Transport Innovation Research Paper

The Possible Use of Airships in the Scottish Forest Industries

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A partnership between Forest Industries Development Council and Scottish Enterprise

1. Introduction

The forest industries are of great importance to the Scottish economy. They contribute over £1.3 billion in terms of sales and employ around 44,000 people. Scottish Enterprise and Highlands and Islands Enterprise (the Government's economic development agencies for Scotland) have adopted a Cluster approach to the development of the economy. Scottish Enterprise is actively involved in a wide range of industry clusters from creative industries to financial services and ship building. The cluster approach is about helping groups of industries to overcome barriers to their development and the role of the state is to help in this process in the provision of infrastructure, education and training, etc [12]. In November 2000, Scottish Enterprise and Highlands and Islands Enterprise, working with the forest industries and local government, developed a strategy for the Forest Industries Cluster called "Roots for Growth" [13]. This highlighted the high cost of timber haulage from forest to mill. The strategy identified three key areas for development:

- Market development;
- Innovation; and
- Infrastructure development (including transport issues).

A major study [15] was undertaken in 2001 to highlight the key barriers to timber flows in Northern Britain and to set out measures to address the challenges – including the development of railheads, sea ports and "agreed routes" for timber haulage at the local level. Although there are opportunities for modal shift to sea and rail the absolute volumes of timber moving by road will not reduce.

Innovation is another key strand of Roots for Growth and is applicable not only to products and processes but also to transport systems. Accordingly, the Cluster has undertaken a number of innovative projects by road and rail. These have ranged from an examination of the use of containers in the forest industries through to the development of specialist forest vehicles and assessing the best way of designing forest roads. These studies have been published on the Timber Transport Forum Web Site [16].

The Timber Transport Forum (made of representatives from industry, hauliers, local government and economic development agencies) has overall responsibility for co-ordinating timber transport activities in Scotland. The Timber Transport Forum is serviced by a Timber Transport Logistics Officer. Similar bodies are being set up in other parts of the UK. The Timber Transport Forum expressed an interest in examining the use of airships in a forest application as a research project for 2002/2003. There are remoter areas of Scotland where extraction can be challenging and the Forum were keen to explore other potential methods, including the use of airships. Accordingly, Scottish Enterprise Ayrshire (on behalf of the Timber Transport Forum) commissioned Napier University, Transport Research Institute (TRI) to undertake research in this area. The research was to focus on the use of airships in the Scottish context taking account of current haulage systems and the prevailing Scottish weather conditions.

2. Air transport

Introduction

At present, heavy loads are globally shipped by rail or ocean, then on special trucks or other means of transport to destination. An alternative is an oversized aircraft such as the Ukrainian Antonov AN124 [4]. Not only does the AN124 afford a huge payload but also both ends of the aircraft can be accessed via the folddown hydraulic ramps, offering full roll on - roll off facilities. Front end loading is further eased by the large flip-up nose-door, and the plane's unique ability to 'kneel' on its front undercarriage whereby the front ramp rises at a mere 8º to the ground. Internally the aircraft is fitted with two 10 tons overhead cranes and two further cranes and can give a lifting capacity of up to 37 tons. Two onboard winches deal with the final positioning of heavy loads without the need for specialised airport ground handling equipment. The Antonovs are the biggest aircraft in the world but need 4,000 metres of runway to get airborne. This is a valid system in Russia but may be not in the UK.

Airships

An airship is, basically, a power driven envelope (balloon-like bag of gas), lift is afforded by the lighter than air gas in the balloon and by dynamic lift due to the movement through the air. Normally, the envelope lasts up to 10 years occasionally being refilled if there is some leakage. Most large modern airships divide the envelope into three main components – two are filled with air (called "ballonets") and a large one filled with helium (derived from natural gas). This is a very light, inert and non-flammable gas. Helium is a lot safer then hydrogen, but has 8% less lifting power and costs about eight times more then hydrogen. Some airships use a metal "skeleton" or frame inside the envelope to give shape to the ship; these were called **rigid** airships. **Non-rigid** airships (or "blimps") use no frame inside, but keep their shape by virtue of the design of the envelope and the gas pressure. This allows for great flexibility in the envelope, which can more easily absorb stresses – bending and flexing, during flight and landing in all sort of weather. **Semi-rigid** airships are like a non-rigid with a "keel" along the bottom of the envelope to help spread the load of the cabin (or gondola) more evenly through the envelope. Due to strong, lightweight materials for envelopes and gondolas developed since the 1970's, virtually all airships today are non-rigid (see also [3]).

Some History

Before the Hindenberg disaster at Lakehurst, New Jersey in 1937, airships had decades of success in carrying freight and passengers between many cities of Europe. In 1928 the airship Graf Zeppelin made the first cross-Atlantic trip carrying 12 tons of freight and 60 passengers and crew and later, in 1929, it flew around the world in 21 days, making only three stops. Altogether the Graf Zeppelin made 650 flights, covering about 1 million miles and carried more than 18 thousand passengers. Over a period of 40 years Germany built 118 dirigibles which flew without an accident due to fire until the Hindenberg disaster. Germany used flammable hydrogen instead of non-flammable helium as a lifting agent. On May 6, 1937, the airship caught fire while landing at Lakehurst, killing 36 of the 97 people on board. The tragedy was captured as it happened by the US media and reverberated around the world (see video at [17]). Due to the public's perception of airships as being dangerous, airships disappeared as a serious commercial proposal, especially in light of aircraft development during and after World War 2.

Modern Airships

Nowadays the airships are used in many countries around the world (see [2] for the main manufacture, operators and services of airships) for commercial advertising, military and government applications, television coverage of outdoor events, environmental monitoring or air or water pollution, scientific missions, surveillance, etc., but there are no current examples of heavy industrial use. Thus for example, Airship Management Services, Inc. (USA) [3] has been actively involved in the sale and operation of airships for various applications beyond promotion and advertisement, from government contract work for the USA Department of Defence to research applications for private institutions, including:

- Use by Woods Hole Oceanographic Institute for marine mammal research;
- Use by Secret Service during World Cup Soccer 1994;
- Use by Atlanta Police Department during Atlanta Olympics 1996 (see Figure 1);
- Lockheed Martin testing of communications equipment in 1996.

Figure 1. Use of Airship by Atlanta Police Department. Picture of Airship Management Services, Inc., [3].

CargoLifter AG: Introduction and Technical specifications

CargoLifter AG [5], established in 1996 by Dr Carl von Gablenz, is designing a new transportation system that will use the latest generation of airships to carry cargo from point-to-point around the world. At 265m long and 65 metres in diameter, the CL160 airship (see Figure 2) will be able to carry a 160 tons payload and will be one of the largest airships ever built. By way of comparison, a Boeing 747 freighter is 70 metres long and can carry 124 tons. The Ukrainian Antonov An-124, frequently chartered by western companies for outsize loads, is 69 metres long and has carried up to 143 tons of cargo. Obviously, both aircraft fly much faster than the proposed airship, but they also need long runway and associated airport infrastructure, while the CL 160, by contrast, will require only an open area the size of a soccer field typically 110m by 73m on which four mooring points can be set up.

While the CL 160 will resemble its dirigible ancestors, the airship will feature a semi-rigid design, including rigid keel, and a compartmentalized envelope filled with non-flammable helium gas. An airplane that is heavier than air requires energy for both propulsion as well as for creating lift. The CargoLifter will stay in the air even when the engines are turned off. Initially power will be from low-revolution diesel engines, whose exhaust will be recycled on board to yield water for ballast, but future plans envisage using solar power for propulsion. The airship will not be much of a free ride, with one estimate of the helium cost put at $2.5m to fill the CL 160. The airship is expected to

cruise at 80-100 kilometres per hour, at altitudes of 2,000 metres or less. Staged ascents to height over 2,000 meters can be made by regulating the airship's helium volume.

Figure 2. The model of the CL 160 airship. Picture of CargoLifter, Inc. [5].

It will have digital controls for its engines, aerodynamic control surfaces, manoeuvring fans and load exchange systems. Its ultimate purpose is to lift heavy or outsized loads from the point of production to delivery site. By using a uniquely designed crane system, the CL 160 should be able to load and unload cargo while hovering at about 100 metres. The load will be lifted and lowered via anchor winches and four anchoring points. In order for the total weight and flight characteristics of the airship to remain constant, the freight will be exchanged with ballast water. CargoLifter says that it is aiming for the cargo unloading cycle to be completed within two hours. This opens up the possibility of transporting heavy or oversize cargoes, in one swift movement, from original place of manufacture to eventual destination, and even final positioning, to almost any location in the world, irrespective of the local infrastructure such as roads and airports. Dr von Gablenz stated: "Unlike fixed-wing aircraft, there is no need for runways, so basically all we need is a large clearing".

Joey

Cargolifter's experimental airship, dubbed "Joey", made its first flight on 20 October, 1999, from the company's base at Brand, near Berlin, Germany. It has a mass of only 1 ton and with a length of 32 m., it is one-eighth of the projected CL160 airship. The experimental airship is fitted with a keel made of carbon-fibre structural components and a tail unit. Despite Joey's relatively small volume, it is a fully functioning airship. The gondola has enough space for two people, making it possible to test the overall concept and check calculations with real-life experience. The flight and load tests with Joey provided basic knowledge for further development of the CL 160.

Ground Facilities

It is one thing to have a 160-ton-capacity airship. It is another to find a place to keep it! The company recently completed what's described as the world's largest self-supporting hangar for airships near Berlin. Without support walls or any other supporting structures, the construction encloses 5.5 million cubic metres of space, which offers enough space for nine soccer fields.

Because an airship with an average speed of 90 km/h is fairly slow the pilot has to get used to the fact that relatively short distances are covered in quite a long time. An airship also reacts very slowly to steering manoeuvres, and so the pilot will need to think ahead and to respond quickly. To cope with flight times of days rather than hours, the

captain and crew of up to 12 will work shifts. Cabins with berths will be provided for crew members to sleep between duty periods.

Figure 3. CargoLifter Experimental Airship "Joey". Picture of CargoLifter, Inc. [5].

For location selection, key factors need to be considered:

- existing heavy load freight traffic;
- future freight traffic trends;
- connections with other carriers e.g. inland and maritime vessels;
- meteorological conditions;
- economic and political conditions.

CargoLifter believes that in the future airships will be able to transport payloads of up to 450 tons. The potential demand of airship's services is huge. Independent studies, carried out by few universities in Germany, have made a thorough analysis of the market potential. And the results are astounding: starting from current transport volumes, some 30 million tons of freight a year can be earmarked as a relevant market for CargoLifter.

3. Cargo-carrying balloons

CargoLifter, Inc [5] successfully tested its helium-inflated cargo-carrying the CL75 AC airship in Germany last year. The craft consists of a 61-metres helium-inflated balloon and multi-purpose load frame suspended with a cable system underneath to carry cargo. This is a massive balloon with a lifting capability of 75 tons. It was originally conceived to carry out tests for the CL 160. However, the transportation balloon has developed into a separate product line itself in cooperation with various partner companies and under the project management of the American subsidiary CargoLifter, Inc.

The transportation balloon uses the following principle. A suspended load becomes "neutrally buoyant" as a result of its being filled with helium. As a result, the weight of the payload in the loadframe is compensated by the ascending force of the buoyant gas in the balloon. The loadframe is on the ground for loading or unloading and the balloon of the AirCrane is held by ropes and winches. The balloon then hovers at a height of about 25 metres above ground; the loadframe is moved via rope winches from the ground. The loadframe of the CL 75AC is 14 metres long, 10 metres wide and 8 metres

high. The freight can be up to 13x6x6 metres in volume, which is enough for 40' containers which can weight up to 75 tons. The transportation speed of the AirCrane is up to 70 kilometres per hour depending on the transportation mode. In opposition to the CL160, the CL 75 AirCrane does not have its own propulsion system. As mobile crane system it can be brought to the place of utilization and used there in a stationary position. For use as a means of transportation, it is towed to its destination by a vehicle on the ground, by a ship or helicopter.

Figure 4. CargoLifter the CL 75 balloon and the hangar. Picture of CargoLifter, Inc. [5], [7].

The transportation balloon is suitable [5] as

- hyper construction crane;
- transportation and erection system for large-volume construction elements;
- provisional bridge for the quick reconstruction of infrastructures;
- supply unit for distant areas, difficult co access;
- mobile receiving and transmitting platform for major events, etc.

Only one balloon of this type has been built and it was sold for US$10 million to an oil and gas exploration company working in the Mackenzie delta in Canada's far north and can be used either as a simple crane, controlled by mobile winching systems on the ground, or as a load-reliever or land vehicles carrying heavy drilling equipment. By towing the balloon above them, trucks could operate on remote roads for which they would be too heavy without the CL75 bearing a high proportion of their laden weight. Because the CL75 is a balloon, not an aircraft, it does not need licensed pilots who have to be trained, and no certification as an aircraft, so it can be brought into operation much sooner.

4. CargoLifter: financial problems

Now CargoLifter is in a race against time to secure funding for its ambitious project as hopes for the development of the world's largest airship seem less and less likely to take off. The company, always a high-risk venture capital investment, now has financial challenges to manage. The future economic success and competitive advantage of the CL 75AC and CL 160 over conventional transport services with regard to time, costs and performance quality will not become evident until the start of commercial use.

Financing risks are influenced not only by capital markets but also by the influence of sticking to cost and time schedules.

Initially the company planned to go into serial production from 2004, turning out four CargoLifters annually – until by 2015 a fleet of 50 zeppelins would be transporting goods around the world. But the launch date of the first CL 160 has already been pushed back until the spring of 2005 - two years later than mooted at CargoLifter's initial public offering in 2000 – and cash flow break-even is now not expected until 2006-7. According to the company's own estimates, total costs until the start of production were last estimated to be at least €720m, (meaning the company would still need to raise an additional €420m), while an additional €370m will be needed later to start production.

On the 1st of August, 2002, at the Cottbus Municipal Court, Germany, insolvency proceedings were opened on CargoLifter AG and six subsidiaries. Neither potential customers nor other aerospace companies want to see the project fail, but potential strategic partners are keen to see more proof of its technical and business feasibility. A sign of faith it may be, but it is not the large-scale source of financing that CargoLifter urgently needs if the airships are to take off on their oft-delayed but eagerly awaited flights.

5. Air Transport: Forest Applications

Helicopters

Helicopters are often used in the forest Industry for highly technical operations. An example of increasing complexity and efficiency is the use of satellite navigation for the spreading of granular fertiliser with great precision. The spreading is controlled by ground and airborne computers and the results are recorded on a post flight map. Another example is the use of helicopters to remove timber from inaccessible places.

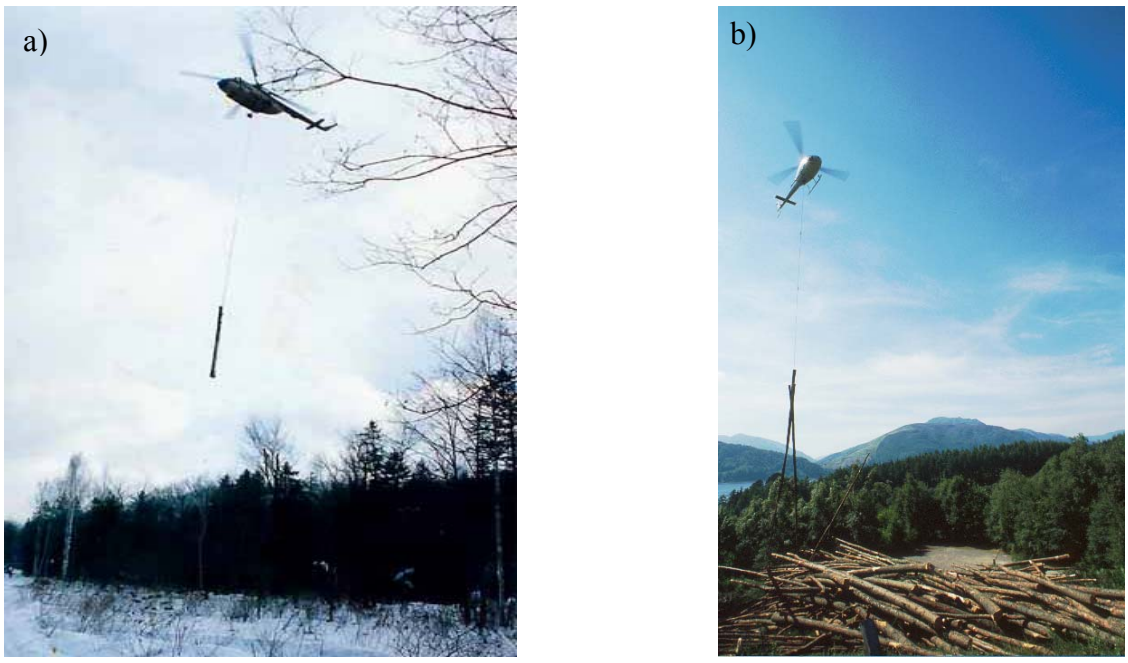

Figure 5. Helicopter extraction a) in Russia [1] and b) in the UK [11].

Helicopter extraction has become an option in the UK for best maintaining the surrounding environment. The technology deals with a lot of the disadvantages of

traditional extraction methods but it is very expensive and insecure. Another approach is to use cable extraction systems or aerostatic airborne vehicles. Comparison of various systems for mountain wood harvesting can be found in [1].

Balloons.

Nowadays, when the ecological demands in forests are becoming very important and the timber industry demands immediate productivity, the aerostat technology may play an important and constructive role in the forest industry. Balloons used for extraction are a lift-augmented skyline system most appropriate for downhill extraction [1]. The balloons are used to lift the logs free of the ground, while the cable system restrains and transports the turn. Logs can be flown completely clear of the ground with a minimum of site disturbance.

According to estimates [1] of the Far-Eastern Aerostatic Centre 'AEROS', Khabarovsk, Russia, the use of helicopters for timber harvesting makes the prime cost of timber uneconomic as the cost of helicopter extraction is $25-$35 per cubic metre of timber. The cost of extraction by using their aerostat-balloon technology is $2.5-$4.5 per cubic metre.

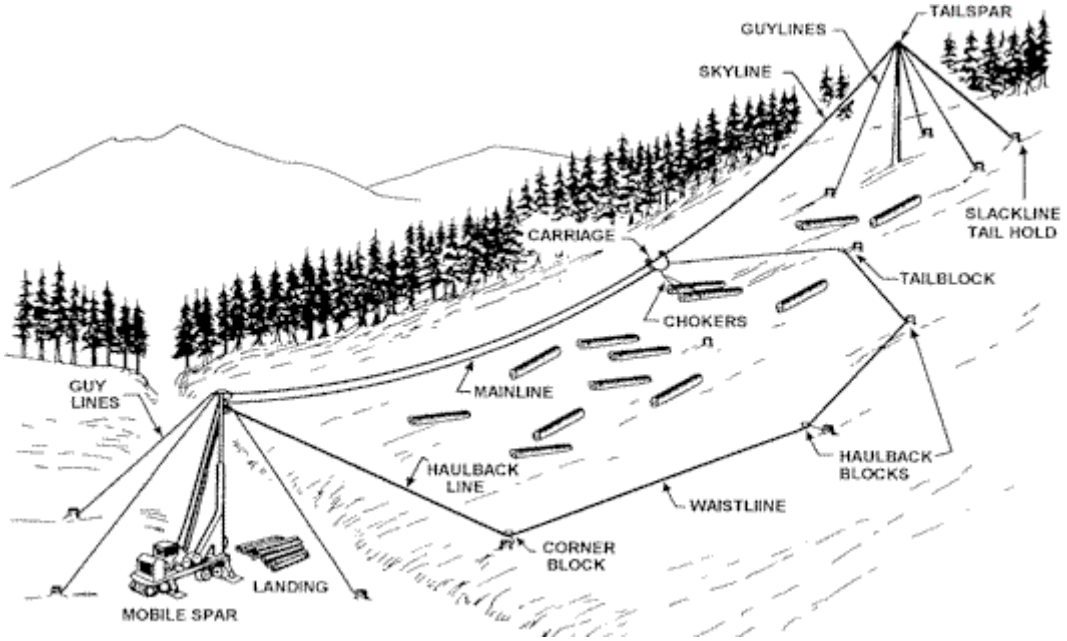

Figure 6. Example of a slack line system used in Scotland. Picture from [9].

Balloon extraction systems developed by the Far-Eastern Aerostatic Centre 'AEROS' have a maximum extraction distance of about 1.5 km, which reduces the road requirements significantly over many skyline systems (see Figure 6). Moreover, it is possible to use chain balloon extraction system containing two or more units working in one line in to extend extraction distance up to 7-10 km. Long slopes that would be difficult to log and would require expensive mid-slope roads for conventional skyline extraction are suitable for balloons. Logs can be extracted both downhill and uphill. With such flexibility the gradient of a slope is not critical. Timber can also be extracted from behind hills or from a hollow. Using AEROS's balloon extraction systems it is possible to carry out loading of timber into barges from unprepared places, where no moorings are

available. All this demonstrates state of the art technology and high versatility of the system.

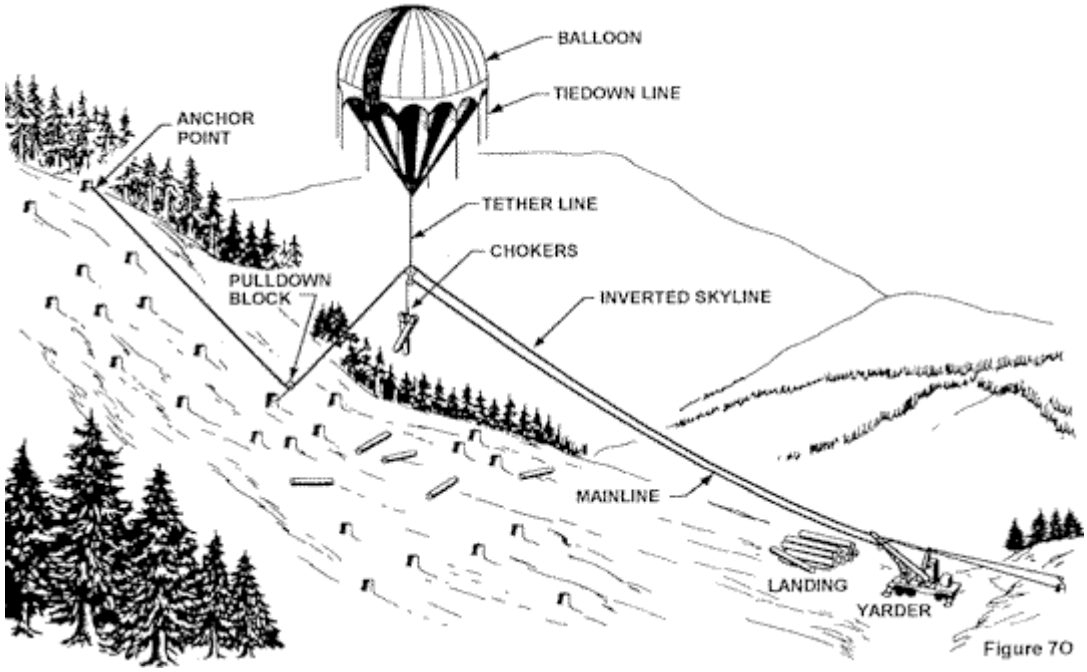

Figure 7. Balloon Extraction – Haulback Configuration. Picture from [9].

The main part of the system is a balloon or aerostat whose payload depends mainly on the logged stand. Circled cables-and-blocks system driven by two single-drum winches enables the balloon to change its position over ground at an altitude up to 500 metres and at a distance up to 2 km. A variant of use of the balloon extraction system is shown in Figure 7.

Cable unreeling over a piece of woodland is achieved with the help of an auxiliary cable (5-6 mm) by an auxiliary winch. The work of fellers, choker men and machine operators is coordinated by wireless radio. During moving the balloon in a certain direction one winch reels in while the other reels out the cable. When the set-point is reached by the balloon both winches reel in the cable pulling the balloon towards the ground lowering it 50-70 metres. After choking is completed the winch brakes are released and the balloon lifts the wood bunch up to 100-150 metres. Afterwards, the balloon with the load is moved to the landing. After finishing work at one location, the system with the help of a winch moves to another. Unfortunately, weather conditions play a critical role in balloon extraction. Balloons may work in a wind blowing at speeds up to 15 m/sec, while parking near the ground permissible wind cannot exceed 25 m/sec [1]. Rain, snow, temperature and elevation can have an effect on the balloon's performance, as well. A description of different balloon cable extraction systems can be seen in [1]. To further improve the current balloon extraction systems, CargoLifter's CL 75 balloons could be used but it will increase the cost significantly.

6. Weather influence on airships and balloons

Like any aircraft, the airship is affected by weather and weather conditions are vital for planning the future airships' routes. By creating flight climate maps, seasonal weather changes are recorded in order to guarantee optimal routes. The climate in Scotland is

particularly variable and flight interruptions would be more than likely due to weather influences. CargoLifter is continuing to conduct research with the experimental airship “Joey”, the training airship “Charly” and the CL 75 AC, and to carry out computer simulations.

CargoLifter says simply that the CL 160 will firstly try to avoid major weather systems such as storms. If they are unavoidable, the airship will take a course similar to that of a sailing ship, ‘tacking’ to take advantage of the wind direction. Delays of a few hours tend not to be significant in the type of mission foreseen for the CL160, says the company. A crucial part of work in progress on the airships is an investigation of the effect of, and ways to prevent, lightning strikes.

The airship’s behaviour when entering and exiting the hangar might cause problems in the event of crosswinds. As these procedures rarely occur, they can only be carried out if there is little or no wind. In order to further minimize risk, CargoLifter in cooperation with the Technical University of Dresden is conducting a series of wind tunnel tests on a model to test the interaction between the hangar, the airship and wind patterns.

Another risk is affected by technical problems since “combining an airship with a crane constitutes an enormous technical challenge which has so far not been tested in practice” [7]. Different technical problems may arise in the interaction of the components with regard to loading and unloading cargo. CargoLifter designed ballast tanks that can be pumped with up to 160 tons of water as the unloading progresses. But that assumes that 160 tons of water are available, which may not be the case in the Siberian tundra or the Sahara, but should not be a particular problem for Scotland.

7. Scottish weather

Scotland is surrounded by water on three sides. To the west and north is the Atlantic Ocean, and to the east is the North Sea. The eastern coast is often drier and cooler than the western, but the weather everywhere is highly variable, changing by the mile and the minute, as well as by the altitude. In the sunniest parts of Scotland (for example Angus, Fife and the Lothians,) there is an average of 1,400 hours of sunshine each year. Even in the mountain regions of the Highlands there are over 1,000 hours of sunshine a year. Average summer highs are about 19 degrees and winter temperatures rarely drop below 0 degrees at sea level. [14].

Scotland enjoys very good visibility. When poor visibility occurs at places on or near the east coast of Scotland the cause is usually a sea fog from the North Sea. In certain weather situations the cloud base can be quite low with all high ground being shrouded in cloud. The resulting hill fog can give very low visibilities which are a potential hazard for airships.

Prevailing winds are from the west or southwest, and annual rainfall ranges from over 60 inches in the west to less than 20 inches in the east. The winter months are usually the wettest but sometimes there is also heavy rainfall in late summer. The western Highlands of Scotland, facing the prevailing westerly winds from the Atlantic, are the wettest parts of Scotland with over 3000mm or 118 inches of rain a year (and some rain falling on over 250 days each year). By contrast, the east coast and the Moray Firth area in particular, has the lowest rainfall - less than 650mm (26 inches) [14].

The frequency of summer thunderstorms and hail in Scotland is low, and significantly less than that in much of England. For instance, on average, Edinburgh have about 7 days per year with thunder while many places in England have an annual average of 15 to 20 days. Along the coastline of the Moray Firth the average is only 3 or 4 days per year [14].

The frequency of strong winds and gales is higher in Scotland than in England and Wales. Nevertheless, the windiest arrears are the Western Isles, the north-west coast, Orkney and Shetland, which all lie at a considerable distance from the main centres of population. The highest frequency of gales occurs during the winter months and prolonged spells of strong winds are unusual between May and August. A 'day with gale' is defined as one on which the mean wind at the standard measuring height of 10m above ground attains a value of 34 knots (17.2 metres per second) or more over any period of 10 minutes during the 24 hours.

Not only the strength of the wind show a strong seasonal variation, but also the relative frequency of winds from different directions. The highest gust recorded at a low-level site was 123 knots (63 metres per second) at Fraserburgh (Grampian, 18m) on 13 February 1989. The highest gust recorded at a high-level site was 150 knots (77 metres per second) at Cairngorm Automatic Weather Station (Grampian, 1245m) on 20 March 1986 [14].

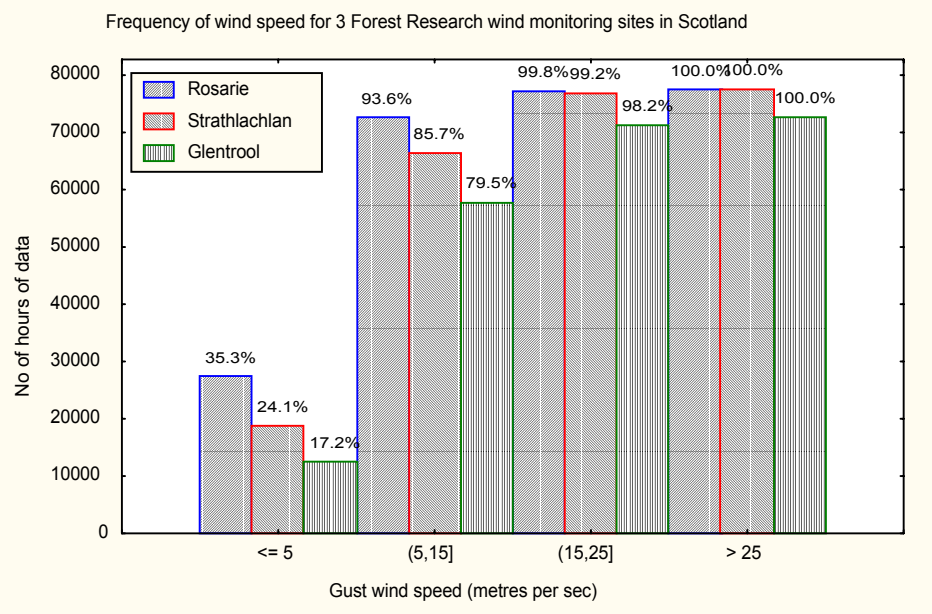

Figure 8. Cumulative frequency of hours with gust wind speeds measured at 10m above the ground on an open site. Rosarie – 320m hill top near Elgin, Strathlachlan – 370 m hill top near Strachur, Glentrool – 420m hill top near Barrhill.

Figure 8 and Figure 9 show the cumulative frequency of hours with gust wind speeds of less than 5m/s, 5-15 m/s, 15-25 m/s and more than 25 m/s measured at 10 m above the ground on an open site (Figure 8) and the estimated data for wind speeds between 10m and 100m above the ground calculated under assumption of 1.6 increase in wind speed. Rosarie is a 320m hill top near Elgin, Strathlachlan is a 370 m hill top near Strachur, Glentrool is a 420m hill top near Barrhill. Y-axis gives number of observation, which vary between sites, hence apparent difference for columns of 100%. These wind speeds are representatives of moderate to high exposed sites in upland Scotland. Valley locations may be significantly more sheltered, except where funnelling of the

wind occurs. Further data exists and could be extracted to analyse this. Once a clearer view is obtained, the DAMS[1] wind scoring system could be used to assess suitability for the entire forest area of Scotland.

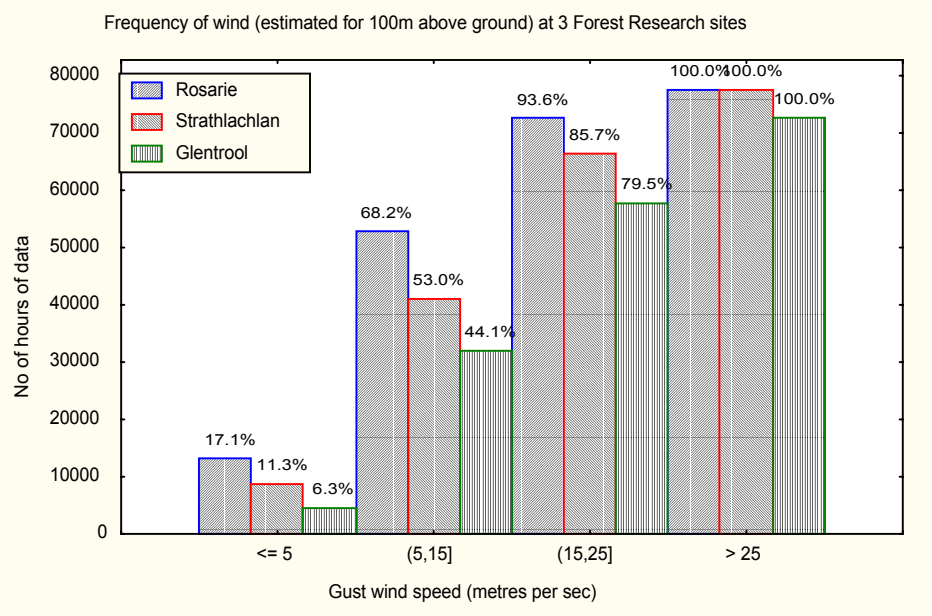

Figure 9. Cumulative frequency of estimated hours with gust wind speeds between 10m and 100m above ground. Rosarie – 320m hill top near Elgin, Strathlachlan – 370 m hill top near Strachur, Glentrool – 420m hill top near Barrhill.

The graphs show that between 79.5% and 93.6% of the time the wind is at, or below 15m/s at 10m above the ground. This drops to between 44.1% and 68.2% for 100m above the ground. This is probably a reasonable result but would need further analysis of the data to give a comprehensive picture of possible use of balloon extraction systems in Scotland [10].

8. Conclusions

In certain conditions due to the cargo size or geographical features of the route, the infrastructure such as roads, tunnels, and bridges is not capable of handling the transport of heavy cargo. CargoLifter aims to overcome this problem by using heavy lift airships. Transporting heavy loads between continents used to take weeks, but such operations could be accomplished by the CargoLifter in a matter of days. If the CL 160 airship is constructed, it will offer to the Timber Industry many advantages over other transportation modes because it can unload freight without landing, meaning there is no need for runway and no need to transfer the cargo from one mode, such as train or plane or ship, to another mode, such as truck. CargoLifter says its system will allow reductions in total cost and transit times for heavy cargo. The main drawback is the potential costs of the CargoLifter system.

The main conclusions of the research are as follows:

- Using balloon extraction systems (specification similar to the systems developed by Far-Eastern Aerostatic Centre 'AEROS', Khabarovsk, Russia) extends the range of

[1] Detailed Aspect Method of Scoring

the existing UK cable extraction systems and minimise environmental damage. Although initial cost estimates are favourable, further research is required on this.
- UK weather patterns are changing and further research will be required in this area, although it will be possible to use balloon extraction systems most time of the year.
- The proposed airships are technically useful but prohibitive in terms of cost.
- It would be possible to use the CarfoLifter CL160 balloons but this would be expensive.
- The balloon extraction system has applications across a wide range of industries where transport has environmental impact.

Recommendation

- The Cluster consider further investigations of the balloon extraction system detailed in the paper in conjunction with possible international partners in Russia and the USA, as the basis for a demonstration project. Scottish Development International (SDI) (which has offices in Russia and the USA) would be willing to facilitate any joint working between Scotland and Russia or the USA.

9. Acknowledgments

The author would like to thank David Killer, Head of Forestry Civil Engineering and Steven Paxton, Scottish Enterprise Ayrshire for valuable advice during the work on this project and Dr Chris P.Quine, Forestry Commission for kindly providing wind speed data from forest research relevant to balloon extraction systems. I also would like to thank Prof. Mike Maher and Dr Allan Woodburn from Napier University, Edinburgh, for their helpful comments on an earlier draft of this paper.

10. References

1. Abusov, A. *Necessity of using aerostats and balloons for logging.* Far-Eastern Aerostatic Centre 'AEROS' . http://www.users.globalnet.co.uk/~chegeo/aeros-eng.htm
2. Airship Association http://homepage.ntlworld.com/michael.rentell/net.html
3. Airship Management Services, Inc. http://www.airshipman.comcargolifter.com
4. G.A. Massey. *Blame it on the Antonov.* http://www.btinternet.com/~guymassey/GuyMassey/antonov.htm
5. CargoLifter, Inc, Web Site http://www.cargolifter.com
6. CargoLifter Annual Report 1999/2000. http://www.cargolifter.com
7. CargoLifter Annual Report 2000/2001. http://www.cargolifter.com
8. CargoLifter Quarterly Report 2001/2002. http://www.cargolifter.com
9. Examples of Cable Yarding Systems. *http://www.osha-slc.gov/SLTC/logging_advisor/manual/yarding/cableyardingsystem.html*
10. Forest Gales. http://www.forestry.gov.uk/forestry/hcou-4u4j3f
11. Forest Life Picture Library http://www.forestry.gov.uk/forestry/hcou-4ubjbw
12. Porter, M. *The Competitive Advantage of Nations.* New York: Basic Books, 1990.
13. *Roots for growth.* Working document. Scottish Forest Industries Cluster. http://www.forestryscotland.com/pages/publications.asp
14. *The Climate of Scotland: Some facts and Figures*. Great Britain. Meteorological Office. London: H.M.S.O. 1989, 22p.

15. *The Scottish Forest Products Transport Mapping Study*. Scottish Forest Industries Cluster. http://www.forestryscotland.com/pages/publications.asp
16. Timber Transport Forum Web Site. http://www.forestryscotland.com/timber_transport
17. Vidicom Media Productions Web Site http://www.vidicom-tv.com/tohiburg.htm
18. *World's biggest blimps set sail soon.* USA Today, May 31, 2000. http://www.cargolifter.com