

Re-supply and Emergency Response in Arctic Resource Development Applications for Lighter-Than-Air Technologies

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Introduction

The extraction of fossil fuels will form the basis of global energy needs for decades, regardless of advances in renewable energy sources. Moreover, petroleum resource development will be pushed further to the margins of human settlement, such as the Arctic. Interests in the extraction process in the north have also been increased by new discoveries of diamonds and precious metals. These activities represent a significant opportunity for areas of the Arctic. However, with these increased economic opportunities come potential environmental risks. The Arctic environment can, at times, appear harsh, but it is also very fragile. It has a slow and limited ability to heal itself from the impacts of civilization's activities – both intended and unintended.

Global warming may accelerate the economic exploitation opportunities of Arctic resources. Longer periods of ice-free water could provide better sea access, and extend operating seasons. At the same time, melting permafrost and a shorter winter could limit access to inland areas. In particular, the winter road system may become unusable.

The combined challenges of increased resource development in the north, and the need to minimize the destructive "footprint" in this sensitive area, must be addressed.

The Challenge of Resource Development and Resupply

The challenges facing land-based mining development in the Arctic are extensive. Distances are great, and transportation infrastructure is limited. Presently, land-based establishment of sites and resupply of those sites is generally limited to a short window of opportunity. All bulky materials associated with a year's operation of the mining sites must be onsite by the end of the winter road season. This places significant pressures on those charged with logistics, and heightens the financial risks associated with "ramping-up" these developments.

The 2001 winter road season in the area around Yellowknife in Canada's Northwest Territories was shorter than usual. The season ran from roughly the beginning of March to mid-April, – a scant 6 weeks. In that period, 8,000 truckloads were dispatched from Yellowknife to the mining sites of Ekati, Lupin and Diavik. These sites range from 250 miles (400 km.) to 350 miles (560 km.) from Yellowknife. This placed a significant load on the ground transportation system, moving 160,000 tons of materials in a short time in inhospitable conditions. The demands for shipments by winter road in the area are expected to increase in the 2002 season.

Some potential mining sites are outside the feasible range of winter roads. For example, the base metal deposits at Izok Lake are unreachable by ground with any economic means of transport.

The largest single supply being moved to the mine sites is fuel. In addition to mining sites, many coastal communities are served by annual sea lifts. Communities' needs must be determined a year in advance in order for supplies to be brought in by barge. Large quantities of aviation and diesel fuel are shipped in 45-gallon drums. Some coastal communities can receive oil products in bulk.

The risk of oil spills is a major concern for Arctic development. At the present time, re-supply missions are the greatest threat to the environment, but by and large, these are relatively small volumes. Once petroleum extraction gets underway in the north, large quantities of crude oil will be moved by pipelines and tankers.

The Challenge of Emergency Response

Handling of potential oil spills in the Arctic is a significant challenge. Moving large amounts of personnel and materiel to remote areas with virtually no existing infrastructure would be difficult under any conditions in the Arctic, but to do so quickly presses the limits of modern technology. For an offshore or coastal oil spill, the Canadian Coast Guard must be able to move materials such as skimmers, booms and collapsible bladders to the site or to the closest shore or ice pack edge. From there,

equipment would be transferred to icebreakers or other vessels to move to the spill site. The time required to reach an oil spill could be measured in days or weeks, rather than hours.

The booms (designed to encircle the spill and contain it during the recovery process) are 50' structures in 8' to 10' sections. Approximately 10,000 feet of boom is required to contain a 2,500 tonne oil spill. While significant, this scale of spillage is dwarfed by the 40,000 tonne Exxon Valdez spill of 1989 or the Erik's 30,000 tonnes off France in 1999. The 10,000' boom length has a shipping weight of about 30 to 35 tonnes.

Current plans call for the boom sections to be transported by small and medium sized aircraft. Repeated flights would be required to move 10,000 feet of boom and other required materials to the site.

Personnel accommodations are another challenge. The movement of 20-foot containers to provide housing for the cleanup crews is a logistic barrier. Problems of accommodations at remote sites set the upper limit of personnel at 20 – 30 individuals.

Collapsible floating bladders are used to store any recovered oil. The bladders remain in the Arctic until barges can be towed to the site. Contents of the bladders are then pumped to tanks on the barges, and the bladders are removed from the water. This procedure is required because of the inability to move large holding tanks to land areas adjacent to spill sites.

A Possible Response to the Challenges

Resource resupply and emergency response are just two examples of increasing needs in Arctic transportation. The Arctic's expanse and environmental sensitivity requires a system that is capable of moving a variety of cargoes over long distances, at rapid speeds, with minimal net energy and materials requirements, and with minimal environmental impact. This is a challenging problem! Surprisingly, the answer may be based on a technology with roots in the 18th Century and which flowered, briefly, during the first half of the 20th Century -- rigid airships.

The advent of a new generation of large (165+ tonne), cargo-carrying airships has the potential for a significant impact on resource development in the circumpolar region. Rigid airships, which were written off 60 years ago as dangerous and uncompetitive for passenger movements, are finding a new purpose filling the growing demand for airfreight service.

Developments in Airship Design

Disastrous structural failures occurred when the large airships are buffeted by storms, in maneuvering and docking. These failures are related to the trial and error construction methods were used. Wind tunnel tests are incapable of determining the actual stresses and torques that vehicles of this size encounter. As a result, the first generation of large, rigid airships (1910-1940) were under-built by a factor of three. The modern ability to perform computer simulations has greatly reduced the design costs for airship, while enhancing the ability to predict and adjust for actual stress factors.

When the Hindenburg ended the first phase of commercial airships sixty years ago, nylon stockings were a luxury and Model-A Fords were cutting edge technology. The early Zeppelins were built with aluminum frameworks and flammable canvas covers. New composite materials, using carbon fibre and kevlar enable the construction of lighter, more robust and safer airships.

Advances in materials and engineering have overcome all the technological problems encountered by the first generation of rigid airships. Of course, the new generation of airships also employs non-flammable Helium, rather than Hydrogen as the lifting gas. What has been missing is a strong business case and investors willing to take the necessary risk. This has now occurred and an international race is on between Germany, the U.K. and the U.S. to create the leading cargo carrying airship design.

Advantages of Airships and Current Design Options

There are four primary advantages to rigid airships. First, they are fuel-efficient. Relative to all other modes, airships require less energy to move a ton of cargo a given time/distance. Airships could use natural gas, which is more plentiful, cheaper, and cleaner burning than petroleum-based fuels. Moreover, the large surface areas of airships offer the potential for using solar power. This may seem more farfetched than the idea of a new generation of airships, but the cost and weight of photovoltaic cells are falling. A solar airship might not be cost-effective today, but research in this field is already well advanced.

The second advantage of rigid airships is that they can accommodate all sizes and types of freight. Rigid airships are constructed with a load-bearing frame that distributes the cargo weight evenly. While non-rigid airships (like the Goodyear Blimp) are limited to about 10 tonnes payload, a rigid airship can be built to carry up to 500 tonnes or more. Density of the cargo is not an important factor because bulky cargoes can be suspended outside the airship.

The third advantage of airships is that, like aeroplanes, they have minimal impact on the terrain. This is particularly important for transport in ecologically sensitive regions such as the Arctic, with movement being feasible up to 12 months of the year.

Speed is the fourth advantage of airships. Cruising speeds of 60 to 100 mile per hour compare favourably with surface transport, particularly over circuitous winter roads.

Just as advances in computer design and lightweight materials have made a new generation of large airships a commercial possibility, environmental concerns and potential markets have stimulated worldwide interest. The leading cargo airship designers are CargoLifter (Germany), Advanced Technologies Group (UK), and Zeppelin Luftschifftechnik (Germany)¹. A number of blimp producers and related manufacturers, like Airship Industries (US), Lockheed-Martin (US), and Lightship Ltd (UK), are also capable of joining the race.

CargoLifter is scheduled to test its first commercial cargo airship in 2003 and bring it to the market in 2005. This semi-rigid airship is designed to carry 165 tonnes, and operate as a sky crane for the delivery of oversized, high technology equipment, such as hydroelectric turbines and oil refinery towers. CargoLifter has constructed a new hangar outside Berlin where two airships can be assembled simultaneously. This US\$100 million hangar is a giant Quonset 35 stories high, 600 feet wide at the base and 1,180 feet long (large enough to play six football games simultaneously under its roof!).

Zeppelin has received certification for its 19-passenger NT model and has inaugurated its scheduled services in Germany. The Zeppelin NT, which is the first rigid airship in 60 years, combines a light frame (1 tonne) with a pressurized envelope. This vehicle is scaleable and larger models are expected.

The Advanced Technologies Group (ATG) has flown a 1/7-scale model of its hybrid "SkyCat" design that is about 40 percent heavier than air. The SkyCat depends on a pressurized twin hull envelope for structure, and utilizes hovercraft technology for landing, mooring and take-off. When the airship lands, the hovercraft fans are reversed and the skirts serve like suction-cups to hold the vehicle while the cargo is unloaded. This is an important feature for Arctic emergency response because no additional ground-handling infrastructure would be required.

The catamaran design provides aerodynamic lift that enables the SkyCat to fly higher and faster than tradition airships. A unique feature of the SkyCat is a roll-on, roll-off deck for rapid cargo exchange. The first SkyCat, which is designed for 20 tonnes, is scheduled for testing at the end of 2002. ATG proposes two other scaled configurations of this vehicle, carrying 200 and 1,000 tonnes, respectively.

Airships' Roles in Resource Development, Resupply and Emergency Response

Fuel movement in the Arctic presents a hazard to the fragile environment, but the collection and removal of the innumerable empty 45 gallon barrels adds another dimension. For some sites, 75,000 litre "Green Tanks" are a desirable alternative. These tanks are double lined, reducing the risk of leakage. Their larger capacity also results in a substantially lower level of inaccessible wasted fuel left in the "empty" tank than is the case with an equivalent fuel load in 45-gallon drums. However, the 10' diameter "Green Tanks" are 40' long – not a potential cargo for the C130 cargo aircraft. These tanks could quite feasibly be brought in by airship, with a lower environmental risk than that posed by current fuel resupply methods.

Other bulky or heavy materials could be moved to the mine sites via airship, and this movement could take place 12 months of the year, removing or reducing the need to meet Arctic needs in a narrow winter road season or by a single annual sea lift. The need to store up to a year's supply of some materials in the Arctic with the corresponding risk of potential environmental degradation would be eliminated or reduced.

Re-supply of the Arctic endeavours must be reliable and cost-effective. Costs of movement by winter road are significantly higher than for truck freight in the lower latitudes. Calculations based upon some specific truck runs to the northern mine sites place the cost of winter road usage in the Yellowknife area at up to \$.80 or \$.90 per ton-mile. Similarly, airfreight rates that range from \$.50 to \$1.00 per ton-mile for southern routes, are considerably higher in the Arctic.

Cost estimates for operating airships in the Arctic are not readily available at this time, but costs for operating an 800-foot airship between Europe/Asia and North America are estimated at \$.15 and \$.25 cents per ton-mile. Even allowing for a substantial "Arctic Premium", movement by airship would be:

1. very cost-effective,
2. timely, moving at upwards of 100 knots (in a fairly direct route to the site), and
3. available throughout the year.

Many rich ore deposits in the Arctic have not been developed because of financial risk and environmental implications. Airships could overcome both concerns and create a new "foot loose" mining industry. The problem in many locations is that the size of the ore body may not be sufficient to initially justify the construction of a road. A cargo airship could airlift the mining equipment to the site, and bring out concentrated ore. If the mine proves large enough to justify a road, it could be built subsequently. If not, when the mine is depleted, the airship could re-locate the equipment to a new site and repeat the process.

In the case of response to oil spills, airships are also ideally suited. Movement of 10,000 feet of oil-retaining boom (30 to 35 tonnes) would be very feasible. The booms and skimmers could be delivered with pinpoint accuracy, replacing many trips with small, overtaxed aircraft.

Also, delivery of the housing requirements of the clean-up crews could be undertaken by several configurations of the new airship designs. Spacious pre-fabricated accommodations could be in place quickly, allowing the crews to begin work in the early critical stages of a spill.

The current system of floating collapsible bladders to retain the recovered oil is the best choice at present. However, this results in the oil remaining in the spill area till recovered by barge. The ability to move large, leak-resistant tanks to the adjacent shore site could be considered. Oil could be pumped directly to land-based holding tanks, with greater safety and security, and some could be returned as ballast with the airships.

Economic and Operational Case for Airships

The economics of operating airships have been greatly improved. Flying an early Zeppelin airship was labour-intensive; the Hindenburg had a crew of 30. Non-rigid blimps have pioneered computer controlled hydraulic systems to minimize crew numbers (to three) and to enhance control.

Advances in meteorology and weather detection/reporting systems, such as satellites, provide the ability of airships to avoid unfavourable and to exploit favourable conditions. These advances have particular significance in the Arctic, where inaccurate meteorological information can have devastating consequences, even for conventional transportation modes.

The ceiling for large cargo airships is approximately 5,000 feet elevation (the SkyCat will fly at approximately 10,000 feet) and, as such, mountain barriers directly affect airship operational range. The geography of the central Canadian Arctic will provide an expansive unfettered range for airships, and this environment is particularly desirable because airships can carry more weight in the colder (denser) Arctic air masses.

The emerging airship designs are truly multi-use vehicles. As such, they have the potential as well to be very cost-effective vehicles. Holding air cargo vehicles on standby is expensive, but airships should find regular duty in resource development and supply. If so, there will be ample justification for airships to not only be used in the Arctic, but to be based in the Arctic, enhancing their ability to be used in quick response emergency use applications such as environment clean-up and restoration.

Possible Barriers or Concerns

To this point, the potential for new airship designs in the Arctic has been extolled, but all advances have potential risks. First and foremost, of all designs discussed, only the Zeppelin NT is actually fully functional at this time. It is also the least ambitious design, and with its focus on passenger service, it is probably also the design with the least potential in the areas of cargo, re-supply or emergency response. (Its applications for eco-tourism are a different matter). Only the hanger and operational scale model of the Cargolifter has been built, and only a 1/7 scale of the SkyCat has taken to the air. While these designs are expected to be scaleable, the actual products have not appeared as yet.

There is also the legacy of the end of the first generation of airships. While the indelible images of the end of the Hindenburg may be perceived by some to be out of proportion with the actual losses in that event, this is still what many think of when the topic of airships is broached. Even in this paper, we have cited the Hindenburg as a reference point. This barrier, albeit possibly psychological, may handicap investment and development of these new designs.

On a more tangible level, there are operational issues associated with the use of airships in the Arctic. For example, some may question the functionality of airships in the bitter cold of the Arctic. While theoretically the cold, dense air would actually be beneficial to an airship's lift capacity, the effects on the airframe and icing have not been tested to any extent.

Also, the effect of the Arctic winds on airship structure, navigability and the loading/unloading processes is as yet untested. Again, tests at lower latitudes point to greater stability than found with earlier designs, but the Arctic is an unknown.

For the Cargolifter design, ground crews will have to be on-site before the airship arrives. The ground crew will have to prepare the area for arrival of the cargo, and will have to sink four strong anchor points into the ground to facilitate the unloading process. During the unloading process, the Cargolifter will have to take on ballast to offset the loss of up to 165 tonnes of cargo. The source of this ballast may become an issue in the remote Arctic. In mining operations, the return ballast would ideally be ore concentrate or some other appropriate backhaul, but these are issues still to be considered.

The SkyCat is a heavier-than-air design and as such the ballast issue is less of a concern. It also doesn't require a ground crew to prepare anchor points. However, it must land to load or unload cargo. A short "runway" area must be found, and if backhaul is intended, that "runway" must be somewhat longer. Also, while on the ground, the SkyCat's vulnerability to the Arctic wind must be ascertained. The hovercraft landing system to anchor large scale SkyCats is appealing, but at this point, is only a theoretical possibility.

As the new airship designs move into production, other issues or concerns, some unique to the Arctic, may become evident. We will have to wait and see.

Final Comments

Transportation is especially problematic in many parts of the circumpolar area where no roads exist, or the damage caused by road construction (e.g. permafrost regions) is deemed unacceptable. Airships based in the north could provide logistical services to the entire Canadian Arctic and beyond.

In overview, if operational issues for use in the Arctic can be adequately addressed, airships could "level the playing field", providing a general improvement in the comparative advantages of areas with poor conventional transportation systems, or non-existent road links to ports and markets, such as the Arctic. Using airships to open mines in remote and sensitive ecological areas like the high Arctic would provide opportunities for employment and help make the north more economically self-sufficient.

The prospect of using airships to move a significant share of freight in the Arctic is not fanciful. Indeed, it may be almost inevitable. The necessary technologies either are already developed, or are within reach. Cost estimates, assuming existing technologies, indicate that the mode already would be competitive in many situations. As pressures increase to conserve energy and reduce environmental degradation, airships become increasingly attractive.

¹ Further information on these ventures can be obtained at www.cargolifter.com www.zepplin.com and www.airship.com