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COMPETING TECHNOLOGIES AND ECONOMIC OPPORTUNITIES FOR NORTHERN LOGISTICS: THE AIRSHIP SOLUTION

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INTRODUCTION

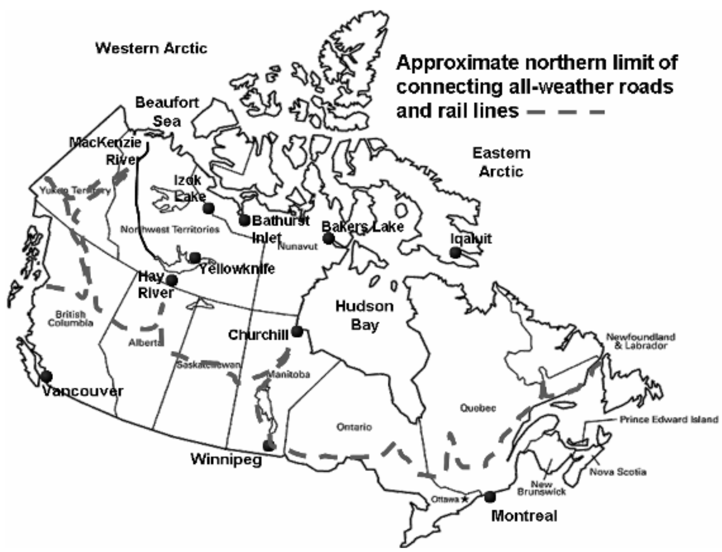
Economic development in Northern Canada is constrained by the cost of transportation and logistics. The limited transportation options available increase the direct costs of shipping and add to the indirect costs of inventories. Concerns about climate change impacts, delays in environmental approvals and uncertainty regarding First Nations land claims further increase investment risk. As a result, the transportation solution offered by airships is gathering increased interest in northern Canada.

The purpose of the paper is to examine the market opportunity for a new generation of airships in Arctic logistics. The paper begins with an overview of the logistical options available and potential roles for airships. Subsequently, airship technology development is examined with respect to the product life-cycle theory and the observation of tipping points. The paper concludes with some thoughts on necessary steps to make this technology available in northern Canada.

OVERVIEW OF TRADITIONAL NORTHERN LOGISTICS

The North holds an abundance of natural resources that could meet world demands for metals and energy. The primary challenge is the cost of extraction. If a development frontier can be defined as an area without railway or road access, 70 percent of Canada's landmass and much of Alaska would be classed as disconnected from the modern North American economy. This access denied territory is where an emerging generation of new cargo airships could fill many gaps in the existing transportation networks.

The northern frontier is characterized by vast distances, thin markets and harsh weather conditions. The map below denotes the northern extent of road and rail infrastructure in Canada. The land area north of the all-weather roads and rail lines encompasses approximately 4 million square miles. Sparse traffic density, few back-haul opportunities, seasonal shutdowns and infrequent transportation service lead to expensive logistics in this under-developed hinterland.



The alternatives for transportation solutions in the Arctic are saltwater ships, barges, airplanes, helicopters, cat-trains and trucks over ice roads. Each of these market segments is described briefly with some thoughts on how airships could be used to support or replace them.

Marine Transport

Sealift is the least expensive form of transport available to communities with seasonal access to open water. Ships and ocean going barges are capable of delivering 5,000 to 25,000 tonnes of fuel and other cargo[1] out of Montreal and Churchill Manitoba to serve the eastern Arctic. The western Arctic can be served by fuel tankers from overseas and ocean barges out of Vancouver or Prince Rupert, BC.

Saltwater transport permits two or three deliveries per year. Infrequent service means that if cargo misses the sailing date, a construction project or other development can be held up for a full year, or forced to use much more expensive air cargo.

Where the ports lack docking facilities, ships lower lighters[2] over the side to take goods to the shore. Port handling is a slow and laborious process. A more efficient system could be to unload all goods at a larger port, like Iqaluit, and use airships to deliver cargo to the smaller communities, or ones that are frozen-in some years. Faster unloading of the ships could enable them to complete an additional voyage each year, or be redeployed for other commercial operations.

The western Arctic can utilize of fuel tankers from Asia and benefit from the introduction of new 12,000 tonne ocean-going barges from Vancouver and Prince Rupert B.C. that can connect to smaller barges in Tuktoyaktuk. The utilization of larger sea going craft will improve the unit cost of goods into the region, which can be enhanced through the use of airships to assist with the cargo discharge and easy transfer to shore bases or smaller barges along the coast.

Communities located on the coasts of Hudson Bay, the western Arctic and the Mackenzie River valley can take advantage of barge shipment. Barge service is more frequent, but can be more expensive than ships because of the extra handling and smaller shipment size. Communities on Hudson Bay are served with barges that connect with the railhead at Churchill, Manitoba.

[1] Goods destined for Iqaluit and other Nunavut and Nunavik communities are assembled in warehouses at Montreal during the spring, then shipped on the Umiavut, Anna Desgagnes, Arctic Viking, Lady Franklin and Aivik. The first ships arrive in Nunavut about mid-July, with another in mid-August and the last trip in late September.

[2] Usually, the lighters are barges.

The western and central Arctic are served out of Hay River, Northwest Territories that is located on the south side of Great Slave Lake. An all-weather road and rail line connect Hay River to Alberta and southern Canada. Barge cargo is trans-loaded at Hay River and taken north down the Mackenzie River. These barges serve oil and gas development and communities along the Mackenzie River valley and the Arctic coast.

Mackenzie River barges suffer a lack of feeder traffic. Resource development along the river is sparse and roads are few. Airships could provide this feeder system lifting pipe, equipment, fuel and supplies from the barges to extraction sites, and feeding mineral concentrates from base metal mines back to the barges. Cargo airships would complement barge transport in the Mackenzie delta and Beaufort Sea, rather than compete for traffic.

All-weather and Ice Roads

Heavy cargo is shipped to remote communities in the interior via ice roads. Cat-trains and tractor-trailers operate on temporary roads that are built over frozen lakes and cleared bush. Typically, it costs $3,500 to $6,000 per kilometer to build an ice road over proven routes that do not require clearing. Pioneering a new route is much more expensive and requires a land use permit. In general, ice road construction costs increase with distance and the proportion of the ice road that is routed over land [Johnson].

Added to the annual cost of building and maintaining the ice roads, truck shipments are 65 to 70 percent more expensive than the equivalent truck transport over all-weather roads[3]. Trucks have to travel more slowly crossing frozen lakes, suffer greater damage to suspension and tires on the land portions, experience longer delays and face more risk associated with pressure ridges and thin ice.

Northern Canada and Alaska have limited all-weather road, rail and pipeline connections to southern markets. The geography and permafrost soils make infrastructure very expensive to construct and

[3] Personal communication, Big Freight Systems, Inc. This freight rate differential applies to Manitoba. Further north, in the Territories, the costs are likely to be higher

in some cases development is constrained by aboriginal land settlement negotiations and environmental approvals. The frontier region is unlikely to receive much new transportation infrastructure anytime soon.

Warming temperatures are a mixed blessing for transportation. Greater melting of the Polar Cap is extending the marine shipping season, but has also increased melting of the permafrost during the summer. This threatens to damage existing roads, landing strips and other infrastructure. As the winters warm, the ice roads are becoming less reliable. The end of the economic use of ice roads is already visible in the central provinces[4].

In Manitoba and northwestern Ontario over 5,000 kilometers of ice roads are built every year. If stretched out and linked together, it would be the equivalent of building an ice road from Montreal to Vancouver. These ice roads serve a population of only 50,000 to 60,000 located in about three dozen remote communities. Building one mile of ice-road for every 20 residents is a large annual drain on the treasury.

Ice roads usually open in January and close in March. The length of the ice road season depends on location and weather. Prior to the mid-1990s, ice roads east of Lake Winnipeg were able to operate 50 to 60 days every year. In half the years since 1996, barely 30 days of operation has been possible. In a severe year, like the El Niño of 1998, ice roads can fail completely and air transport is the only option[5]. An El Niño year in 2006 caused the premature closing of the winter road serving the diamond mines out of Yellowknife, Northwest Territories. Out of the 10,000 truck loads planned over the ice road that winter approximately 3,500 truck loads of fuel and materials were undelivered when it closed. The expense to fly in fuel and supplies added $100 million to cost of the mines' operations.

One of the diamond mining companies affected by the 2006 El Niño had an 80 tonne piece of equipment that had to be delivered in order

[4] Manitoba, Ontario and Quebec.
[5] In 1998, the Government of Canada had to spend an additional $12 million to fly in fuel and supplies to First Nations communities in Manitoba.

to continue the operations of the mine. Premature closure of the winter road stranded this critical piece of mining equipment 400 kilometers from the site in Yellowknife, NWT. Airborne Energy Solutions brought the Russian made *MI-26* helicopter to Yellowknife carry this equipment to the mine. The mining equipment had to be cut into four 20 tonne pieces to be ferried in by the MI-26, with several stops along the way for refueling. The total costs of the move are unavailable but the helicopter's fuel consumption is 3,000 liters of fuel per hour, and it charges out at more than C$20,000 an hour. [Siku News]. The threat of similar ice road failures increases as climate change progresses[6].

The ice roads problem extends across all of northern Canada and into Alaska even where all-weather roads are available. At major rivers, like those on the Dempster Highway on the route to Inuvik, NWT 6-week gaps occur during the spring break up and the fall freeze up. Trucks have no ferry service and it is unsafe to cross on the ice road. As the climate becomes milder, the transition periods can be expected to grow. Compared to the cost of building bridges or converting ice roads to gravel, airships would be an inexpensive means to complement the existing network and expand service to remote communities and resource developments[7].

Air Transport

Air transport offers the greatest convenience in the northern frontier with year-round, fast transportation service. The limitations of fixed-wing aircraft include the conditions of the landing strip (length and surface covering), high freight rates and restrictions on cargo weight

[6] Climate change is a global problem, but it has greater impact in the higher latitudes [ACIA]. Evidence of climate change is indisputable in the North. The polar ice cap continues to melt further and less of the total is made up of multi-year ice. Experts are now predicting that the Arctic Ocean could be open water in the summer time by 2015.

[7] The Deh Cho bridge is being constructed across the upper MacKenzie River to provide year-round access to Yellowknife. This crossing is blocked for three weeks in the fall and four weeks in the spring. The bridge is a two-lane structure totaling 3,000 feet in length consisting of 9 spans with 8 piers. The estimated cost in 2007 was $165 million. Currently, small helicopters lift loads across the Mackenzie River to maintain service to Yellowknife.

and dimensions. Indivisible freight can only be shipped if it can fit through the airplane's cargo door.

Air transport has significant economies of vehicle size. The larger the aircraft the lower the unit costs of air shipment. The disadvantage of airplane size is the greater infrastructure cost for longer landing strips.

The costs of air cargo in the north and the airstrip requirements are presented in Table 1 for a comparable 300 kilometer flight. The airstrip requirements represent the length at the landing site. Longer runways may be necessary to take off fully loaded. In the winter, an ice strip over a lake can be constructed to accommodate a Hercules aircraft but requires between 50 and 60 inches of ice to support it.

Table 1 Aircraft Cost Comparison for a 300 km Flight

Aircraft Type	Cargo (kg)	Cost ($/km)	Cost ($/kg)	Airstrip (m)
Twin Otter	955	$6.50	$4.09	310
DC3	2500	$10.60	$2.46	925
Curtis C-46	6800	$17.95	$1.58	1075
DHC Buffalo	7500	$17.00	$1.37	925
Boeing 737C	13500	$20.99	$0.97	1700
Hercules	20000	$35.78	$1.12	1700

Sources: [Petrie, Johnson]

Airships would be able to complement existing airplane fleets for the movement of oversized cargo or oddly shaped pieces. From spring to fall airships have no competition to serve remote locations with loads greater than 20 tonnes.

Summary

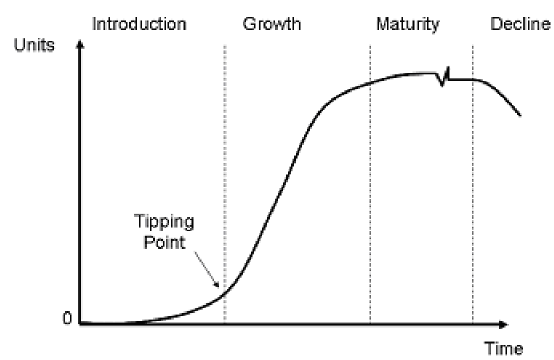
Arctic logistics is a case of doing the best we can with what we have. Whether it is effective is another matter. By any measure, consistent delivery success is limited and transport cost is expensive. Greater financial and human risks are taken than would be considered in the developed parts of Canada. Indirect costs are also high because of the need to store large quantities of goods for a whole season, requiring larger warehouses and bigger fuel storage tanks. Finally, the opportunity costs are immense. Resource development opportunities languish for decades in the Arctic, assets are stranded for long periods and local people suffer illness because of unbalanced diets and substandard shelter.

A new generation of cargo airships would have a revolutionary impact on northern transportation and logistics. Transportation and logistics costs would fall, and problems of environmental regulations and aboriginal land ownership would greatly diminish. The airship may be the only means of transport that can mitigate the negative consequences of climate change on northern transportation.

POTENTIAL FOR A CARGO AIRSHIP SOLUTION

Tipping points are periods of accelerated growth. The concept of a tipping point is derived from the biological sciences, but it also applies to many economic phenomena. The dissemination of new technology is an example of a tipping point that is closely related to the product life cycle. In Figure 1 the classic product life cycle is illustrated together with the tipping point.

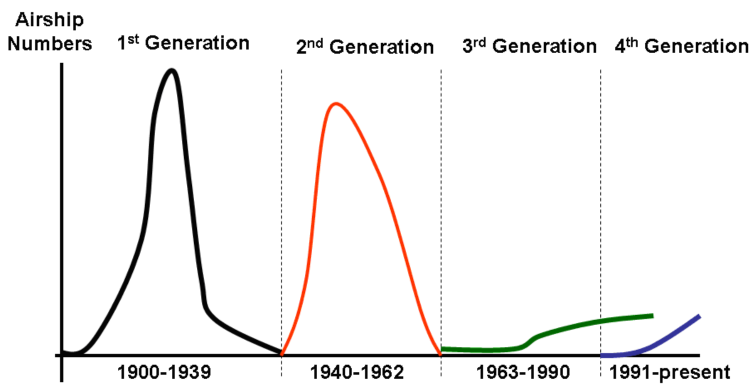
Figure 1 Theoretical Product Life-Cycle



The number of units produced for the market is few during the introductory stage. During this period technological barriers are overcome and markets are developed for the product. At some point the needs of the market and the cost of producing the new technology meet, and sales begin to accelerate at an increasing rate. Once the tipping point is passed the industry enters a period of rapid growth. Sales finally level off when the technology matures and growth is similar to the general economy. The maturity period can be quite extended, but eventually the technology enters a period of decline, or re-invents itself and returns to a growth path and extended maturity.

It is arguable whether airship technology has ever reached a tipping point. An approximate histogram of the airship industry since 1900 is presented in Figure 2. The histogram divides the history of airships into four generations of technology.

Figure 2 Development of Airship Product Life-Cycle: 1900 - present



<u>1900 – 1939</u>

In the early decades of the 20th century giant airships were built in Britain, France, Italy, Germany, Russia and the United States. The majority of these airships were built for military purposes, but in Britain and Germany airships were also built for civilian use. In 1910 the giant airships entered regular civilian passenger service in Germany. The greater development of German airship technology during World War I enabled the Zeppelin Company to enter trans-Atlantic passenger services in the 1930s. This era proved that dirigibles could operate scheduled services, provide 65 to 80 tons of useful lift and be safely moored and hangared.

The periods of commercial development produced relatively few civilian airships before the Second World War (WWII). Although airship technology appeared ready to expand rapidly prior to the Hindenburg accident, the industry never reached a tipping point. The outbreak of WWII ended the development of rigid airships, but introduced a new generation of non-rigid designs, or blimps as they are often called.

<u>1940 – 1962</u>

The war effort from 1939 to 1945 focused mostly on fixed-wing aircraft technology. The combined combatants of WWII built a total of 500,000 airplanes and advanced the technology to high altitude bombers and jet engines. Civilian airplanes hit a tipping point after the war and an accelerated growth rate for the next 30 years.

The achievements of airship technology during WWII are less known. The large US Navy blimps could lift about 10 tons of crew, supplies, accommodations, fuel and water. They were used to spot submarines along the coast and escort convoys on the North Atlantic. Endurance records set during this period still stand. They proved the reliability of large non-rigid structures and engines. The Navy blimps withstood hurricanes and weather on the north seas, but experienced a number of ground-handling incidents.

The envelopes were made of multiply cotton-neoprene fabric and painted to reduce permeability. Damage to the envelopes occurred from stretching, flexing, scraping, scrubbing and unintended contact with hard surfaces. In service, all envelopes required overhaul and repair every two years[8].

<u>1963 – 1990</u>

When the US Navy terminated airship operations in 1962, the world supply sank to three small advertising blimps operated by Goodyear. This changed in the mid-1970s when the dramatic rise in oil prices re-

[8] The authors acknowledge helpful information on the US Navy Blimps from Albert Robbins and Richard Van Treuren.

awakened interest in lighter-than-air technology. Although the period of high oil prices ended before commercial airship developments could hit a tipping point, a number of technological changes were introduced.

The rigid airships where covered with painted canvas that served only to streamline the exterior and offer some protection from rain. The canvas deteriorated within four years of exposure to ultraviolet light and proved to be very flammable. The rubberized envelopes of the Navy blimps were more robust and provided structural support, but were also short-lived. During the 1980s new composite envelope materials were developed that could last over 15 years in direct sunshine.

Gases pass through membranes in both directions; the rate increases with increasing pressure differential. The Navy blimps lost 100 percent of their helium each year in part because the pressure had to be double the level of the advertising blimps. With less permeable materials and lower pressures, they lose only 10 percent of the helium annually. The other significant advances in the third generation airships were FAA air worthiness certification, fly-by-light avionics and vectoring engines.

Despite the many technical advances, advertising blimps still need a crew of 12 or more holding ropes for ground-handling. The large labour requirement makes this airships costly to operate and limits their size.

<u>1991 – Present</u>

The fourth airship generation includes a broad spectrum of innovations that permit unassisted landing and take-off. The hybrid designs that are about 20 to 40 percent heavier than air are particularly interesting for cargo applications. One approach is to use a catamaran hull shape to provide aerodynamic lift (Lockheed, HAV). When on the ground the catamaran hybrids use modified hovercraft pads that operate as suction cups to hold their position for loading and unloading. Another hybrid configuration in development utilizes airship with helicopter technology to undertake precision pick up and placement (Boeing-SkyHook). The airship lifts the craft and fuel, while the helicopter rotors lift the cargo.

Other technological developments include unmanned flight systems and very high altitude operations as telecommunication relay stations. Robotic operation techniques have opened a wide spectrum of applications for unmanned automated applications, e.g. stratospheric lighter-than-air systems. Photovoltaic systems are being adapted to the specific requirements for stratospheric airships and hydrogen technology is proceeding towards a renaissance.

The *Zeppelin NT07* is the only commercially available fourth generation airship. Technically, the NT07 is a semi-rigid airship. An internal frame carries half the stresses, while the pressurized envelope carries the remaining loads. The NT07 can land and takeoff unassisted. Two side propellers swivel 120 degrees to push the airship up or down for landing. A third aft engine drives a pusher propeller that can rotate down 90 degrees to assist with takeoffs and slow speed control. A second side propeller on the aft assembly revolves in a neutral pitch during flight, but can act as a helicopter tail rotor in takeoff and landing situations and in hover mode. All this is controlled by computers that connected to the pilot’s side stick.

Although four *Zeppelin NT07*s have been constructed, the tipping point for commercial success has not been achieved. The high capital costs (approx. US$12 million) and small passenger size (12) limits its market appeal.

WAY AHEAD TOWARDS CARGO CARRIER AIRSHIPS

One hundred years of technological change has created the opportunity to build large, robust airships that could deliver cargo to the most inhospitable corners of the earth. At the current time, over 16 teams are working in 8 different countries with actual airships and aerostats. At least as many airships are on the drawing boards waiting only for investment to explore alternative designs. The development of a cargo airship now seems inevitable, and the race is on to find the dominant design.

Unlike passenger airships, cargo airships have to consider the replacement of the weight they are dropping off. Hybrid airship concepts that are heavier than air when empty are being developed to eliminate ballasting. Conceptually, they can drop off a load and return to base empty, but this has yet to be proven. Other ideas for ballast control feature the compression and/or heating of helium to compensate for weight change. Of course, the addition of ballast water or other material is possible. Each method has its merits and more than one approach in combination may be used.

It is clear that future cargo airships will not depend on large ground crews. The ability to vector engines and computerized control with GPS location has eliminated this barrier. And in any case, economics require unassisted landing and takeoff.

The materials exist to build cargo airships that are much larger than the giants of the past. Envelope materials that can build a 250 ton lift hybrid have already been developed, and designers are projecting 500 to 1000 ton lift airships as likely.

Airships are compatible with Arctic conditions and terrain. Colder air provides more lift and the lack of surface thermal activity is an advantage for smoother flight. Airships need to be field tested in winter conditions to prove that they can deal with snow accumulation and extreme temperatures, but winds can only be managed. Under some conditions many aircraft will not fly, but airships have long endurance which may allow them to wait out storms. Airship captains will have to work with the wind, rather than fight it. A non-linear flight path that tacks against the wind may take a bit longer, but airships can cruise easily at 130 kmph so they will still arrive faster than a truck over any ice road.

The primary impediment to the development of cargo airships is the lack of business confidence. Government has a role in providing infrastructure and dealing with market failures. The absence of modern airships, when the need is so obvious and the technical barriers are so few, is a market failure. The case for governments to fund the first few cargo airships and to build suitable hangars is strong given the need for northern economic development and the protection of national sovereignty in the Arctic.

The aerospace industry in Canada is well established. The new generation of cargo airships will likely be built in these established centres, but they will be hangared and maintained in the Arctic where they would operate. The actual size of airship manufacture and operations in Canada make it an appealing industry to encourage for its own sake, but the payoff to northern development will be nothing less than revolutionary.

For too long people in northern Canada have had to make the best of whatever transport they could with limited infrastructure and a sparse population. This is no longer necessary, but the North has to make its voice heard, if it wants to accelerate the development of cargo airships. Sufficient demand exists in northern Canada to produce cargo airships and no technological barriers remain. The commercial tipping point is in sight, it just needs a final push to make it happen. When the people of the North decide that they can no longer wait for outsiders to solve their transportation problems, governments will be forced to act.

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