Global Trade of Perishables in the 21st Century: The Case for Giant Airships

Barry E. Prentice, Transport Institute, University of Manitoba, Richard P. Beilock, University of Florida, and Alfred J. Phillips, Transport Institute, University of Manitoba

The 12 second flight of the world's first heavier-than-air powered vehicle in 1904 heralded the birth of a new transport mode. In the days, months, and years following that event, it must have been evident that airplanes had a future, but not its shape and extent. The first propeller driven airship was flown 50 years earlier than the Wright Brothers airplane in 1852[i]. A century and a half later, we may be about to witness the birth, or rebirth, of airships as a transport mode.

For airships, it is not like the day after Kitty Hawk, but it almost could be. Except infrequently as billboards, camera platforms and novelty tours, commercial uses for large airships ended with the Hindenburg disaster, three quarters of a century earlier. For decades, the memory of the Hindenburg catastrophe, as well as technological advances in heavier-than-air flight, trucking, and maritime transport conspired to make the airship seem a slow, cumbersome, and ultimately tragic detour in the history of transportation. More recently, however, interest has been renewed in airships due to technological developments in a number of fields; including materials science, engines, weather forecasting, avionics and computer assisted design. With improved performance and cost profiles, airships are being considered now for new roles in the movement of general freight, fluids, indivisible loads, perishable food products and passengers[ii].

Interest in airships has been heightened by their indirect advantages. These vehicles could mitigate several negative externalities associated with other forms of transport. Concerns about port, road, and airport congestion, and evidence of climate change have caused the economically advanced nations to reconsider their transportation systems. As most industrial countries are net importers of petroleum, the inherent fuel efficiency of airships is a further economic incentive. Consequently, many nations are taking a hard second look at airship technology.

Over the last 30 years, airship technology has gained a large and loyal following. At the time of this writing, at least a dozen firms in ten different countries are developing research prototypes and commercial airships. In addition, the U.S. Department of Defense has issued a request for information (DARPA, 2004) for development of an airship capable of carrying very large and/or heavy cargoes and personnel.

The creation of a new mode of transport can have unpredictable economic effects. Improved service and lower transportation costs can stimulate new commodity flows, industrial activity and trade routes. In this paper, we consider the business case for using airships to transport Hawaiian pineapple/papaya to the U.S. mainland. The inherent strengths and weaknesses of airships, relative to other modes, are examined with a particular view toward exploring this possible early application of long-distance transport. On a more general level, it is hoped that this paper will stimulate thought and discussion about the potential for airships to create a paradigm shift in freight and passenger transportation.

Global Food Trade and Transportation

The history of global food distribution is punctuated by turning point developments in transportation and storage technology. The spice market was first to attain global dimensions. The improvement of sailing ships over camel caravans opened up the spice trade between Europe to East Asia.[iii] Two hundred years later, the advent of steam power enabled marine transport to link the continents together and form a global grain market. Subsequently, the development of freight railways and mechanical refrigeration enabled markets for frozen meats and dairy products to become globally traded.

As ships became faster, refrigerated transport connected international markets for storable temperate zone fruits and vegetables, like apples and potatoes. The first tropical fruit that gained a global market was bananas.

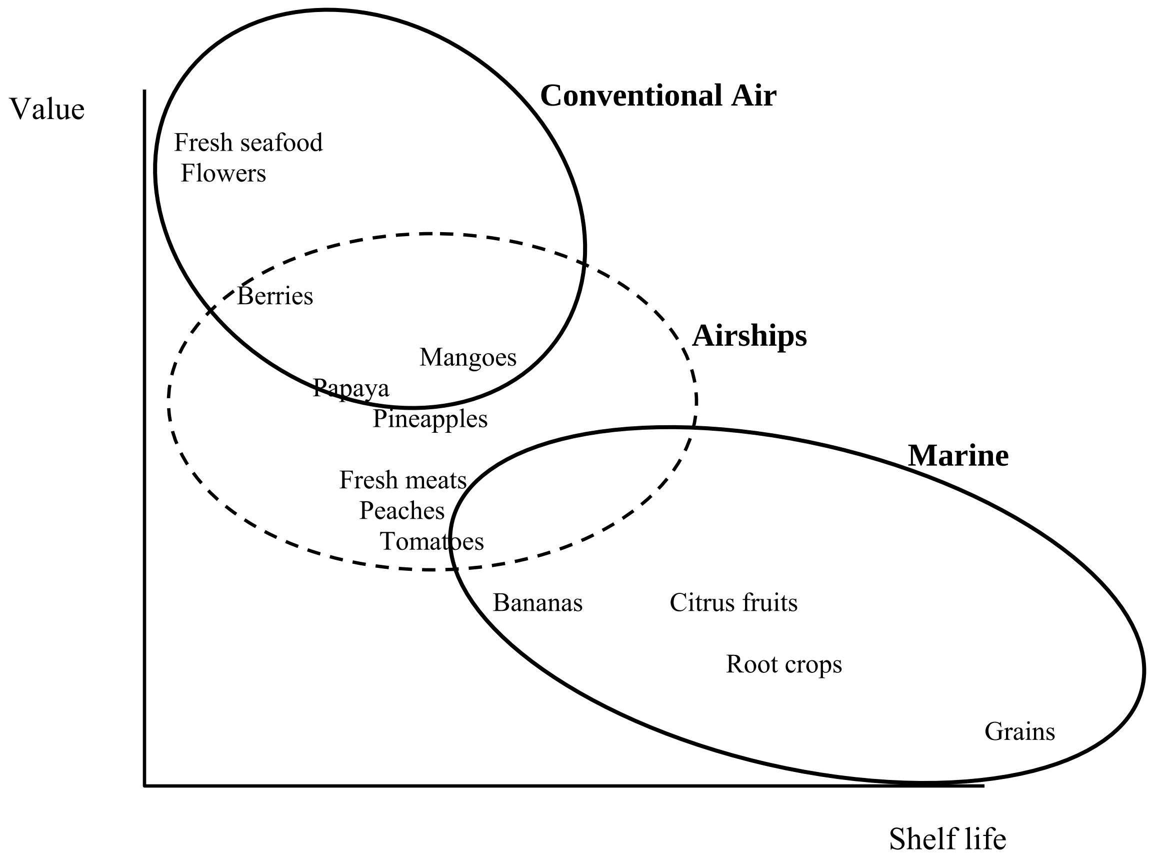
Airplanes are responsible for the latest integration of world markets for food and perishables. Airfreight of perishables is important in some long-distance markets, such as intercontinental movements of fresh flowers, seafood and some higher value tropical fruits. However, the absolute volumes of air shipments of perishables are small, relative to world production. The world trade of perishables is reminiscent of the spice trade when the relatively expensive camel caravans were the only means of transport. A latent demand for high quality perishables far exceeds the effective demand for the quantity supplied at the current price.

The failure of the airplane to have more than marginal impacts on perishables transported is reflected dramatically in the modal split of produce movements within the U.S. Despite the very long distances produce is frequently moved within the U.S., less than one quarter of one percent is by air (USDA, 2003). Over half of what is shipped by air is from an origin having no truck or rail alternatives, Hawaii. But even for Hawaii, less than half of its produce shipments to the mainland are by air.

Airships have the potential of improving the market share of air transport in existing produce markets and expanding the range of products and markets for which air transport is used to ship produce. Figure 1 illustrates the general relationship between product values and shelf life, and identifies the principal transport mode for intercontinental trade. As is well-known, highly valued and perishable goods, such as flowers and fresh seafood [and people], are the near-exclusive province of conventional air transport, while goods at the other end of the spectrum, such as grains, slowly and cheaply ply their way between the world's land masses in ships. Goods in the middle, such as fresh meats and medium valued tropical fruits, may be carried by either mode, if at all. Airships (dashed circle) could split the difference. While slower than conventional air, airships would be three to five times faster than marine transport with freight rates somewhere between air cargo and intermodal ocean container shipment.

Considerable uncertainties remain regarding the cost of operating airships, but it appears clear that large airships could be profitable, offering rates above those typical for marine transport, but well below those of conventional air. As such, airships could greatly expand long distance trade of mid-range value/perishability goods. Moreover, except over extremely long distances, such as Australia to Europe, airships would also be attractive for high value/perishability goods.

Figure 1: Value, Shelf Life, and Dominant Transport Modes in Intercontinental Movements of Foodstuffs and Ornamentals



Inherent Advantages and Disadvantages of Airships

Each mode of transport has unique strengths and weaknesses, in terms of total logistics costs and service. These advantages tend to dictate their uses (ships—big volume, slow, cheap; air – low capacity, fast, costly; etc.). Airships can travel relatively fast (100 mph) and have sufficient endurance for long trans-oceanic flights. They are ideally suited for bulky low value cargo like lettuce or green peppers because they are limited only by the weight of fuel and cargo. As huge displacement vehicles with static lift provided by Helium gas, airships can have voluminous cargo holds.

Like all modes of transport, airships have to trade off cargo payload against vehicle range, speed and capital costs. The data necessary to quantify the optimum vehicle and operating characteristics for specific markets is beyond the scope of this paper. Rather, these will be considered conceptually.

Speed

Conventional air transport is the greyhound of intercontinental commerce. Its great speeds are purchased in terms of extremely limited cargo capacities and very high costs per unit weight. The plodding ox is marine transport. Despite technological advances, even the fastest container ship operates between 20 and 30 mph (e.g., see Lloyd's Register), far slower than the average speeds of any other mode. The saving graces of marine transport are high capacity, long range, and low cost per unit weight. As noted earlier, if both perishability and value are very high, conventional air transport dominates. When the reverse is true, marine transport is ideal. But most goods are not at the extremes of value and perishability. Over distances required for intercontinental trade, neither the cost premiums required for conventional air nor the very slow speeds of marine transport may be attractive. It is here that airships have the greatest potential.

Being lighter than air, fuel consumption is required only for forward motion of airships. As with all transport modes, fuel consumption per unit distance is an increasing function of speed. At a cruising speed of 50 mph, an airship could travel approximately twice the distance without refueling that it could if it were flying at 100 mph. Alternatively, more freight could be carried at a slower cruising speed because less fuel is consumed.[iv]

On the cost side, the advantage of going faster is an increase in vehicle utilization and reduced crew costs. The return on capital is determined by the number of revenue ton-miles per year. If the airship travels faster, the fixed costs of the airship are spread over more trips. To the extent that cargoes are time sensitive, speed can also be rewarded through rate enhancements. So, not only are fixed costs spread over more trips, each trip garners more revenue than would be the case with lower speeds.

Adding to the complexity of the optimal cruising speed for an airship is weather conditions. A strong head wind, or tail wind, could make a significant difference to the time of the voyage. A zero-sum "wind" game could be expected on single route, but with good information and experienced pilots, the wind could be managed to advantage[v].

Little impact from topography

Relative to other modes, airships have a comparative advantage when operating across rougher terrains with less developed surface transport infrastructures,[vi] and where inter-modal transfers occur. Physical barriers of topography impose few limitations on airships, which do not require lengthy landing facilities. Airships can travel over land or sea, and can thrive in tropical or frigid air masses. Consequently, they can serve remote road-less land-masses or island archipelagoes equally well as the more developed and populated, contiguous areas.

Transfers associated with ocean-land boundaries can be over flown and intermodal transshipments can be performed with minimal infrastructure. This could reduce the numbers of such transfers in a point-to-point movement and, as the location of transfers are not tied to geographic features, such as coastlines, allow transfers to occur in non-congested locations. Airships are capable of delivering door-to-door service for large indivisible loads, but, in most cases, regular freight would be interlined with truck and intermodal rail for final delivery. Again, such transfers could occur away from congested areas[vii].

Cost Analysis

The strengths and weaknesses of airships in meeting cargo-carrying needs can be itemized, but the levels of those strengths and weaknesses may be the subject of debate. At present, cargo airships are, at best, on the drawing board or in the scale model prototype phase. Consequently, "hard" data on their costs of manufacture and operation simply do not exist. It is left for the economist to make assumptions, and the strongest case is made for the scenario that requires the fewest or weakest assumptions. A search for a historical precedent would logically yield the scenario requiring the fewest assumptions regarding this as yet non-existent modern heavy lift airship. Semi-rigid or non-rigid operational models reached their design zenith in the 1950's, immediately preceding their demise. However, these designs generally had a useable lift of only a few tons. Even the larger designs (e.g. ZPG-3W), would have a useable lift of less than 15 tons, and this in an airship of about 400 feet in length – a not inconsequential scale.

In contrast, rigid designs, some of which flew successfully for years, provided a useable lift of up to 80 tons, with longer projected life cycles and faster point-to-point delivery speeds. While assumptions could be made to contemplate a semi-rigid or non-rigid heavy lift craft (possibly along the lines of the Cargolifter CL160), in the mind of the economist, fewer leaps of logic are required to envision a rigid heavy-lift design. More to the point, in order to develop projections dealing with costs of construction and operation of a ship meeting lift requirements, the rigid design moves us closer to the target.

The advocates of semi-rigid or non-rigid designs point to the structural qualities of new fabrics, such that these fabrics could replace the internal framework of the rigids. Indeed, the WWII and later non-rigids of the US Navy were strong evidence of the feasibility of that concept. The capabilities of the modern fabrics under consideration are nothing short of astounding[viii]. However, new LTA and hybrid vehicles are, as yet, untested in the field in full scale. Consequently, an updated rigid design may require fewer assumptions, thereby satisfying *Occam's Razor*.

Significant size economies

Like ocean-going ships, airships are subject to significant economies of size. Large airships could have ton-mile freight costs much lower than fixed-wing airfreight, and travel three to five times faster than surface shipping. The consideration of economies of size has been pushed furthest by the hybrid designers that envision airships with a useful lift up to 10 times any rigid airship ever built.

The extent of anticipated size economies are reflected in the cost estimates of Advanced Technologies Group Ltd. (ATG) of the UK. This research team has developed the Skyship 500/600, Sentinel 1000, and the AT-10 airships. They are in the planning stages of a family of hybrid airships capable of carrying from 20 MT up to 1,000 MT of cargo. The estimated freight costs for this family of hybrid airships are presented in Table 1.

Table 1: ATG Cargo Freight Rates Estimates

Airship Cargo Capacity	Freight Rates $ per tonne kilometer
20 MT	$1.50
200 MT	$ .20
1,000 MT	$ .06

The 20 MT hybrid airship would actually be slightly more costly than conventional airfreight. At 200 MT, according to ATG, costs would be comparable to trucking and for the very largest of their planned vehicles, with 1,000 MT capacity, freight rates would be comparable to marine freight (Advanced Technologies Group). It should be emphasized that ATG's cost estimates are based upon computer simulations, rather than experience under real world conditions. Moreover, these rates do not apply to a defined mission or level of utilization. Whether ATG, or another firm, will be able to realize costs as low as these for a hybrid airship is unknown, because nothing beyond a demonstration model has been built. However, these economies of size are an indication of the longer run promise of airship technology.

Looking again at technology that existed in the early part of the 20th century, it is clear that there were efficiencies associated with the larger scale vehicles. Even within the group of rigid airships from the 1920's and 1930's, the larger vehicles had a higher cargo capacity as a percent of gas dead-lift. As illustrated in Table 2, the Los Angeles (a slightly smaller precursor to the extremely successful LZ127 Graf Zeppelin) was designed to contribute about 43% of its gas dead-lift to "useful lift", which we may consider to be cargo lift. The larger Graf Zeppelin II would be in the range of 46% (although lower if Helium were to be used). The ZRCV, while never built, could have approached half of its dead-lift going to cargo.

While there is evidence of efficiencies of scale, the efficiencies of technological development may be greater. The Zeppelin NT, a modern airship and closest in design to the large rigid airships of the past, contributes almost 60% of its gas dead-lift to cargo. This performance is from an airship that is dwarfed by the behemoths of the past. In the absence of hard data, it is left to the imagination to hypothesize the efficiency of a modern design if the technological advances of Zeppelin NT could be applied to a ship the size of the Graf Zeppelin II.

Table 2: Airship Useful Lift versus Dead-weight Lift

Airship	Envelope Volume (cu. Ft.)	Useful Lift (lbs.)	Cargo Lift as a % of He Gas Dead-lift
Los Angeles (LZ126)	2,472,000	66,970	42.7%
Graf Zeppelin II (LZ130)	7,063,000	224,200	46.3%*
ZRCV (proposed 1936-1937)	9,330,000	297,000	49%
Zeppelin NT	110,700	4,184	59.5%
Cargolifter CL160	19,500,000	352,416	28.6%
* Hydrogen filled			

By way of comparison, the Cargolifter CL160, with an envelope size proposed to be almost 3 times the volume of the Graf Zeppelin II, would be expected to only contribute about 29% of its gas dead-lift to cargo. It should be remembered, however, that this semi-rigid concept incorporated a complex and no doubt heavy cargo keel design to facilitate winching and lowering. Nonetheless, the evidence would suggest the features of an updated rigid design could be the most efficient from the point of view of maximizing the percentage of gas dead-lift going towards cargo lift. Also, the higher λ (airship length/maximum beam or diameter) of the rigid design ensures a higher top speed and superior fuel efficiency relative to the non-rigid or semi-rigid designs. When considering time-sensitive cargo, and increasing fuel costs, these two traits of the rigid design are significant factors.

As indicated earlier, the hard data does not yet exist for the large scale modern heavy-lift airship, although the rigid design does provide a good starting point. We must also move forward in quantifying the impacts of technological advances in adapting the tested rigid designs to the present day. To this end, research is needed to quantify the impacts on vehicle deadweight (the complement of cargo lift) of:

- Strong, lightweight fabrics to replace the canvas "patchwork" of the old envelopes
- Replacement of heavy engines with modern, thrust-vectoring, fuel efficient designs
- Fewer crew members, quarters and corresponding infrastructure
- Lighter, stronger composite frame materials
- Fly-by-light avionics and light weight control systems

The deadweight of the LZ130 was 260,200 lbs, leaving 224,200 lbs. (112 tons) of its 484,400 lbs. of Hydrogen dead-lift to go towards cargo lift. Even if the technological advances described above only brought the deadweight from 130 tons to 100 tons, that basic 70 year old design could have carried over 120 tons of cargo (even using Helium instead of Hydrogen). This would boast cargo lift as a percent of gas dead-lift to about 59%, which is comparable to that of the Zeppelin NT. If evidence supports the idea of an efficiency of scale, even this expected percentage is conservative.

In Table 3, we "reverse engineer" several rigid designs incorporating the technological developments discussed, and affixing some plausible cargo lift/gas dead-lift percentages. Rigid airships of 100 ton and 200 ton capacity would be well within the scale of what was in the air 70 years ago, or on the drafting boards in 1937 (i.e. ZRCV). A modern airship about 80 percent the size of the Akron or Macon could possibly handle railway car-sized loads.

Table 3: Hypothetical Second Generation Rigid Airships

Envelope Volume (cu. Ft.)	Useful Lift	Vehicle Deadweight	Cargo Lift as a % of He Gas Dead-lift
5,128,000	100 tons	67 tons	60%
9,767,000	200 tons	117 tons	63%
13,776,000	300 tons	148 tons	67%

A rigid design, using an envelope volume only about 70% that of the proposed Cargolifter CL160, could perhaps be used to handle loads of up to 300 tons.

Moving from the previous engineering discussion to hypothesized ton/mile costs for the various designs requires complex analysis. Again, much of the information to support that analysis is unavailable. At least in the case of the rigid designs, however there is some precedence in the historical record of airships such as the Graf Zeppelin, which logged 590 flights, and more than one million miles (Althoff, 1990). Updating cost information is more complex than adjusting for the effect of inflation on 1935 data. For example, newer fabrics would have a much longer useful lifespan and hence their replacement costs could be amortized over an extended period.

The complexities of quantifying direct operating costs are challenging, but there is also the need to calculate the fixed costs of design, construction, financing, certification and training. The costs of these other aspects would be spread out over the life of each vehicle and the number of vehicles of a given design being constructed. Manufacturing costs also need to include some overhead contribution for the construction and maintenance of a fabrication hangar.

At least in part, these tasks have been addressed by Chester (1992), using the British R100/R101 airships as a model. For the most part the analysis used the airships as they were in 1930, with little adjustment for the effects of technological development. The 5,500,000 cu.ft. envelope of these British airships puts them in the range of the 100 ton design discussed in the previous table. Chester's direct operating costs associated with shipping freight were calculated in the range of $0.06 to $0.07 per nautical ton-mile. This is likely too favourable a freight rate[ix], but Chester's work represents an important step in addressing the dearth of useable economic case studies. As with several other technical issues, more work is needed to incorporate all costs associated with an airship program, and also to allow for the effects of technological development on these costs.

In addition to hard costing data, also lacking in the analysis is a model for a loading/unloading mechanism required to transfer cargo to or from the rigid airship. Any on-board cargo handling mechanism would reduce the operational cargo capacity of the airship design. The simplest design (and possibly the lightest) will be needed, but at the same time, it must be safe and rapid. "Mules"(mobile anchoring equipment) could be used to hold the airship over the cargo module and then winch the airship down to facilitate lock-up with the module, or vice versa. The design of the cargo handling component is outside the scope of this paper, but is discussed in further detail later.

Other Considerations

Environment

Airships have the potential of becoming the cleanest form of intercontinental transport since the sailing ship. Airships have inherently low greenhouse gas emissions because of the static lift provided by the Helium gas. There is also the potential of full or partial reliance on effectively zero emission solar power. The large dorsal surface of an airship could support a massive solar array. For example, the proposed Lockheed-Martin stratospheric airship, which is 500 feet long and 160 feet in diameter, is being designed with a solar collector to provide regenerative power. Solar energy equipment that will operate at 65,000 feet should be adaptable to the 1,000 to 5,000 foot level where a cargo airship would operate.

The low power requirements of airships will also assure that noise and air pollution associated with airports will be much less problematic. A better understanding of noise propagation might also help in situating "blimp ports", such that disturbance to neighbours is minimized.

Mixed freight/passenger potential

Potential exists for mixed, freight/passenger long haul movements. The rising popularity of cruise ships, underscored by the recent maiden voyage of the Queen Mary II, suggests that a growing market could exist for more leisurely travel options. Just as airships could provide an attractive middle ground between costly, but fast conventional air, and cheap, but slow marine transport, they could also satisfy demands for passenger transport as entertainment without the very lengthy commitments of cruise ships.

Studies by de Heer (1980) and Hochstetler (2001) conclude that airships could provide competitive short haul passenger services. de Heer concluded that a 420 ton airship could ferry passengers and their cars competitively from the U.S. mainland to Hawaii.

Military Interest in LTA Technology

New technology requires significant investments in research and development for the construction and airworthiness testing to obtain commercial certification. While some technical problems are as yet unsolved regarding giant airships, none appear to be insurmountable given sufficient investment. However, what would constitute "sufficient investment" could be significant. It is unreasonable to expect that a completely new airship could be designed, built and certified in less than three years, and a five-year schedule might be closer to reality. Like a new fixed wing aircraft, the development costs of a new cargo airship could easily lie between $600 million and $1 billion to reach full commercial status.

Many innovations now taken for granted in the private sector were funded by the military. Airships appear poised for this boon. The U.S. Defense Department is interested in airship technology for long distance transport of heavy and large cargoes as well as for possible roles in missile defense (Woodgerd, 2003). In addition to helping to offset development costs, the military could provide a stipend to help sustain airships for stand-by airlift to difficult to reach conflicts. For example, the U.S. Department of Defense gives U.S. airlines an annual stipend in return to access to their crews and craft in the event of need. A similar program for cargo airships could lower average costs and encourage a wider range of trade goods by enabling lower cost goods to compete. At the same time, it would create a valuable reservoir of strategic airlift for emergency response and conflict situations.

Weather

Contrary to the image held by many, airships are not powerless victims of extreme weather conditions. Indeed, one airship developer indicates its ships will be able to "operate in all weather conditions open to a standard civil aircraft," (Advanced Technologies Group). Airships would have sufficient power to overcome all but the strongest and most persistent head winds. Modern weather prediction and monitoring capabilities would allow airships to avoid potentially hazardous storms. Indeed, with their considerable speed and ability to move over both land and water, they would be much better able than marine transport to avoid severe weather conditions. And when they could not, experience of the US Navy (1940-62) with blimp operations in severe weather conditions suggests that survival is not a major concern. Colder temperatures generally impose greater stresses on all transportation equipment, but airships do benefit from greater lift as the density of the air increases. However, some details of cold weather operations, like de-icing systems, have yet to be demonstrated.

Rather than survivability, the greater weather concern is the impact on utilization. Strong head winds and routings to avoid severe weather will require more fuel and reduce utilization. Like all forms of transport, severe weather will also limit the operating window for airships and affect ground handling. Like a ship standing off the coast, or an airplane holding at an alternative airport until weather clears, in some instances airships may have to remain aloft until conditions permit docking and the on/off loading of cargoes. Again, weather extremes affect all transport modes. Airship vulnerability to weather extremes will likely be no greater, and probably less, than for conventional air transport and should be able to avoid potentially dangerous storms (Woodgerd, 2003).

Ground handling

Ground handling procedures for the safe exchange of cargoes and ballast require development for large airships. A great deal of effort has been directed to developing ground handling systems, but none of the proposed systems have undergone extensive field-testing. There are a variety of potential solutions.

Fixed ground facilities able to attach to and guide airships to the ground,

Mobile ground handling equipment (staffed or robotic) able to attach to and guide airships to the ground.

Docking facilities carried onboard and lowered to the ground, with the airship hovering aloft during on/off loadings.

Hybrid airships landing under their own power employing hovercraft technologies to ensure smooth landings and reversing thrust to anchor the vehicle in place.

Tail and bow thrust engines on airships that improve lateral control and reduce the number of ground crew necessary.

Problems related to developing viable ground handling systems appear surmountable by existing technology. "Modern robotic technologies have reached a technological maturity to permit the design of extendable, articulated mooring mast systems fully automated launch and recovery capability. Such a system could safely capture and launch an airship in all but the worst weather conditions, and would minimize ground personnel requirements." (Hochstetler, 2001, p. 11) Whatever the final configuration of the ground handling system, it seems clear that airships will not require anywhere near the extensive land area and capital of conventional airport facilities. For the sake of economic analysis, the cost of ground handling future airships could be approximated by the ground handling costs of fixed wing aircraft.

A Potential Early Application: Hawaiian Cargo Airship Service

The primary goal of this paper is to acquaint readers with the potential of airships as a significant mode for moving freight and, to a lesser extent, passengers, and to stimulate thought and discussion about the routes and cargoes for which it is best suited. To that end, in the balance of this paper one likely early use will be discussed: a cargo service between Hawaii and North America, with particular focus on movements of Hawaiian produce. The basic reason for identifying this market are listed below and later presented in further detail:

1. No land transport option: As airships prove themselves and associated technologies improve, competition with rail and truck could increase. However, in the early years of development, it seems most likely that large airships would be employed over water, where they will enjoy clear speed advantages relative to marine transport and cost advantages relative to conventional airfreight[x].

2. Distance: It is 5,007 kilometers (3,113 miles) from Hawaii to Los Angeles. This distance is long enough to make significant the airship's speed advantage over marine freight, particularly for perishable and more valuable cargoes. At 20 mph, a ship could make the crossing in just under one week, versus 36 hours for an airship (at 80 miles/hour). This distance is well within the operational parameters of several airships currently in planning, and certainly within the range of the Atlantic Zeppelin services of the 1930s.

3. Congested and sensitive port/coastal areas: One of the principal advantages of airships is the ability to avoid congested or otherwise sensitive areas for on/off loading. The attraction of this capability for Hawaii and the West Coast of North America is evident.

4. Sufficient market size: The large volume of freight passing through Hawaiian ports is coming from or going to North America. Perishables account for a considerable part of that volume. From Hawaii eastbound perishable cargoes consists primarily of papaya and pineapples, as well as some ornamentals. Going to Hawaii is a wide array of produce and meats. Both westbound and eastbound trade flows are fairly steady throughout the year.

5. Moderate weather conditions: As already discussed, evidence from U.S. Navy experience with blimps as well as manufacturer simulations indicate that airships will be able to operate in a wide range of weather conditions. Nevertheless, it seems likely that initial uses will tend to be along routes having few weather extremes. The Hawaii-U.S. Mainland route over the Pacific ocean is subject to temperate weather conditions.

6. High potential for mixed freight/passenger: Both Hawaii and the west coast of North America are significant tourist destinations. Hawaii already serves as a Pacific ocean cross-roads for air travelers. Passengers could use the airship for all or one leg of their trips.

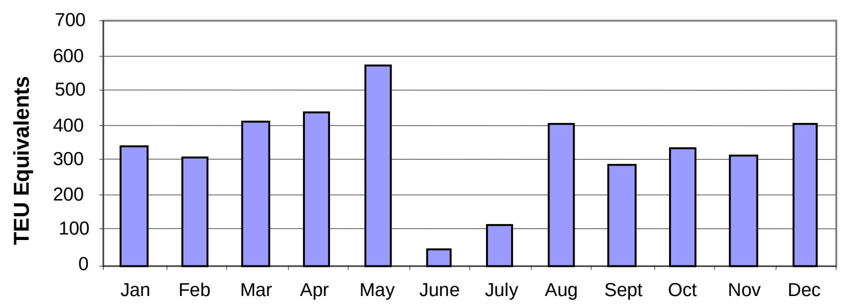
7. Hawaiian interest: A study was prepared in 1980 by de Heer (State Representative, Thirteenth District) that considered the use of airships for inter-island and mainland service. This study concluded that "not to pursue LTA airships for Hawaii's transportation needs would be a

regrettable disservice to Hawaii's future in general, and the viability of the neighbor islands in particular."

8. Military interest: The potential for a partnership between commercial operators and the U.S. military is better because the application is domestic.

The very large majority of Hawaiian pineapples and papayas are marketed in North America. Approximately half of these are shipped via air and the balance by boat (53 and 47 percent, respectively in 2002). Save for a dip in the summer, there is little seasonality in these shipments, see Figure 2. Additional cargoes to fill out mainland-bound movements or complementary cargoes for return haulage would normally be available. The Port of Honolulu, alone, handles over 150,000 containers annually, with 90 percent shipped between Hawaii and the U.S. Mainland (Choo, 2003).

Figure 2: Pineapple and Papaya Movements from Hawaii to Mainland U.S.: TEU Equivalents, 2002



As already noted, airships have the potential to charge cargo rates close to conventional airfreight for the more perishable goods e.g. papayas. The freight rates for refrigerated 40 foot marine containers between Hawaii and Los Angeles were quoted in 2004 at $3,678 for eastbound loads and $4,828 for westbound shipments of fresh fruits and vegetables (Matson, 2004). Assuming a 20 ton load, the ocean rates are between 9 and 12 cents per pound. Though airships could be two or three time more expensive than marine movements, they would be three and five times faster. The reduction in indirect logistics costs (packaging, inventory in transit, damage) and market premiums for freshness could help airships capture part of this marine market share.

A potential land route through the southern U.S. might enable airships to surmount the west coast mountain barrier and deliver fresh produce from Hawaii into the center of the continent. Initially, however, the cost and door-to-door advantage of trucks is likely to encourage transshipment once airships clear congested coastal areas. This is not to say that airships will never operate deeply into the interior of North America. Rather, it seems likely that the initial applications will be over routes for which the comparative advantages of the mode are greatest. Those advantages are not over continental areas with highly developed surface transport infrastructures (except for indivisible loads). Usage of airships over such areas is likely to increase gradually as their costs lower and/or congestion and environmental costs associated with other modes increase.

Year round utilization is imperative to justify the fixed costs of large airships. As can be seen in Figure 2, with the exception of June and July, Hawaiian produce exhibits very little seasonality in outbound shipments. Outside these summer months, pineapple/papaya shipments ranged from 300 to 600 TEU-equivalents (20 foot containers). Inbound shipments to Hawaii could include perishables like strawberries, lettuce and other fresh produce, as well as general freight and mail. The lower cost of airships might enable Hawaii to lower its average inbound freight costs, as well as expand its agricultural sector. Hawaii might also serve in the future as a transshipment point where horticultural trade between North America, Asia and Australia are sorted and dispatched to their final markets.

Looking Ahead

At the dawn of the 20th Century, a new transport mode came into being, the airplane. In the early years, it was little more than a novelty, but the airplane became one of the two or three most significant developments of the modern age. The same phenomenon may be happening again at the beginning of this century with regard to the airship. Reasons for suspecting this might be true have been reviewed in this paper. They are, primarily, the confluence of technological advances that promise to improve greatly the performance of airships over their predecessors, the potential of airships to mitigate many of the negative externalities in transport ---- congestion, pollution, and depletion of liquid fuels, and the opportunity to serve the large transportation requirements gap of lower value perishables.

Based upon the comparative advantages of airships, relative to other modes, a likely early application was discussed, mixed freight/passenger service between Hawaii and the West Coast of North America with particular focus on perishables transport. History shows that world food markets become integrated over time with advances in transportation technology. A large latent demand exists for better trans-oceanic transport that can provide a mid-point in cost and speed between existing aircraft and surface shipping. Airships could fill this niche. The global market for perishable food products in the 21st Century is certainly large enough to justify a world scale airship manufacturing industry.

No doubt there are many more potential uses for trans-oceanic airships. The primary goal of this paper has been to acquaint readers with airships and encourage them to consider the probability of their rebirth and what will be its role in our world. Although precise economic analysis is impossible at this point, the weight of evidence suggests that airship technology deserves a second hard look.

References

Advanced Technologies Group *World SkyCat*. World SkyCat Ltd., Oxford UK, 2002, available at www.worldskycat.com

Althoff, William F. *Skyships – A History of the Airship in the United States Navy*, Pacifica Press, 1990.

Barlow, David. "Applications for Northern Transportation: Proceedings", *Airships to the Arctic Symposium.* Winnipeg, MB: University of Manitoba Transport Institute, October 2002, available at www.umti.ca

Chester, David. "Comparison Between the Direct Operating Costs of a Freight-Carrying Airship and the Boeing 747-200F", *Airship-The Journal of the Airship Association*, No. 95, March, 1992.

Choo, D. "Safe Harbor?" *Hawaii Business*. Hawaii Business, Honolulu, October 2003, available at www.hawaiibusiness.cc

DARPA. "Special Notice: Reference-Number-SN04-12", Defense Advanced Research Projects Agency, January 14, 2004.

de Heer, Gerald. *Study on the Viability of Lighter-than-air (LTA) Airships in Hawaii's Interisle and Mainland Mission*. Report prepared by the State Representative Thirteenth District, May 1980.

Hochstetler, Ron. "Current Trends in Transportation and Their Impact on the Potential Market for Lighter-Than-Air (LTA) Transports." 14th AIAA Lighter-Than-Air Systems Convention and Exhibition, 16-18 July 2001

Lloyd's Register "Leading the Way in Developing the Optimum Ultra Large Container Ship" *Lloyd's Register*, London, 2004, available at www.lr.org/market_sector/marine/ulcs

Matson Navigation Company, Customer Quote, 03-21-2004 (personal communication).

Prentice, Barry E. and Jim Thomson. "Airship Applications in the Arctic: Preliminary Economic Assessment" *American Institute of Aeronautics and Astronautics*. 3rd Aviation Technology, Integration, and Operations (ATIO) Technical Forum: 2003.

USDA *Fresh Fruit and Vegetable Shipments: by Commodities, States, and Months: 2002* Agricultural Marketing Service, USDA, Washington DC, 2003.

Woodgerd, Mike. "Ultra Large Airlifters (ULA): A North American Window of Opportunity" *Canadian Transportation Research Forum*. Proceedings Issue: 38th Annual Meeting (2003): 577-591.

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[i] Jules Henri Giffard (1825-1882) was the French inventor of the first passenger-carrying powered airship, called a dirigible.

[ii] In contrast to the Zeppelin Era of the 1930s, the goal of most current efforts is freight haulage. Similar to the early development of the railways, smaller vehicles are envisioned primarily for passenger carriage. It seems almost certain that the return of large airships will occur within the next ten to twenty years and will be based on cargo, but mixed carriage of freight and passengers is both conceivable and likely the next step in the path.

[iii] Trans-Eurasian caravans over the so-called Spice Route predated improvements in sailing ships by several centuries. However, the volume of spice traffic carried overland was extremely small.

[iv] Fuel and speed can be fine tuned on an airship because some dynamic lift and engine thrust can be used to take off "heavy". As the fuel is burned, the airship loses weight and may need to condense engine exhaust to capture ballast. Hence, more fuel and more cargo are obtainable within a certain range.

[v] The captain has a route choice other than a straight line. With good meteorological data, airships could take routes that avoid headwinds and pickup advantageous trade winds or the slip streams of storms.

[vi] Mountain ranges are the one physical barrier to commercial airship transport. While an empty airship may be able to cross a mountain range, a loaded airship might not.

[vii] Indivisible loads are not considered in this paper, but are a particularly interesting case for transshipment by airships across topographical barriers. Airships are likely to reinforce transportation gateways where efficient topography yields favourable routes and freight rates. New gateways may be formed at locations where other forms of surface transportation infrastructure end.

[viii] See Dave Barlow, President, TCOM, *Airships to the Arctic Symposium, 2002, www.umti.ca*

[ix] This rate is in the range of that estimated by ATG for their gigantic 1,000 tonne capacity design.

[x] The same logic applies to airship transport over road-less terrain. Prentice and Thomson (2003) examined the use of a large airship to carry fuel to an Arctic diamond mine.