THE REBIRTH OF AIRSHIPS

Until the outbreak of the Second World War, uncertainty existed whether airships and airplanes would dominate intercontinental passenger transportation. The massive investments in fixed-wing aircraft during these hostilities made airplanes the decisive winner, and relegated airships to a negligible role in transportation. As the 21st Century progresses, airships are making a comeback fueled by the growing demand for air cargo, the unique environmental and operational characteristics of buoyant flight, and advances in engineering science and materials.

This paper examines the market niche for airships that exists between air and marine transport and the inherent advantages and disadvantages of this mode of transportation. The economics of airships are considered in light of their past achievements and current designs. The paper concludes with the discussion of two potential applications. A long haul mission for airships between Hawaii and the U.S. mainland is considered for perishable freight, and a short haul mission for airships in northern Canada is considered for the transport of freight and passengers to remote communities.

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For the first several decades of man's commercial exploitation of aviation, airships and airplanes were intramodal competitors, particularly on the long distance cross-oceanic markets. However, except for infrequent use as billboards, camera platforms and novelty tours, commercial uses for airships ended in flames three quarters of a century ago. The memory of the Hindenburg catastrophe, as well as technological advances in heavier-than-airflight, trucking, and maritime transport made the large airship seem a slow, cumbersome, and ultimately tragic detour in the history of transportation. At the dawn of the 21st Century, however, we may be about to witness the return of large airships as commercial vehicles.

Interest in airships has been heightened by technological developments in a number of fields including helium recovery, composite materials science, vectoring engines, satellite weather forecasting, fly-by-light avionics, and computer-assisted design. This interest has been furthered by the indirect advantages of airships. These vehicles could mitigate several negative externalities associated with other forms of transport. Congestion problems at ports, highways, and airports, and evidence of climate change have caused economically advanced nations to reconsider their transportation systems. The inherent fuel efficiency of airships creates economic and environmental incentives for innovation. Consequently, many nations are taking a hard second look at airship technology.

At the time of this writing, at least a dozen firms in 10 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 rebirth of commercial airships has been very difficult, but it seems at last to be gathering momentum. The creation of a new mode of transport can have profound economic effects. Improved service and lower transportation costs can stimulate new commodity flows, diversify industrial activity, and forge new trade routes. In this paper, potential uses for airships and their inherent economic strengths and weaknesses, relative to other modes, are examined.

PEOPLE, PARCELS, AND PECULIAR THINGS

Unlike most aspects of space travel, mankind is not starting from scratch with airships. Many aspects of airship technology and operations are well-established. Indeed, when Model Ts were common on our roadways, airships had already proven themselves commercially.[1] New technologies can, and already are, building upon this wealth of experience to improve and expand airship capacities. But even if the technological hurdles are manageable, developing airships for commercial purposes will be costly. Almost surely the greatest risk is that demand will prove disappointing rather than the ability to develop airships capable of commercial uses.[2]

The more varied the potential uses for airships, the lower the demand-side risks. Diversification lowers risk because some applications could have explosive growth that offset the disappointments. Transport applications may be divided into three areas: passenger (people), freight (parcels), and specialties (peculiar things). Airships have considerable potential in all three.

Passenger Demands

Demands for passenger transport may be derived from needs to get from one location to another or directly from the pleasure of traveling or a combination of the two. In most circumstances, airships will not be suitable to compete in passenger service markets for which primarily interest is in expeditious movements from one location to another (i.e. derived demand). Over very short distances, time spent docking and loading/off-loading may render airships less attractive than modes such as rail, bus, and auto. Over longer distances, the speed of conventional air service dominates. The exceptions that constitute markets for airships are likely characterized by the following:

- water barriers or lack of surface transport infrastructure,
- distances too long for economical helicopter service and too short for economical conventional air service, or
- cargo that cannot be carried physically or economically by traditional modes of transport.

Examples of potential markets include: inter-island transport in Hawaii and Indonesia, the Vancouver-Victoria-Seattle triangle, and across the Adriatic and Red Seas.

It is quite possible that airships could compete in these derived demand (i.e., travel for the sake of movement) passenger transport markets. However, beyond short haul markets, not many commuter service opportunities exist for passenger airships.[3]

The main future of passenger transport for airships is likely in those markets for which a significant portion of the demand is for transport as entertainment (i.e., primary demand). The beauty and grandeur of seeing the world from a virtually silent, soaring platform is self-evident. From eco-tourism over the Amazon to floating by Gibraltar on the way to Marrakech, the potential appears vast.

Freight Demands

Freight transport is strictly derived from the enhanced value of the cargo in another location, with the choice of mode being that which offers the lowest cost combination of time in transit, ride quality, climate control, and freight rate. In almost all transport markets, airships would not be competitive for transporting either the most valuable freight per unit weight, such as diamonds, or the least valuable, such as coal. They likely would not serve most short haul markets nor, at least in the foreseeable future, extreme long haul markets, such as between North America and Australia. But there exists a sizeable range of cargo types and origin-destination combinations over which airships could be competitive. The characteristics for these markets and a specific example are presented in the next section, entitled “Freight and Mixed Freight/Passenger Uses.”

Specialty Uses

Transportation technologies are sometimes employed to meet highly specialized needs. The use may involve the transport of passengers or freight under extraordinary conditions, such as in conflicts, or be for reasons unrelated to transport, such as surveillance. Another variant of specialty use would be to move cargoes having extremely unusual requirements. In this regard, the most important are oversized cargoes.

All transport modes are employed for at least some specialized uses. Almost surely, the mode for which specialty uses is most important, relative to its other functions, is the helicopter. The reasons for this are evident – helicopters can land on and takeoff from very small areas and, of even greater importance, they can hover.

As such, helicopters are used as “sky hooks” to transport electric transmission towers; to harvest trees in remote locations; as vehicles to transport food and other supplies to isolated military theaters or disaster sites; and to serve as platforms to monitor traffic conditions, criminal activity, etc.

Specialized airships may be able to match the precision of helicopters with regard to hovering and landing/takeoff, but this is not their strength. For example, helicopters are used, stage-by-stage, to transport and then assemble giant electric transmission towers. For tower assembly, it must be possible to control their vertical and horizontal location in the air to within a few feet, at most. With enough engines and computerized controls, it might be possible for airships to offer helicopter precision. Whether airships could assemble such towers economically is another matter. But, airships might re-engineer such construction. Airships have the potential of greatly exceeding helicopters with regard to lift capacity and range. Airships may be able to transport fully assembled towers to remote sites.

The relative strengths of airships and helicopters could facilitate joint use. The greater lift capacity and range of airships could be employed for ‘linehaul’ movements, with the more nimble helicopters providing local pickups or deliveries. For example, helicopters are used to harvest standing tree stems with less damage to the lumber or the environment (Smith, 2003). These Sikorsky S-64E helicopters are limited to about 10 tons lift and short ranges. Airships could be employed to transport bundles of tree stems that would extend the range of the helicopters without the need to build damaging logging roads or clear-cut the forest. Similarly, large volumes of supplies could be transported by airship to disaster sites or a military theater, with helicopters employed to effect final deliveries to individual locations or units.

For functions requiring a stationary or near-stationary aerial platform for prolonged periods, airships are ideal. Such uses include surveillance, search and rescue, radar, and communications. Helicopters have high maintenance and operating costs. Relative to helicopters or fixed wing aircraft, airships have much greater endurance and lower costs (Van Treuren, 2001). In the not-too-distant future, it may be possible to power a hovering airship using only photoelectric cells mounted on its topside.

Another example of a specialty use is presented below in the section entitled “Northern Supply.” As with the following section, it is not our intent to assert that these examples will be the exact shape of the airship renaissance. Rather, we only intend to convey the breath of potential uses for airships and, in that, communicate the likelihood of such a renaissance.

Freight and Mixed Freight/Passenger Uses

Whether across town or to another continent, trade is impossible without the means to transport goods in a manner that preserves sufficient value and net of the costs of production and that transport, to be attractive at the destination. For cargos that are low valued per unit weight and not subject to rapid deterioration, transport modes with lower costs per ton-mile are favored, even when speeds are slow. As cargo value characteristics move to the other end of the spectrum, modes with higher speeds and better cargo handling are preferred. Factoring in mode-specific scale economies regarding cargo sizes explains most of the currently observable division of transport across the modes.[4]

To be viable, airships have to find a place within this universe that exploits their strengths relative to other modes. Upon preliminary examination, airships do not appear to have many comparative advantages. Airships are slower than airplanes, less flexible than trucking, and unable to carry loads of comparable sizes or costs per ton-mile as either rail or shipping. As such, airships would never be suitable for cargoes that essentially require one of these extremes.[5] Airships will not carry diamonds or coal or make local milk deliveries, but they may offer some interesting service options for the carriage of goods that are simply average.

NOT EVERYTHING IS DIAMONDS OR COAL

Rather than being the best at some performance extreme, airship transport potentially could offer a mix of characteristics making it the best mode in some middle ranges of performance measures.

Fortunately for airships, for most cargoes, tradeoffs in transport performance characteristics are advantageous. Particularly for trip lengths over 1,000 miles, airships could be:

Speed			
	Much Faster than Maritime and Rail	Faster than Trucks	Much slower than Airplanes
Freight Rates			
	Less expensive than Airplanes	More expensive than Trucks	Much more expensive than Maritime and Rail
Service			
	Much more flexible than Maritime and Rail	More flexible than Airplanes	Less flexible than Trucks (with roads)
Capability			
	Less capacity than Maritime and Rail	More capacity than Airplanes	Much more capacity than Trucks

Added to these attributes, airships are unaffected by topography (save for extremely high mountain ranges). Airships can cross land/water boundaries without the necessity of transferring cargoes to another mode and can operate, land, and takeoff in confined spaces with minimal infrastructure.

Airships could potentially compete well for cargoes with one or more of the following characteristics:

- longer lengths of haul across land/water boundaries and/or across territories with poor road or rail infrastructures,
- freight premiums realized for faster delivery windows,
- oversized, overweight and awkward freight, or
- relatively low density, fragile or perishable products

Figure 1 illustrates the general relationship between per unit weight values and the durability of value[6] and identifies the principal transport mode for intercontinental trade. As is well-known, highly valued and/or highly perishable goods, such as flowers and fresh seafood, people,[7] and diamonds, are the near-exclusive province of conventional air transport, while goods at the other end of the spectrum, such as grains and coal, slowly and cheaply ply their way between the world's land masses in ships. Goods having qualities between these extremes, such as fresh meats, medium-valued tropical fruits, and most consumer goods, may be carried by any of the three modes. Airships (dashed circle) could split the difference. While slower than conventional airplanes, airships potentially could cruise at speeds three to five times faster than marine transport and have freight rates somewhere between air cargo and intermodal ocean container shipment (Van Treuren, 2001).

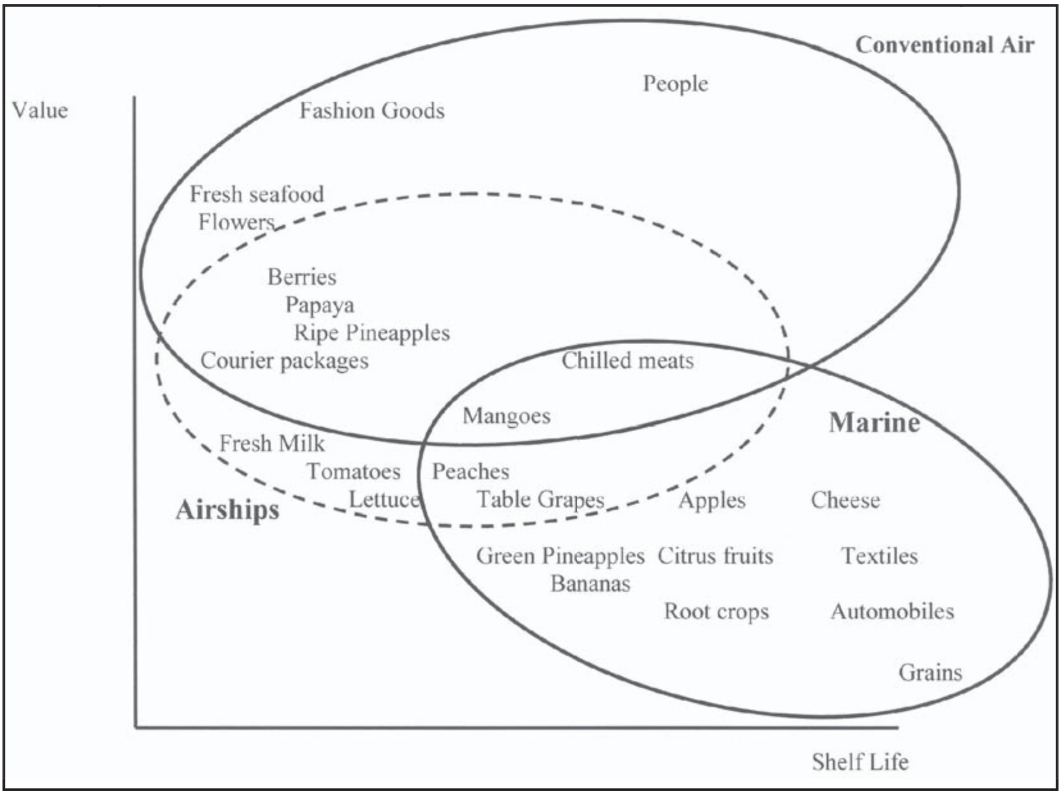
Considerable uncertainties remain regarding the cost of operating airships, but it appears clear that large airships could be profitable offering rates above those typical for marine transport, but well below those of conventional air. As such, airships could greatly expand long-distance trade of mid-range value/perishability goods. Moreover, some products that do not enter into inter-continental trade, such as fresh milk or tomatoes, might do so with the availability of airships.

INHERENT ADVANTAGES AND DISADVANTAGES OF AIRSHIPS

Each mode of transport has unique logistical strengths and weaknesses and service advantages that dictate their uses (ships – big volume, slow, cheap; air – low capacity, fast, costly, etc.). Airships can travel relatively fast (80 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 must balance cargo payload against vehicle range, speed and costs (capital and operating). The data necessary to quantify the optimum vehicle and operating characteristics for specific markets is beyond the scope of this paper. Rather, these

Figure 1: Value Per Unit Weight, Shelf Life, and Dominant Transport Modes in Intercontinental Transportation



will be considered conceptually.

The Value of 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 of weight. The plodding ox is marine transport. Despite technological advances, even the fastest container ship operates between 20 and 30 mph (Lloyd's Register, 2004), far slower than the average speeds of any other mode. The advantages of marine transport are high capacity, long range, and low cost per unit of 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 near the extremes of value or 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 for these products that airships have the greatest potential.

Conventional airships consume fuel only for forward motion because the lifting gas provides buoyancy. Fuel consumption per unit distance is an increasing function of speed. At a cruising speed of 40 mph, an airship could travel approximately twice the distance without refueling that it could if it were flying at 80 mph. Alternatively, more freight could be carried at a slower cruising speed because less fuel is consumed.[8]

Return on capital is determined by the number of revenue ton-miles per year and operating costs. Going faster increases vehicle utilization, reduces average crew costs and spreads the fixed costs of the airship over more trips. Speed can also be rewarded through rate enhancements if cargoes are time sensitive but is penalized by higher fuel costs.

Weather adds to the complexity of determining the optimal cruising speed for an airship. Strong headwinds, or tailwinds, 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 an advantage.[9]

The Value of Service

Airships can overfly ocean-land boundaries and conduct intermodal transfers at non-congested internal gateways. Such intermodal transshipments can be performed with minimal infrastructure. Transfers are not tied to geographic features, such as coastlines, because airships do not require extensive landing facilities. 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.[10] Airships can operate across rough terrain with less developed surface transport infrastructures.[11]

With the exception of higher mountain ranges, physical barriers of topography impose few limitations on airships. 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, continental areas.

The Value of Size

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 air freight. The consideration of economies of size has been pushed furthest by the hybrid designers who 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 catamaran-shaped, hybrid airships capable of carrying from 20 metric tons (MT) up to 1,000 MT of cargo. ATG's estimated freight rates for this family of hybrid airships are presented in Table 1.

The 20 MT hybrid airship would actually be slightly more costly than conventional air freight. At 200 MT, according to ATG, rates 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. It should be emphasized that ATG's rate 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 other hybrid airship designers[12] will be able to realize vehicles with these costs 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.

AIRSHIP TECHNOLOGY AND COSTS

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 on the drawing board or in the scale

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

Source: Personal Communication between B.E. Prentice and Gordon Taylor (ATG), Oct. 2002 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.

Conventional airships under discussion would fall into one of three main categories; rigid, semi-rigid, or non-rigid. The rigids, the best examples of which were the traditional huge airships of the 1930s such as the Graf Zeppelin, used an external fabric covering over an extensive internal framework. This framework retained the shape of the airship even in a deflated state. Internal gas bags of variable volume provided lift, but did not appreciably affect the silhouette of the craft. At the other end of the spectrum, non-rigids lack an internal framework, obtaining and holding their shape in accordance with the shape and flexibility of the external envelope. Semi-rigids, as the name would imply, combine the traits of both rigids and non-rigids, employing a partial internal framework in conjunction with a shape-determining external envelope.

Semi-rigid or non-rigid operational models reached their design zenith in the 1960s. The larger designs (e.g. ZPG-3W) had a useable lift of less than 15 tons, and this in an airship of about 400 feet in length – a not inconsequential scale. Larger rigid Zeppelin designs (up to about 800 feet in length), which flew successfully in the 1930s, provided a useable lift of up to 80 tons, with longer projected life cycles and faster point-to-point delivery speeds.

The advocates of semi-rigid or non-rigid designs point to the structural qualities of new fabrics. Envelopes built of composite materials can replace the internal framework of the rigids. Indeed, the WWII and later non-rigids of the U.S. Navy were strong evidence of the feasibility of that concept. The capabilities of the modern fabrics under consideration are nothing short of astounding (Barlow, 2002). However, new Lighter than Air (LTA) and hybrid vehicles are, as yet, untested in the field in full scale.

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 1920s and 1930s, the larger vehicles had higher cargo capacities as a percent of gas dead lift. As illustrated in Table 2, the extremely successful LZ127 Graf Zeppelin was designed to contribute about 33 to 34% of its gas dead-lift to "useful lift," which we may consider to be cargo lift, as would the larger Graf Zeppelin II (in both cases, adjustment has been made based on helium inflation, not hydrogen).

The Graf Zeppelin II, like its sister ship, the Hindenburg, was designed as a much more opulent craft than the Graf Zeppelin. Literally "floating hotels," these ships were designed with smoking rooms for the passengers, dual-deck quarters and even a piano (albeit of aluminum construction). These features contributed to the fact that while the empty weight of the Graf Zeppelin was only 122,000 pounds, the Hindenburg weighed, by various estimates, between 100 and 120 tons.

Table 2: Airship Useful Lift versus Dead-Weight Lift

Airship Design	Envelope Volume (cubic feet)	Useful Lift (pounds)	Cargo Lift as a % of Helium Gas Dead lift
Graf Zeppelin (LZ127)	3,700,000	62,300	34%
Hindenburg (LZ129)	7,063,000	115,000	33%
Graf Zeppelin II (LZ130)	7,063,000	127,000	36%
LZ131 (proposed)	7,994,750	181,000	46%
ZRCV (proposed 1936 1937)	9,330,000	297,000	50%?
Zeppelin NT	288,000	4,800	28%

As the LZ130 approached completion, weight-saving design changes relative to the LZ129 had been incorporated (structural hull changes, radiators & piping, electrical system, and in particular, a reduction in the scale of the passenger quarters), such that the LZ130 weighed 12,000 pounds less than the LZ129. Although never built, the specifications of the LZ131 were well-documented. It would have used the basic LZ129 design with an additional hull section, bringing the envelope volume to just under eight million cubic feet. Of particular interest to this analysis, was that this airship, with a 13% greater hull volume than the LZ129, would have weighed about 10 tons less than the Hindenburg. These weight savings would, in large part, have come through a new structural material, resembling American Alclad, which after heat treating, would have 25% better strength in compression (Dick, 1985).

Even over a short period of time from 1936 to before the outbreak of WWII, significant weight-saving technological advances, coupled with increases in lift through scale of the airships, had pushed the feasible cargo lift as a percent of deadlift towards the 50% level. Had these vessels been redesigned to serve a cargo role with no passenger quarters, it is likely their useful lift as a percent of helium dead-lift would have approached or exceeded 50%. The ZRCV, while never built, was expected to lift close to 300,000 pounds. In doing so, it also could have approached half of its dead-lift going to cargo. Van Treuren (2001) has suggested a 50% cargo lift airship in previous work assessing the relative benefits of lift from helium vs. hydrogen.

Economies of size are obvious in displacement vehicles, but 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 (although a semi-rigid design with a pressurized envelope rather than separate internal gas cells), can contribute almost 30% of its gas dead-lift to cargo despite its relatively small displacement. 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 or the LZ131.[13]

Perhaps more important in the context of ensuring the most efficient design from a cargo-carrying basis, 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 traits of the rigid design could be 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 (likely diesel-electric systems, with solar power assist)
- Fewer crew members, quarters and corresponding infrastructure
- Lighter, stronger composite frame materials
- A less dense internal framework, allowing a higher percentage of envelope volume for lifting gas
- Fly-by-light avionics and light-weight control systems

The deadweight of the LZ129 was, by some accounts, about 118 tons, leaving 143,000 pounds (72 tons) of its 380,000 pounds of hydrogen dead-lift to go towards cargo lift. Even if the technological advances described above only brought the deadweight from 118 tons to 90 tons, the 70-year-old basic design could have carried about 86 tons of cargo (even using helium instead of hydrogen). This would boast cargo lift as a percent of gas dead-lift to about 49%, comparable to that of the much larger ZRCV. If evidence supports the idea of an efficiency of scale, even this expected percentage is conservative.

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 implies a 100-ton design. Chester's direct operating costs associated with shipping freight were calculated in the range of 6 to 7 cents per nautical ton-mile. This freight rate is likely too favorable,[14] 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 to allow for the effects of technological development on these costs.

In addition to hard operating cost data, the analysis lacks costs for a loading/unloading mechanism to transfer cargo on/off the rigid airship. On-board cargo handling mechanisms reduce the operational cargo capacity of the airship design. The simplest design (and possibly the lightest) is needed, but 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, or unloading of, the cargo module. The design of the cargo handling component is outside the scope of this paper, but is discussed by Hochstetler (2001).

EXAMPLES OF A POTENTIAL AIRSHIP SERVICES

The primary goal of this paper is to acquaint readers with the potential of airships as a significant mode and to stimulate thought and discussion about the routes and cargoes for which it is best suited. The balance of this paper addresses two applications. The overland use is a short-haul application (less than 200 miles) that considers a 30-ton and a 150-ton hybrid airship. The overseas mission assumes a rigid airship of 100-ton capacity.

Long-Haul Airship Service Between Hawaii and North America

A mixed cargo/passenger service between Hawaii and North America is a likely early application. The rationale for identifying this market is listed below:

1. <u>No land transport option:</u> 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.[15]
2. <u>Distance:</u> It is 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. <u>Congested and sensitive port/coastal areas:</u> 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 consist 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-North American 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 crossroads 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 greater because this application is domestic.
9. Value of Freshness: Not ripening or getting sweeter after being picked is a logistical problem of strawberries and pineapples. Ripe pineapples, if shipped by sea, deteriorate before they arrive at markets on the mainland. Del Monte shipped the first ripe pineapples by air to the U.S. mainland markets in 1976. Maui Jet-Fresh pineapples arrive within 36 hours of their harvest. Consumers are willing to pay a premium for ripe pineapples, relative to sour green pineapples.

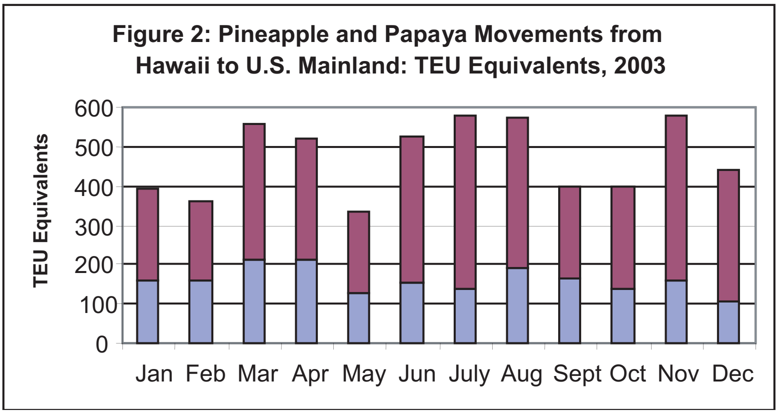
The very large majority of Hawaiian pineapples and papayas are marketed in North America (USDA, 2003). Approximately a third of these are shipped via air and the balance by boat (34% and 64%, respectively in 2003). Additional cargoes to fill out mainland-bound movements or complementary cargoes for return haulage would normally be available. The Port of Honolulu alone handles more than 150,000 containers annually, with 90% shipped between Hawaii and the U.S. mainland (Choo, 2003).

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 times more expensive than marine movements, they would be three and five times faster. The reduction in indirect logistics costs (packaging, inventory in transit, damage/spoilage) are important, but the market premium for freshness is the key for airships' capture of marine market share. A 100-ton airship should have the potential to charge lower cargo rates than airplanes and capture part of their premium market.

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 fall 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

Figure 2: Pineapple and Papaya Movements from Hawaii to U.S. Mainland:



Source: USDA. *Fresh Fruit and Vegetable Shipments: by Commodities, States, and Months: 2003.* Agricultural Marketing Service, USDA, Washington, DC, 2003. TEU equivalent assumed to be 20 MT.

can be seen in Figure 2, Hawaiian produce movements continue year around, with monthly volumes generally at or above 400 TEU. Inbound shipments to Hawaii could include perishables like strawberries, lettuce and other fresh produce, as well as general freight and mail.

Airship passenger transport to Hawaii was examined 25 years ago by de Heer (1980). This analysis holds that the technology at the time was sufficient to create a passenger service between Hawaii and the mainland. The cars of tourists were envisioned as the main cargo. The increasing popularity of cruises as a vacation choice suggests that an airship passenger/freight combination could be economically viable.

Short-Haul Airship Service to Remote Northern Communities in Canada

Airships have the potential to provide year-round transport service with minimal infrastructure requirements. Several airship designers have proposed catamaran-shaped hybrid airships for cargo usage. The catamaran design has several advantages that would favor its use in the North. They are amphibious and could operate out of the myriad of lakes typical in the Far North. They do not require large landing crews, which in remote areas may not be available. They can operate without ballast, which may be difficult to obtain in the frigid temperatures of winter. The rationale for identifying this market follows:

1. Few transport options: Northern Canadian villages rely on small airplanes (less than 10 tons capacity) and trucks during the limited winter road season for supplies. Airships could offer a year-round service with greater capacity and competitive freight rates. Annual re-supply of storables imposes significant inventory financing costs on buyers. Perishable food product prices are double the cost of the same goods in the south.
2. Distance: Canada has a vast hinterland, but many remote communities are located less than 200 miles from a road or rail line.
3. Environmentally sensitive areas: The small "footprint" of the airship enables it to provide service in otherwise sensitive areas for on/off loading. All-weather roads and airstrips are costly to build and maintain and have a negative impact on the ecology.
4. Sufficient market size: The remote communities are dependent on outside supplies for all food, building materials, and fuel as well as personal goods.
5. Evidence of climate change: Milder winters are worsening the transport situation. Winter roads require frozen ground and solid ice over lakes and rivers. Since 1996 the length of the winter road season in Manitoba has been shrinking dramatically (Kuryk, 2003).
6. High potential for mixed freight/passenger: Combi airplanes that carry both passengers

and freight are standard transportation in northern Canada.

7. Northern interest: The First Nations and the new territories (Nunavut and NWT) are demanding better services and income support from the federal government. The living conditions in many remote communities are comparable to low income Third World countries.
8. Military interest: Climate change is increasing the need for northern sovereignty and coastal patrols by the Canadian military.
9. Value of connectivity: Few options for economic development are possible without access to cost-effective transportation. New ventures might include forestry or light manufacturing, which could be developed locally thus providing jobs within these remote communities. Affordable transportation could support other new non-community development activities such as mining that would bring economic activity to the North.

The economic analysis is based on a cost simulation spreadsheet for a 30-ton hybrid airship[16] (courtesy of AeroVehicles). The economic model has been modified to simulate a scheduled service to remote communities in northeastern Manitoba. Transportation demand and cost information is available for a number of northern communities (Manitoba Government, 2003). Using these data as a benchmark, transportation costs for a 30-ton and 150-ton hybrid airship are developed and compared to the conventional winter road/airplane service. The scope of the cost comparison is a cluster of communities east of Thompson. Community size and transport demand are presented in Table 3. These communities do not have all-weather road access. Thompson, which is the northern terminus Highway 6, was selected as the supply point from which the airship operations are assumed to be based. All flight costs are calculated on the basis of individual missions, in which the airship flies from Thompson to its destination and back. No backhaul freight is assumed available for the return trip. While point-to-point operation simplifies the analysis, a flight model with multiple deliveries would reduce empty miles of the return trip and lower overall costs. The geographic location of the study is presented in Figure 3.

The cost and operational assumptions for a catamaran hybrid airship are presented in Table 4 for a 30-ton and a 150-ton payload vehicle. The analysis assumes that the hybrid airship operates year-round, but flies only 285 days per year due to maintenance, crew rest and inclement weather. All goods are transported by trucks on paved all-season roads from Winnipeg to Thompson, and then delivered by hybrid airship to the specific remote community. The trucking cost from Winnipeg, which is the main supply point for the north, to Thompson is estimated at $1,995 per 25 tons.

Hybrid Airship versus Conventional Transportation Cost and Operation

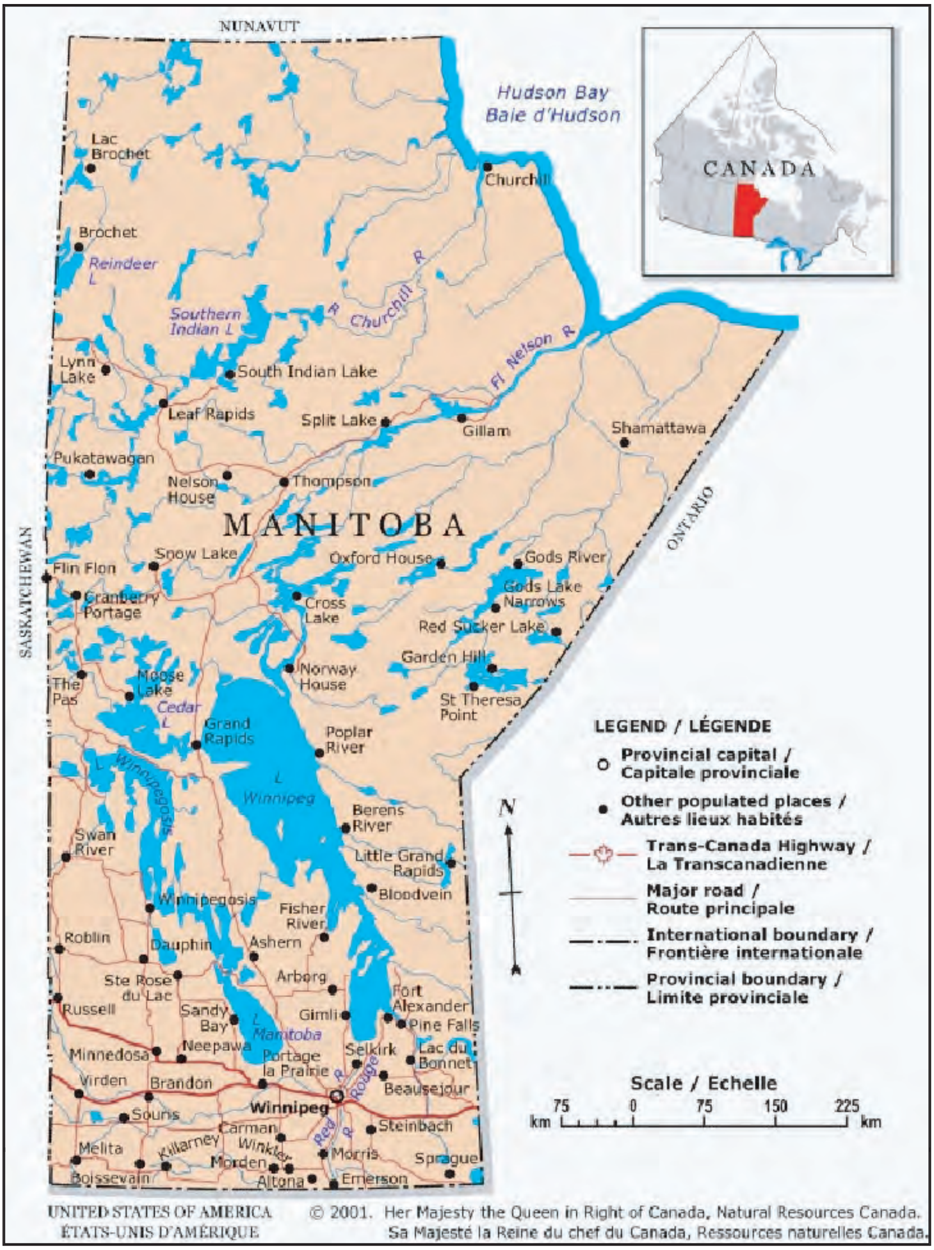
The analysis assumes a combi-configuration for a 30-ton hybrid airship that includes freight and up to 18 passengers. Space is not a constraining factor for hybrid airships. The hybrid airship could be configured to carry many more passengers if there is sufficient demand. Table 5 presents a cost comparison with conventional air service for a 30-ton hybrid airship used nine hours per day (flight time) for scheduled

Table 3: Profiles of Remote Communities

Community	Population	Estimated Annual Freight (Tonnes)	Number of Passengers	Number of Flights
St. Theresa Point/Wasagamach	4,021	11,600	14,127	6,061
Garden Hill/Island Lake	3,204	13,000	37,933	11,245
Red Sucker Lake	773	3,200	6,073	1,923
Oxford House	1,998	8,150	9,649	3,102
God's Lake Narrows	1,393	6,260	9,741	3,396
God's River	466	2,100	5,957	2,399

Source: 2020 Manitoba Transportation Vision

Figure 3: Map of Communities to be Served by the Hybrid Airship



cargo/passenger operations. The conventional cost numbers used for comparison purposes are based on an assumption that 25% of the freight rate is for air movements and 75% of the freight would be moved by truck over winter roads. Having the ability to provide steady re-supply would provide shippers and customers with greater flexibility in how they manage their inventories. The avoided inventory carrying costs would be significant, but are not factored into the present analysis. Similarly, the annual costs of building and maintaining the winter weather roads, airports and ferries are not included in this comparison. On a direct cost basis, the

Table 4: Catamaran Hybrid AirshipAssumptions

Assumptions	Attributes 30 Ton	Attributes 150 Ton
Payload	30 tons	150 tons
Configuration	dual cargo passenger	same
Flight speed	70 knots or 130 kph	same
Fuel costs	$3.52 USD per US gallon	same
Operations	9 hours operation per day with 285 days of weather available flight conditions	same
Ground support	All ground handling and maintenance costs are included plus fees for airport landings	same
Routes	Point to point operations for Thompson based on one way loads	same
Financing Purchase price Interest rate	C$36 million (US$30 million) 4.51%	C$135 million (US$112million)
Insurance	2.90% of hull value	same
Depreciation	80% straight line based on a 15 year useful life or 5.3% annually	same
Trucking costs to Thompson	$1,995 per truckload	same
Passenger airfare	Equivalent to fixed wing scheduled air services	Not included
Profit and overhead	Administrative overhead of 5% and a profit factor of 15% of the estimated per flight costs	same
Crew costs	$2.7 million based on FAA requirements	same

Table 5: Comparative Costs for a 30-ton Hybrid Airship

Destination	Conventional Costs ($/Tonne)	Hybrid No Passengers ($/Tonne)	Hybrid With Passengers ($/Tonne)
St. TheresaPoint/ Wasagamach	$435	$671	$304
Garden Hill/Island Lake	$450	$676	$366
Red Sucker Lake	$500	$696	$550
Oxford House	$530	$591	$456
God's Lake Narrows	$500	$648	$502
God's River	$525	$650	$552

Table 6: Comparative Costs for a 150-ton Hybrid Airship

Destination	Conventional Costs ($/Tonne)	Hybrid No Passengers ($/Tonne)	Hybrid With Passengers ($/Tonne)
St. Theresa Point/Wasagamach	$435	$301	N/A
Garden Hill/Island Lake	$450	$305	N/A
Red Sucker Lake	$500	$219	N/A
Oxford House	$530	$249	N/A
God's Lake Narrows	$500	$285	N/A
God's River	$525	$286	N/A

30-ton hybrid with passengers competes with conventional transportation costs in three of the seven communities shown.

A flight schedule designed to optimize the use of the airship would enhance its cost/benefit. The cost comparison for the same freight movements using a 150-ton hybrid airship is presented in Table 6. The economics of a larger airship are more advantageous because the fixed costs are spread over more units of revenue. In addition, the variable costs of airships increase at a decreasing rate. The 150-ton airship is competitive without passengers and provides significant direct cost advantages compared to conventional transportation options. This larger airship could fly a circular route that makes multiple stops without having to come back to the base empty to re-load. This would greatly reduce the number of "dead miles" flown on the empty return trip.

Larger airships are very competitive with conventional costs, disregarding any additional revenue that could be obtained from passenger transport. A 150-ton airship would need to carry all the freight currently moved to these communities, but at the lower cost. It would likely stimulate demand to exceed the single hybrid capacity.

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, and the potential of airships to mitigate many of the negative externalities in transport – congestion, pollution, and depletion of liquid fuels.

Airships have considerable potential for passenger and freight transport, as well as for specialty uses such as surveillance and transport to isolated communities. As examples, we have discussed possibilities for mixed freight/passenger service between Hawaii and the west coast of North America. As an example of a specialty use, the potential was explored for passenger and freight service to isolated communities in the Canadian far north. No doubt there are many more potential uses for 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 their role will be 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.

Endnotes

1. Reflecting this, the enormous spire atop the Empire State Building was intended as a docking facility for airships.

2. Disappointing demand is all too common in transportation, however well-conceived the innovation. Recent examples include the Chunnel, RoadRailer, and South Florida's commuter rail.

3. Trans-oceanic jet flight combines business and leisure travelers. Speed is seen to be vitally important for business, whereas tourists are more flexible. What if airships could offer an office to accompany the traveler using wireless internet and a comfortable cabin? The business traveler could have a productive day at work while gradually adjusting to changing time zones, arriving fresher and prepared to negotiate business upon arrival.

4. Tonnage or with regard to market value.

5. The condition on this advantage is that it would only apply to lower density goods. Airships could, for example, have the modal advantage in carrying polyurethane insulation.

6. The degree of durability of value is determined by both a physical characteristics, such as perishability, and demand characteristics, such as changes in market value if a document is delayed or a turkey arrives after Thanksgiving. Not all perishability is time related. Some goods like wine are sensitive to vibration.

7. As will be discussed later in this paper, there is considerable potential for airships in tourist markets.

8. 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.

9. 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 slipstreams of storms.

10. 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.

11. 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.

12. Advanced Technologies Group (SkyCat), AeroVehicles Inc (AeroCat), Millennium Airships and World Aeros (Aeroscraft) are discussed in "Applications for Northern Transportation: Proceedings," *Airships to the Arctic Symposium.* Winnipeg, MB: University of Manitoba Transport Institute, October 2002, available at www.umti.ca.

13. The NT design with an internal frame does appear to offer some tradeoff on the envelope. Zeppelin notes that its envelope is only half the weight of other airships. (Airship No.143, March 2004)

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

15. The same logic applies to airship transport over roadless terrain. Prentice and Thomson (2003) examined the use of a large airship to carry fuel to an Arctic diamond mine.

16. AVI is AeroVehicles Inc. personal interview Bob Fowler, VP Operations. This is also the size that was chosen by DARPA because it matches the payload of a C130 transport that is now used for cargo logistics by the U.S. military.

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