises and war. In its *Canada First Defence Strategy*, the GoC identified security challenges in an uncertain world, especially in fragile states in

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[94] Newbegin, *Modern Airships*…, 26, A-1, B-1.

regions such as Africa, the Middle East, and South Asia, as a threat to national security.[95] While a concept of operations for airships in the Arctic will be addressed shortly, it is important to compare and contrast the utility of existing CF aircraft with hybrids in a more traditionally military role. The comparative fictional scenario requires the rapid, long-term deployment of a large, self-sustaining mechanized or armoured force to an austere environment, such as those found in Africa or South Asia, to address a dual military and humanitarian crisis.

Strategic Lift Deployment Comparison

Embarkation and Take-Off Phases

The differences in capabilities between a conventional strategic airlift asset and a hybrid airship in a major international expeditionary deployment are immediately evident. As opposed to staging at a major air hub, such as CFB Trenton, distinct and distant from the deploying forces' home base, such as CFB Edmonton, Petawawa, Valcartier, or Gagetown, a strategic lift hybrid airship reduces pre-deployment time, arriving directly at operating formations. A fleet of airships could arrive and transport the deploying force whole. Proposed expansive cargo containers permit the carriage of armoured vehicles, large machinery, and helicopters without the requirement for disassembly typically required for transport in traditional aircraft. This capability further reduces the time required to ready a ground force for transport. Once loaded to its maximum capacity, in this case 500 tons, the airship requires a long, level and unobstructed runway to take off, relying on aerodynamic principles for lift. In this

[95] Department of National Defence, *Canada First Defence Strategy*. (Ottawa: DND Canada, 2008), 6.

regard, a hybrid airship's take-off capabilities are only marginally better as compared to traditional aircraft.

Transit Phase

While the conceptual hybrid airship's advantages over conventional aircraft are pronounced in the pre-deployment phase of this scenario, it faces numerous disadvantages during the transit phase; however, mitigation strategies are available to reduce some of the disparities. Once airborne, a hybrid must chose an optimal route based on prevailing winds, terrain obstacles, and state over-flight clearances, due to an airship's slow speeds and low service ceiling, 120 kts and 10,000 ft respectively. Tailwinds must be maximized, headwinds minimised, and the opposing jet stream, if pertinent, avoided. Over-flight of enemy or inaccessible territory, such as mountains, must also be circumvented. In the African/Middle East deployment scenario, the airship would likely fly a non-stop route from Canada, across the Atlantic Ocean, through the Mediterranean Sea to the point of disembarkation. Over-flight of land would be minimised for several reasons. First, this would be done to avoid elevated terrain, which the hybrid may not be able to ascend above due to its maximum weight ceiling limitation, possibly much lower than 10,000 if fully loaded. Second, sea routes would be chosen to avoid the requirement to secure over-flight permission from affected states. Third, sea routes also reduce the chances of enemy attack, though such attacks remain a possibility, though persistence at sea is much more difficult to maintain than on land.

As the airship transit phase will take several days, as opposed to several hours for the C-17, the crew and any personnel aboard must be provided with living accommodations. Aboard a 500-ton payload airship, space is plentiful, permitting for such requirements. A rapid C-17 deployment delivers troops and senior officers much more quickly to a theatre of operations, allowing them time to plan as opposed to remain isolated in transit. To mitigate this deficiency, planning and briefing facilities aboard an airship can be provided. This ability to plan enroute further reduces the time required during the traditional pre-deployment phase.

Approach Phase

Both conventional and hybrid aircraft require secure landing sites. As airships are not tied to traditional airports and facilities, they may land in truly austere settings. Thus, once near the theatre of operations, some form of reconnaissance party is required to secure a safe landing zone. Scouting of multiple landings sites are required in ahead of the landing but no advanced force is required to hold and defend the area prior to the hybrids landing. With conventional, airport-bound aircraft, the enemy is easily alerted to likely airfields and associated facilities. A hybrid requires little in terms of port facilities; thus, the absence of a prepared airfield permits the deploying force elements of surprise and flexibility.

Landing and Disembarkation Phases

When heavily loaded, an airship requires a landing surface as long or longer than a conventional aircraft, such as the C-17. This disadvantage is countered by an airships ACLS, which enables a hybrid to land anywhere a relatively flat surface exists, even using bodies of water as runways and taxiways. Once stationary, or sufficiently slowed, the ACLS turns to suction mode to moor the airship to the selected terrain. With systems contained within the airship, personnel, equipment, and supplies are unloaded as required; intact vehicles can even be driven off the airship and immediately placed into a defensive perimeter. As the entire deploying force, or force package, is present during the unloading phase, it will be ready to begin operations much quicker than if deployed by conventional aircraft, no longer requiring as much time to reassemble equipment.

Departure Phase

Depending on the specific design of the hybrid, once its payload is unloaded, the airship will be slightly positively or even neutrally buoyant, in the case of the SkyCat 1000, likely the latter. Unlike the C-17, requiring a runway measure several thousand metres, the SkyCat is able to conduct a vertical take-off by employing aerostatic principles. The ACLS, acting as a pre-take-off mooring system eliminates the need for an independent mooring system or taking ballast in the form of water or sand, as previous airship models required. The airship would return to base just as a conventional aircraft would, though its transit time would last much longer, increasing time between sorties.

Chapter Summary

Strategic lift hybrid airships utilize both aerostatic and aerodynamic principles to operate; thus, they possess advantages and disadvantages inherent to both. When compared to conventional fixed-wing aircraft, such as the C-17, conceptual airships may perform much better or worse given the particular phase of flight. In some cases, such as the loading and landing area selection phases, airships can measurably improve the speed of deployment response and reduce in-theatre support requirements. On the other hand, airships perform significantly more poorly than conventional transport aircraft during the transit phase, flying much slower and lower. Although mitigation strategies, such as providing planning and briefing space aboard airships, can reduce inherent shortcomings, the CF would necessarily have to change some of its operating concepts. Even taking advantage of an airship's characteristically flexible choice of landing sites would require the CF to adopt a more flexible approach to deployments, a change the institution may resist.

Chapter 4 – Hybrid Airships in the Arctic

As with other strategic lift assets, hybrid airships would likely fulfill a niche role within the CF. To justify their cost and the risk associated with integrating a new airframe into the present force structure, strategic lift hybrid airships would require a clear concept of operations for not only the Arctic but also other existing CF requirements and commitments. Airships' inherent advantages and disadvantages will drive this concept of operations and the degree to which they would supplant other conventional transport assets. The ability to leverage existing infrastructure and operating concepts, and to function without the need to create new structures, physical and organizational, will facilitate the acceptance of airships into the CF.

Arctic Concept of Operations

A CF strategic lift hybrid airship concept of operations for the Arctic must address several aspects of the Northern sovereignty strategy. Airships ought to demonstrate presence through routine resupply missions, such as to CFS Alert, military capability through participation on annual exercises, such as Op NANOOK, and humanitarian assistance and development through deliberate and crises deployments to isolated Northern communities, such as Attawapiskat. From a conceptual standpoint, operating airships in the Arctic will appear similar to conventional strategic air assets serving on both domestic and expeditionary missions. Much like the conceptual Middle East deployment scenario from a previous chapter, airships will load their payloads in location, delivering them directly to the point of necessity. During deliberate operations, small advanced teams will conduct on-the-ground reconnaissance of the area to ensure optimization of the landing site. On rapid response missions, airship crews will plan their point of arrival en route, using satellite imagery when advanced ground teams are unavailable.

Advantages and Disadvantages

Although airships will function at the conceptual level much like their conventional airlift cousins, they will have distinct advantages and disadvantages while operating in the Arctic. Aside from the aforementioned benefits associated with loading and unloading at the points of need, this feature will reduce both the footprint required on the ground and the need for additional tactical transport resources, some of which may not be readily available in the North. Operating in the North typically costs four times (construction costs, three to five times) as much as does operating below Canada's Arctic Circle,[96] so any reduction in resource requirement will produce measureable cost savings.

Strategic lift hybrid airships may experience some difficulty conducting Arctic operations. Many proponents of hybrids suggest that airships will depend on solar energy to power their engines. If so, airships will encounter problems during periods of no and low light above the Arctic Circle. To mitigate this issue, transport airships will have to either trade payload capacity for increased conventional fuel stores, or battery technology will have to improve to store the necessary energy for flight under the cloud layer and at night.

Adequate hangar space for the CF's proposed future fleet of airships is also a concern. When inflated, strategic lift airship envelopes will occupy a volume of approximately 1,100,000 cubic metres. As a comparison, no hangar in the CF inventory even approaches that size and the former pressurized, inflated dome sports stadium, B.C.

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[96] Department of Defense, "Report to Congress on Arctic Operations and the Northwest Passage," May 2011, 24.

Place, displaced 2,644,800 cubic metres.[97] The cost to create and maintain such enormous storage facilities for the sole purpose of housing strategic lift airships during inclement weather would be immense. Operating such facilities in the North, if deemed a necessity, would be prohibitively expensive and logistically problematic.

The Problem of Procurement

The challenges associated with the procurement of airships and the training of airship crews will prove the most difficult hurdles in the process to utilize hybrids in the Arctic to enhance sovereignty. Military capital projects are notoriously costly and time consuming but these issues are exacerbated when the process involves the development of equipment and systems as opposed to a simple off-the-shelf purchase. Recent military aerospace capital procurements that suffered delays caused by technological and financial issues include the cancelled US Comanche helicopter program, the mired Canadian CH-124 Sea King and CF-18 Hornet replacement projects, and the ultimately successful but over time and budget US Osprey venture.

According to the RAND Corporation, myriad factors are responsible for the inherent difficulties faced by governments in military procurement schemes. The organization cites a lack of inadequate competition creating inadequate market indicators for military-unique products, a shift of the workload to the contractor in proposal preparation to determine market-based fair cost in the absence of historical data, and high risk of price gouging by defence contractors as the ultimate sources of contract delays and dissatisfaction.[98] CF procurement of strategic lift hybrid airships will undoubtedly encompass these three major issues. Although there exists a direct commercial

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[97] BC Place, accessed 11 August 2013, http://www.bcplacestadium.com/index.php.
[98] Lorell, Mark A., John C. Graser, and Cynthia R. Cook, "Price-Based Acquisition – Issues and Challenges for Defense Department Procurement of Weapon Systems," *RAND Corporation* (2005), 14-15.

application for transport airships, the private sector market does not yet exist. If the CF were to purchase hybrids in advance of the civilian marketplace, the institution would be subject the high costs associated with a monopsony.[99] As DND has negligible knowledge and even less experience with airships, the organisation will unquestionably have little notion of fair market value, subject to assured price inflation. Further exacerbating the procurement of hybrids is the fact that they do not currently exist in their operational form. The CF, as potential first adopter of these technologically advanced platforms, would serve as the test bed for strategic lift airships, facing the same pitfalls as experienced by other early adopters of advanced weapon systems, such as the Comanche, Cyclone, Joint Strike Fighter, and Osprey projects.

Integration of Airships into the CF Operational Framework

With airframes procured, and operators and maintainers trained, strategic lift airships would likely integrate easily within the existing CF operational framework. The CF recently incorporated its four CC-177 Globemaster IIIs in 2007-2008, the airframes flying their first operational missions only twelve days after entering service.[100] Although there exist myriad basing options for the CF, likely the best candidate for airships would be with the other strategic lift assets at 8 Wing Trenton. On a day-to-day basis, the airships, including aircrews, would fall under the command of Commander 8 Wing. When deployed on operations, Commander Canadian Joint Operations Command (CJOC) would assume authority over strategic lift airships.

With regard to Arctic sovereignty assertion, operational authority over airships would also change depending on the nature of the activity. Under the current command

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[99] Lorell, *Price-Based Acquisition…*, 15.
[100] RCAF, accessed 11 August 2013, http://www.rcaf-arc forces.gc.ca/en/aircraft-current/cc-177.page?.

and control structure, the commanding officer (CO) of the airship squadron would retain command of his or her assets when deployed on routine resupply missions within the North or on the annual resupply mission, Operation Boxtop. Command for airship operations would fall to Commander CJOC during the annual Northern exercise, Operation Nanook. In the case of a response to humanitarian or environmental disasters in the North, the CF would retain control of its airships but DND would likely serve as the supporting department to an other governmental department (OGD).

On the airworthiness side, authority for the safe operation and maintenance of airships would rest, as they do with the RCAF's other air assets, with Commander 1 Canadian Air Division (CAD) and Director General Aerospace Equipment Project Management (DGAEPM), respectively.[101] Despite their hybrid nature, airships would be governed by the same maintenance and operations policies as described in the Canadian Aeronautics Act, and flight rules outlined by Transport Canada in its Canadian Aviation Regulations and by the International Civil Aviation Organization. From a rules and policy standpoint, strategic lift hybrid airships have the potential to integrate seamlessly with the existing CF force structure.

Chapter Summary

With notable but surmountable exceptions, hybrid airships should be able to operate comfortably in the Arctic within the existing CF operational framework. Airships will fulfill a similar niche role as do other strategic lift assets, but with a specific host of advantages and disadvantages. In fact, airships flying routine resupply and rapid response missions to the Arctic will appear no different than existing CC-117 operations,

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[101] Government of Canada, *Defence Administrative Orders and Directives*, accessed 18 August 2013, http://www.admfincs-smafinsm forces.gc.ca/dao-doa/2000/2015-1-eng.asp.

aside from increased remote access on the part of hybrids; the general concept of operations between the two types of fleets will seem nearly identical.

Airships' most apparent advantage operating in the Arctic is the ability to load and unload at the points of necessity, concomitantly increasing access and reducing costs in the hostile and unforgiving North. However, dependence on solar energy may prevent airships from reaching their full potential during the seasonal no and low light periods. Hangar space for the ballooned giants will also prove a concern in the high Arctic as strong winds and freezing rain can damage airship hulls.

Procuring such massive, technologically advanced hybrid airframes will undoubtedly prove the most challenging hurdle. The polar opposite of an off-the-shelf purchase, airship procurement will likely face delays similar to those observed with recently advanced procurement programs. Once in service, hybrids should have little difficulty integrating into the existing command and technical airworthiness structures currently in place.

Chapter 5 – CF Airship Policy Recommendation

If CF capability is to match GoC rhetoric, DND must improve its response in the North to fulfill the government's mandate to respond to challenges to Arctic sovereignty. Current RCAF assets provide a limited conventional response to traditional problems. Emerging threats will require unconventional solutions.

The advancement of several technologies applicable to aerospace design and manufacture makes possible the construction of increasingly large airships. Proponents of hybrid airship technology believe these innovations, in concert with radical design ideas, can make strategic lift hybrid airships a reality. Although not all components thought necessary to make this endeavour possible are yet mature, as they have not been field tested at full scale, now is the time for serious study of hybrid technology and the airship industry.

While DND does not have the resources nor the political inclination to conduct relevant studies in this field, it is appropriate that the CF raise its awareness regarding the capabilities of this technology. The CF cannot afford to conduct independent design, manufacture, and testing of strategic lift hybrid airships, but it can support private industry. By signalling an interest in the technology and the capabilities it may provide to response in the North and military expeditionary capabilities, the CF may spur private industry to increase advancements. GoC technology grants to domestic industry partners would have a direct financial impact. The GoC, DND, and the CF should coordinate a multilevel response to hybrid airship technology to hasten its development and to position Canada as an early adopter.

It is recommended that the GoC:

a. Increase awareness of and funding to existing programs, such as the Scientific Research and Experimental Development (SR&ED) Incentive Program, and Defence Research and Development Canada (DRDC);

b. establish additional technology bursaries for those organizations committed to the research and development of hybrid airship technology; and

c. provide increased tax breaks and incentives for companies that research, test, or develop, strategic lift hybrid airship technology

It is recommended that DND:

a. commission studies regarding the use and state of strategic lift hybrid airship technology with regard to military aerospace to determine its applicability to the Canadian context and any associated timelines for its adoption;

b. engage in limited partnerships with commercial industry and defence organisations, such as DARPA, for the purpose of gaining technological insight into hybrid airship advancements; and

c. encourage the defence and aerospace science and technology communities to participate in international initiatives to advance heavy lift airship capabilities.

It is recommended that the CF:

a. monitor hybrid airship industry advancements; and

b. develop an initial concept of operations for strategic lift hybrid airships to prepare for their inclusion into the CF force structure.

Although industry stakeholders, such as Lockheed Martin, claim transport airships will be operationally employable by 2014,[102] strategic lift hybrid airships capable of moving payloads in excess of one hundred tones are estimated by even the most optimistic airship enthusiasts as over a decade away. Government, Department, and CF initiatives in the airship field will yield at least two significant benefits. Timelines for the maturation of the technology to improve Arctic response will be shrunk and the period during which military users will become accustomed to their usefulness will be shortened.

[102] Lockheed Martin. *Hybrid Airship*, accessed 05 July 2013, http://www.lockheedmartin.com/us/products/HybridAirship html.

Conclusion

To truly secure the North in a military, economic, and social sense, the GoC must address its claims of sovereignty with a capability that facilitates rapid and appropriate responses to crises in the Arctic and strategic lift hybrid airships may fulfill that niche role. The CF's current strategic lift assets are adequate based on the equipment available but the burgeoning airship industry may provide technological solutions for foreseeable complex problems in the changing Arctic. Airships are not yet capable of transporting strategic payloads to desolate environments but DND must encourage industry leaders to continue developments in this field, remaining abreast of improvements to seize opportunities as they become available.

A fleet of strategic lift hybrid airships will allow the CF to quickly deploy personnel, equipment, and supplies to any location in the Arctic, no matter how remote and austere, to aid in the response to an industrial, environmental, or social disaster. As envisioned, these airships will load response teams at their place of origin, transit to destination using less fuel than conventional lift platforms, and land and unload cargo at any location a relatively flat surface exists, independent of a runway and port facilities, allowing vehicles and equipment to simply roll off because they did not require disassembly during the loading process. This concept of operations is made possible only by the advent of improvements to envelope material tensile strengths, material bonding techniques, computer-aided design regarding airship shape and function, and the addition of the ACLS. While smaller scale models of such airships have been successfully operated, technological advancement along these paths must continue to permit the flight of the predicted and revolutionary 500-ton capacity airships.

This technology gap is similar to the GoC's gap between its Arctic sovereignty rhetoric and the response capability for the region. While the government has trumpeted its claims of dominion over the North, it has not backed up its words with development of capabilities. Sea and air ports remain substandard for large operations and the promised ice breakers have not materialized.[103] The government's presence and surveillance of the North has improved but measures to respond to immediate crises are not in place. As interest in the Arctic continues to grow and the region becomes more accessible, the risk to the fragile ecosystem and its inhabitants increases.

The Arctic is an inhospitable landscape with sparsely populated communities situated in remote and nearly inaccessible locations. Simply inhabiting the North and placing *boots on the ground* (ref needed) is not enough to claim sovereignty. Sovereignty is no longer simply about protecting one's territory from military invasion. Sovereignty in the modern world is now includes a duty to protect one's citizens, prevent harm from coming to them, and responding to crises when they are threatened. The criteria for fulfilling a state's sovereign duties are not easy, especially in an environment as unforgiving as the North. If the GoC's priority for its Northern Strategy is the protection of the nation's Arctic sovereignty, then it must not only *use it*, but also it must have the capability to respond to and resolve crises when others use it maliciously.

[103] Senate, "Sovereignty & Security in Canada's Arctic – Interim Report," *Standing Senate Committee on National Security and Defence*, (March 2011), 40.

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